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SUPPLEMENTAL REMEDIAL ALTERNATIVES ASSESSMENT REPORT

E.W. BROWN STATION, HERRINGTON LAKE, MERCER COUNTY, KENTUCKY

DOCUMENT DEVELOPMENT AND APPROVAL

Title and Approval Sheet

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ACRONYMS AND ABBREVIATIONS

~	approximately
#	number
%	percent
AMEC	AMEC Consulting
AECOM	Architecture, Engineering, Construction, Operations, and Management
AUX	Auxiliary
BATW	BATW Bottom Ash Transport Water
BRN	Brown
Bws	below water surface
bws	below water surface
Cabinet	Kentucky Energy and Environment Cabinet
CAP	corrective action plan
CCR	coal combustion residuals
CFD	Central Fisheries Division
CFD-A	Central Fisheries Subdivision A
CFD-B	Central Fisheries Subdivision B
cfs	cubic feet per second
CI	Curds Inlet
COPC	Constituent of potential concern
CSM	conceptual site model
ISARA	Investigation, Source Assessment, and Risk Assessment
ITRC	Interstate Technology and Regulatory Council
Dix Dam	Dix River hydroelectric dam
DO	dissolved oxygen
DR	Dix River
ECOTOX	Ecological Toxicology
e.g.	exempli gratia
EMNR	Enhanced Monitoring Natural Recovery
ELG	effluent limitation guidelines
ERA	ecological risk assessment
ESV	ecological screening value
FEMA	Federal Emergency Management Agency
FGD	flue gas desulfurization
FDGWW	flue gas desulfurization wastewaters
GWRAP	groundwater remedial action plan
HHRA	human health risk assessment
HQ Inlet	HQ Inlet
i.e.	that is
IRM	interim remedial measure
ISARA	Investigation, Source Assessment, and Risk Assessment

KAR	Kentucky Administrative Record
KDFWR	Kentucky Department of Fish and Wildlife Resources
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
KU	Kentucky Utilities Company
LCI	Lower Curds Inlet
LHL	Lower Herrington lake
MCI	Middle Curds Inlet
mg/kg	milligram per kilogram
mg/L	milligram per liter
MHL	middle Herrington lake
M	meter
MM	Million
MNR	monitored natural recovery
NIOSH	National Institute for Occupational Safety and Health
OSWER	Office of Solid Waste and Emergency Response
PE	Professional Engineer
pH	potential Hydrogen
Plant	E.W. Brown Generating Station
PWS	process water system
QAPP	quality assurance project plan
RAO	remedial action objective
RSL	regional screening level
SOP	standard operating procedure
SRAA	Supplemental Remedial Alternatives Assessment
sq. mi	Square mile
SW	surface water
SWS	Surface Water Standards –Here refers to Kentucky Administrative Regulation KAR 224.10:031
TDCS	Toe Drain Collection System
TDCPRTS	Toe Drain and Coal Pile Runoff Treatment System
UCI	upper Curds Inlet
UHL	upper Herrington Lake
USACE	United States Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
YOY	young-of-the-year
ZLD	Zero Liquid Discharge

1. Introduction

This Supplemental Remedial Alternatives Assessment (SRAA) report is provided to the Kentucky Energy and Environment Cabinet (Cabinet) in accordance with the approved Corrective Action Plan (CAP) for the E.W. Brown Generating Station (E.W. Brown Station) on Herrington Lake (Ramboll 2017a) and the approved Corrective Action Investigation, Source Assessment, and Risk Assessment Report (*Corrective Action ISARA Report*) (Ramboll 2019). Implementation of the CAP is a requirement under the 2017 Agreed Order between Kentucky Utilities Company (KU) and the Cabinet. Specifically, the Agreed Order directed KU to implement a plan for:

> *" (1) the further investigation of sediments, surface water quality and biological receptors in Herrington Lake, including an appropriate assessment of human health and ecological risks, (2) an assessment of the sources of selenium impacts, and (3) a consideration of remedial actions, if necessary, to supplement the Groundwater Remedial Action Plan (GWRAP), and a schedule for implementation of such plan for selenium impacts found to be from the E.W. Brown Station."*

While the Agreed Order focuses on selenium impacts, the CAP was designed also to address other constituents of potential interest typically present in coal combustion residuals (CCR), including arsenic, mercury, cadmium, boron, lead, zinc, magnesium, and iron.

KU has completed the first two elements of the CAP as documented in the Corrective Action ISARA Report and the Corrective Action ISARA Coal Pile Addendum (Coal Pile Addendum) submitted by KU to the Cabinet in 2019 and 2020, respectively (Ramboll 2019, 2020). On May 31, 2021, the Cabinet approved the Corrective Action ISARA Report and the Coal Pile Addendum and provided responses to the public comments on the ISARA Report (Cabinet 2021a, 2021b). With respect to this SRAA, KDOW stated (2021a):

> *"The Department approves the ISARA and the Errata in accordance with the above referenced agreed order. KU will now prepare a Supplemental Remedial Alternatives Analysis Report (SRAA) and submit this report within 4 to 6 months from the date of this letter in accordance with the approved Corrective Action Plan."*

This SRAA addresses the third element of the CAP by presenting the results of an assessment of potential supplemental remedial actions based on the findings and conclusions in the Corrective Action ISARA Report and the Coal Pile Addendum.

1.1 Background

1.1.1 Site Setting

The E.W. Brown Station and adjacent Herrington Lake are in the southern Inner Bluegrass (Shawnee: Eskippakithiki) region of Kentucky (see Figure 1-1). The Bluegrass Region makes up the northern part of Kentucky, roughly bounded by the cities of Frankfort, Paris, Richmond, and Stanford. The Inner Blue Grass Region is characterized by gently rolling hills and rich, fertile soils. The Plant is located on the eastern edge of Mercer County, approximately 3.8 miles northeast of the city of Burgin, along the northwestern shore of Herrington Lake. Dix Dam, a hydroelectric dam built by KU in the 1920s, impounded the Dix River to form Herrington Lake. A detailed Site description is also provided in the CAP and in the Corrective Action ISARA Report (Ramboll 2017a, 2019).

1.1.2 Plant Operations

The E.W. Brown Station has generated Coal Combustion Residuals (CCR) since the late 1950s. Historically, CCR consisted primarily of bottom ash and fly ash generated from coal combustion. Beginning in 2009, gypsum began to be produced from scrubbers installed to remove sulfur dioxide from the plant's air emissions. Historically, ash from all coal combustion units (1, 2, and 3) was sluiced to the Main Pond until 2008 and thereafter to the Auxiliary Ash Pond (Aux Pond). Currently, only Unit 3 remains in operation. The Main Ash Pond, located directly south of the Generating Station, was created by placement of an embankment across a valley that drained into Curds Inlet. As the Main Pond was filled with ash sluiced from the boilers, it was expanded multiple times, to a surface area of approximately 114 acres. In 2008, the pond was taken out of service, and sluice waters were redirected to the Aux Pond. Much of the Main Pond was covered with soil in 2011. Construction of a special waste landfill over the top of the Main Pond was permitted in 2015 and completed in 2016 and is currently receiving plant-generated CCRs including bottom ash, fly ash, and gypsum. The constructed landfill also serves as a remedial cap for the Main Ash Pond.

Water that accumulated in the Main Ash Pond from sluicing operations and precipitation was decanted and discharged to Curds Inlet at a discharge point referred to as Outfall BRN001 located at the head of the inlet. Beginning in the mid-1970s, this discharge was authorized and regulated under a KPDES permit issued by the Kentucky Division of Water. The KPDES permit for the E.W. Brown Station was most recently renewed in November 2019 (Permit Number KY0002020) (KPDES 2019a, 2019b; KU 2021a, 2021b). Decanted water from the Aux Pond also was discharged at Outfall BRN001 via an underground pipeline that routed the water to the same discharge channel that previously carried water from the Main Ash Pond to Curds Inlet. During the decades of operation of the ash ponds, these discharges represented the largest source of CCR-related contaminant loading to Curds Inlet. All process water discharges to Outfall BRN001 were discontinued in 2019 when the plant's KPDES permit was renewed. As discussed below, treated wastewater from the plant now discharges at a new Outfall BRN006 through a multi-port diffuser anchored to the rock wall and extending out into the main body of Herrington Lake.

1.2 Summary of Completed and Planned Interim Remedial Measures (IRMs)

This SRAA evaluates the effects of previously implemented and currently planned remedial measures to determine the baseline against which to assess the need for supplemental remedial measures. Table 1-1 summarizes the IRMs implemented at the Site during the period of 2014 to 2020 and briefly describes other IRMs planned or underway at the Site. These IRMs are also described in Section 1.2 of the Corrective Action of the ISARA Report. This includes actions specified in the GWRAP and other actions taken or planned by KU, such as the construction of new wastewater treatment facilities to ensure compliance with KPDES discharge requirements and treat groundwater collected at the Main Pond Toe Drain Collections System. These IRMs limit the contributions of constituents of interest, including selenium, to Curds Inlet and Herrington Lake by eliminating surface water discharges from the ash ponds (the single largest source of selenium) and preventing surface water infiltration and groundwater migration from source areas at E.W. Brown. The identification of potential supplemental remedial actions will take the effects of the IRMS into account, particularly those which have been implemented subsequent to the field sampling for the Corrective Action ISARA Report in 2017 and 2018, as described further below.

1.2.1 Elimination of Process Water Discharge Via Outfall BRN001

In November 2019, in accordance with the 2019 renewed KPDES permit, KU redirected all process water flows from KPDES permitted Outfall BRN001, which discharges to Curds Inlet, to a new KPDES permitted Outfall BRN006. Treated wastewater from the plant no longer discharges to Curds Inlet. The flow discharges at Outfall BRN006 through a multi-port diffuser anchored to the rock wall and extending out into the main body of Herrington Lake at a depth of 40 feet below winter pool level. The flows to Outfall BRN001 now consist solely of stormwater drainage and are required to be monitored in accordance with the 2019 renewed KPDES permit. Because none of the current flows come into contact with CCRs, the loading of selenium and other CCR constituents from Outfall BRN001 to Curds Inlet has been eliminated. This change should improve environmental conditions in Curds Inlet, including surface water quality.

1.2.2 Treatment and Elimination of Aux Pond Discharge

In November of 2019, KU discontinued all flows of ash sluice water to the Aux Pond. In December 2019, KU commenced dewatering of the Aux Pond in preparation for its closure. Water removed from the pond is treated in a temporary on-site system prior to discharge through Outfall BRN006 with the high rate multi-port diffuser. The CCR impoundment dewatering treatment system is a physical-chemical water treatment system that receives influent from the Aux Pond. Free water and interstitial water removed from the Aux Pond is pumped into the dewatering treatment system. After treatment, the water is pumped to a storage basin from where it is pumped to the Process Pond and then discharged through Outfall BRN006. The Auxiliary Ash Pond closure/capping activities are substantially complete. The remaining work (placement of cover soil and construction of stormwater runoff channels) is expected to be complete by the end of 2021 (KU 2021b). Auxiliary Ash Pond Dewatering flows, addressed in Outfall BRN006A conditions and limits, have been substantially reduced and are expected to be discontinued by the end of 2021 (KU 2021a,b). Mass loading of constituents through Outfall BRN006 will be substantially reduced after dewatering of the Aux Pond is completed.

1.2.3 Toe Drain and Coal Pile Runoff Treatment System (TDCPRTS)

The TDCPRTS is a chemical water treatment system that receives influent from the Toe Drain Collection System and stormwater runoff from the Coal Pile Runoff Pond. Prior to the construction of the TDCPRTS, both influent streams discharged into the Aux Pond. The TDCPRTS commenced operation during the 4th quarter of 2019, concurrent with the redirection of the toe-drain flow and coal pile runoff. The treatment system consists of two parallel and redundant treatment trains. Each treatment train consists of three tanks which drain into a common effluent tank. The system treats the effluent with polymer, caustic, and organo-sulfide. The effluent then drains into the Landfill Leachate Pond to allow for solids to settle before it is discharged into the Process Pond and out through Outfall BRN006. The TDCPRTS system design ensures compliance with water quality-based limits in the facility’s 2019 renewed KPDES permit.

1.2.4 Recirculation of Bottom Ash Transport Water

Since 2015, the facility has operated the bottom ash transport water (BATW) management system at Unit 3 to recirculate sluice water. As of the renewal of KPDES permit in November 2019, wastewater from the BATW management system discharges to the new Process Pond and ultimately to Herrington Lake via Outfall BRN006 subject to effluent limits established by the facility’s KPDES permit to ensure compliance with applicable Kentucky Surface Water Quality Standards. In addition, KU will be upgrading the existing BATW management system to meet the requirements for recirculation of BATW flows under the Effluent Limitation Guidelines (ELGs) for steam and electric power generating facilities issued by the USEPA (KU 2021b Attachment 2). KU recently submitted an application to modify the KPDES permit to specify an ELG compliance date of July 1, 2023 for operation of the BATW high recycle rate management system and allow for a purge rate of up to 10 percent in accordance with recent revisions to the ELGs.

1.2.5 Treatment and Elimination of FGD Wastewater Discharges

As of late 2019, most process waters from the Unit 3 flue gas desulfurization (FGD) system are recycled to supply FGD system makeup water (KU 2021a,b). Any surplus FGD process water is treated in a new Process Water System (PWS). The PWS treatment system consists of two reaction tanks, one clarifier, filter system, and an effluent tank. Within the system, the influent is treated with caustic, organo-sulfide, ferric chloride, and polymer. The treatment system removes suspended solids, adjusts pH, and removes metals by chemical reactions with organo-sulfide compounds. The effluent is then pumped from the effluent tank to the Process Pond and then discharged through Outfall BRN006 subject to effluent limits established by the facility's KPDES permit to ensure compliance with applicable Kentucky Surface Water Quality Standards. Prior to the construction of the PWS treatment system, FGD wastewater discharged into the Aux Pond and then to Curds Inlet via Outfall BRN001.

KU recently submitted an application to modify the KPDES permit to reflect its plans to install additional equipment to convert the FGD wastewater system to fully zero liquid discharge (ZLD) to meet the requirements for FGD wastewater under the ELGs. This conversion is currently expected to be completed by July 1, 2023, at which point there will be no further discharges of FGD wastewater to the PWS or Outfall BRN006 (KU 2021b Attachment 3).

1.2.6 Ongoing Monitoring

To verify performance of the IRMs, KU is conducting ongoing monitoring of groundwater. The results of this monitoring are reported semiannually to the Cabinet. KU is also monitoring changes to conditions in the Main Ash Pond as a result of the IRMs and construction of the new overlying CCR landfill. In addition, the new KPDES permit includes requirement for KU to conduct whole-body fish tissue sampling whenever the monthly average concentration of selenium in the effluent at Outfall BRN006 exceeds a trigger level of 0.075 mg/L. If the fish tissue concentrations exceed the Kentucky water quality standard of 8.6 mg/kg dry weight (or if no fish tissue samples can be collected), KU will be deemed in violation of its permit.

1.3 Overview of the Remedial Action Assessment Process

The Agreed Order requires "consideration of remedial actions, if necessary, to supplement the GWRAP." KU was required to submit and implement the GWRAP as a condition of the permit for the special waste landfill at the E.W. Brown Station for disposal of CCR. As explained in the Agreed Order, the overall objective of the GWRAP was to address "the totality of surface water impacts from both groundwater and surface water discharges," and KU's obligations under the Agreed Order included "the development and implementation of corrective action plans and other remedial measures set forth herein to address any threat or potential threat to human health or the environment". The SRAA was guided by these overall objectives of the Agreed Order.

The SRAA process for the E.W. Brown Station consisted of the following steps outlined in the CAP:

- Identification of conditions warranting supplemental actions

- Definition of Remedial Action Objectives
- Identification of potentially applicable additional remedial action alternatives
- Evaluation of remedial alternatives
- Identification of preferred remedial measures(s)

The remedial action assessment relies on the key findings and conclusions provided in the Corrective Action ISARA Report and the Coal Pile Addendum, which evaluated (1) the nature, extent and source of CCR-related constituents in Herrington Lake; and (2) any potential human health or ecological risks associated with those constituents. In addition, as specified in the CAP, the evaluation of remedy alternatives generally follows the requirements of the Kentucky Administrative Regulations (KAR) Section 401 KAR 10:030 (KDOW 2018c under "Remediation requirements").

1.4 SRAA Report Organization

The remainder of this report is organized as follows:

- Section 2 provides a summary of site conditions potentially warranting supplemental remedial action based on the findings from the Corrective Action ISARA Report and the Coal Pile Addendum.
- Section 3 describes the remedial action objectives considering the expected effects from the IRMs described in Section 1 of this report.
- Section 4 presents the proposed scope of supplemental performance monitoring to confirm the improved conditions in Herrington Lake from the IRMs and that facility operational changes implemented by KU are sufficient to meet the RAOs identified in Section 3.
- Section 5 assesses contingent supplemental remedial measures for RAO 3, comparing the relative benefits and costs of the alternative remedies.
- Section 6 provides recommendations for a schedule for implementing the performance monitoring outlined in Section 4 and a proposed path forward for decisions regarding the need for contingent supplemental remedial measures, if warranted.
- Section 7 provides information for references cited.

2. IDENTIFICATION OF CONDITIONS POTENTIALLY WARRANTING SUPPLEMENTAL REMEDIAL ACTION

The following summary of site conditions is based on the findings reported in the Corrective Action ISARA Report for Herrington Lake and the Coal Pile Addendum (Ramboll 2019, 2020). Additional detail is contained in these documents.

2.1 General Site Conditions

2.1.1 Site Location

Herrington Lake is a large freshwater impoundment (approximately 35 miles long including inlets) located within the Dix River watershed which begins at Highway 52 and ends at Dix Dam. As noted above, the lake was formed in the 1920s by the construction of the Dix Dam for hydroelectric power. Herrington Lake was Kentucky's first large-scale impoundment, and is also the deepest lake in Kentucky, reaching a depth of approximately 250 feet below water surface (bws) near Dix Dam, with an average lake depth of approximately 75 feet bws. The estimated capacity of the lake is approximately 175 billion gallons. A short distance below Dix Dam, the Dix River enters the Kentucky River at High Bridge, Kentucky. Dix Dam regulates Herrington Lake and Dix River water flow and levels. Dix River downstream from the Dix Dam is approximately 40 to 70 feet wide interspersed with shallow 2 foot or less water depth areas and deeper pools and runs of several feet deep. Tall limestone cliffs border portions of Lower Dix River. A spillway enters the river approximately half mile downstream of the dam.

There are seven Kentucky Department of Fish and Wildlife Resources (KDFWR) Fishery Districts. Herrington Lake is located within the Central Fisheries Division (CFD) jurisdiction. KDFWR CFD provides Annual Sportfish Lake Performance Reports for Herrington Lake (KDFWR 2008, 2014, 2016). The CFD described the lake sections in terms of CFD-A and CFD-B Subdivisions (KDFWR 2008). For this SRAA Report, those general areas identified by the CFD for the lake were used to identify three study sections of Herrington Lake: Upper, Middle, and Lower Herrington Lake, as illustrated on Figure 2-1A.

2.1.2 Biological Conditions

The varied habitats within Herrington Lake support a variety of algae, plants, and invertebrates, which serve as the base of the food web for the lake. The upper water layer of the lake, where sunlight penetrates, supports algae and a variety of floating aquatic plants (e.g., duckweed), and submerged and emergent aquatic plants. The vegetation concentrates along the shallower shorelines among the submerged rocks or woody debris. Invertebrates inhabit the water column, as well as the sediment (benthic or sediment-dwelling). Benthic invertebrates include crayfish and larval-stage flies, such as mayflies, damselflies, stoneflies, and dobsonflies. Fish are the dominant species in terms of biomass in the lake. Like Herrington Lake, aquatic-feeding wildlife (e.g., ducks, raccoons, muskrat, mink, river otters) likely inhabit Dix River below Dix Dam. The fish species in Dix River, including trout, reflect colder water conditions compared to Herrington Lake. Dix River also supports algae, aquatic plants, and invertebrates, although the species may differ slightly due to the differences in aquatic habitat. Several areas of emergent vegetation are present in the shallow shoals of the river. Crayfish and larval-stage flies are also present.

2.1.3 Site Hydrology

This description of the E.W. Brown Site hydrology is summarized from the GWRAP (AMEC Foster Wheeler 2015a). Herrington Lake has a surface area of 4.6 square miles (sq. mi), a volume of 254,000 acre-feet, a length of 35 miles (at full pool), and average and maximum depths of approximately 75 feet bws and approximately 250 feet bws, respectively. KU currently manages the pool of Herrington Lake so that the base level is set to 725 feet in winter, and 740 feet in summer. In response to precipitation events, the lake level fluctuates higher (occasionally over 750 feet, the bottom level of the spill gates in Dix Dam) for limited periods of time, usually in spring. The 100-year flood elevation shown on Federal Emergency Management Agency (FEMA) mapping of the lake is 760 feet. The U.S. Environmental Protection Agency (USEPA 1977) estimated the mean flow through Herrington Lake to be 593 cubic feet per second (cfs). The United States Geologic Survey (USGS Crain et al. 2000) reported the mean annual flows for Dix River in 1995 and 1996 were 442 and 591 cfs, respectively, and estimated that average annual runoff in the watershed ranges from 18 to 20 inches. Under low flow conditions, the flow out of Herrington Lake occurs as seepage through Dix Dam. Minimum seepage rates provided by KU for the 10-year period from 2000 through 2009 ranged from less than 10 to 46 cfs and averaged 22 cfs.

Although most of the E.W. Brown property drains to Herrington Lake, part of the property drains to Cedar Branch, which flows almost parallel to the Dix River but is located outside the Lower Dix Watershed to the west. The Cedar Branch watershed surface area measures 4.1 sq. mi. Cedar Branch flows into the Kentucky River at Shakers Landing. Flows measured by Amec Foster Wheeler at the mouth of Dix River just above its confluence with the Kentucky River, in the spring and summer months of 2011 and 2012, ranged from zero to greater than 25 cfs. Both the Dix River and Cedar Branch flow into the Kentucky River just upstream of Lock 7, less than a half-mile apart from each other. The historic High Bridge (a steel railroad bridge) crosses the Kentucky River Palisades between the mouths of Dix River and Cedar Branch. Under low flow conditions, the flow in the Kentucky River at Lock 7 is about 60 cfs.

2.1.4 Site Geology

This description of the E.W. Brown Site Geology is summarized from the 2015 GWRAP. E.W. Brown Station sits on top of the Curdsville/Logana Member of the Lexington Limestone. The tributary valleys occupied by the ash ponds are incised through limestone, shale, and dolomite of the Middle Ordovician Lexington Limestone formation, and into the underlying High Bridge Group. Existing CCR in the former Main Ash Pond overlies (from bottom to top) the Tyrone Formation (the uppermost formation in the High Bridge Group), the Curdsville/Logana Member, and the lower section of the Grier Member of the Lexington Limestone. A relatively thin (less than 5 ft.) veneer of clay residuum is present locally over bedrock, but disturbance and construction around the Main and Aux Ponds, including the removal of overburden and rock, and the placement of manufactured rock fill, altered those areas.

Groundwater flow at the Site occurs primarily in bedrock, through a shallow system of fractures and poorly to moderately well-developed solution channels, generally following topographic gradients. Extensive hydrogeologic characterization activities completed in 2011 and 2012 relied primarily on dye tracing to confirm groundwater flow paths. The Groundwater Assessment Report (AMEC 2013) documented the investigation and assessment results. Many of the identified springs monitored in the dye trace studies are located in the Dix River and Cedar Branch watersheds and occur between elevations of 835 feet and 810 feet, appearing to emerge in the upper Tyrone Formation, just below the contact with the overlying Curdsville Member of the Lexington Limestone, most likely due to the presence of bentonite beds in this horizon. Bedrock above this level is presumably seasonally dry and only intermittently saturated, with localized flow occurring from recharge into fractures and conduits. Some of the monitored "springs" at the Site occur deeper in the Tyrone, at elevations closer to perennial or frequently flowing surface drainage. The discharges into Curds Inlet, at the toe of the former Main Ash Pond eastern embankment, emerge at an elevation of about 750 feet, and are a comprised of flows from the embankment seepage collection system, mixed with groundwater flow from bedrock.

Groundwater moving through the area of the now inactive ash ponds in the direction of Herrington Lake has been confirmed to emerge at springs east of the ash ponds, as well as at historical seeps at the toe of the former Main Ash Pond now collected in TDCS. A surface water divide occurs immediately west of the ash ponds, between the watershed containing the ponds and the Cedar Branch watershed to the west. Dye tracing has confirmed that a groundwater divide is coincident with this surface water divide, and that groundwater does not flow west into the Cedar Branch watershed from the area of the ash ponds.

2.2 Key Findings from Corrective Action ISARA Report

2.2.1 Overview of Sampling to Support the Corrective Action ISARA Report

The Herrington Lake field effort described in the Corrective Action ISARA Report took place in a phased approach. The Phase I sampling effort completed during October to December 2017, included field sampling locations in the lower and middle Herrington Lake regions, and in Dix River (Figures 2-1A). The Phase I effort included collection of fish, surface water, sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates, which were collected and analyzed in accordance with the Cabinet Approved CAP, Quality Assurance Project Plan, and Standard Operating Procedures. Sample analyses focused on the following CCR-related constituents: Total and speciated selenium, total and speciated arsenic, and total and methylated mercury, as well as cadmium, boron, lead, zinc, iron, and magnesium. Additional analyses were conducted to understand chemical fate, including sulfate, dissolved oxygen, lipids, moisture content, solids, and total organic carbon.

Upon completion of the Phase I field efforts, KU presented findings to the Cabinet and proposed Phase II data collection efforts designed to fill the data gaps identified following the Phase I effort. Following approval by the Cabinet, the Phase II field effort was conducted, including constituent analyses and young-of-the-year [YOY] bluegill deformity assessment (Figures 2-1B, 2-1C, and 2-1D). The analytical data for fish tissues, surface water, sediment, sediment pore water, vegetation, and aquatic invertebrates collected as part of Phase I and Phase II field efforts were used to develop the conceptual site model and understanding of the source of CCR-related constituents to Curds Inlet and Herrington Lake presented in the Corrective Action ISARA Report.

2.2.2 Summary of the CSM and Source Assessment for Herrington Lake

2.2.2.1 CSM Summary

The Corrective Action ISARA Report conceptual site model of surface flow patterns and discharge is illustrated in Figures 2-2A and 2-2B. Prior to November 2019, Outfall BRN001 was the primary source of CCR-related constituents into Curds Inlet. This outfall discharged to the uppermost portion of Curds Inlet. Two other KPDES permitted outfalls, Outfalls BRN002 and BRN003 also discharge to Curds Inlet (Figure 2-2A). Neither Outfall BRN002 nor Outfall BRN003 is a source of CCR-related constituents because the discharge flows do not come into contact with coal or CCR. Under the 2019 renewed KPDES permit, Outfall BRN002 conveys stormwater from the roof drains at Buildings 1 and 2, and

Outfall BRN003 conveys stormwater from roof drains at Building 3 in addition to cooling tower blowdown. Outfall BRN005 (not displayed on the figures) is the intake for lake water for cooling.

Under the 2019 renewed KPDES permit, all process water flows were rerouted from Outfall BRN001 to newly constructed Outfall BRN006, located in the main body of lower Herrington Lake. As noted above, Outfall BRN006 discharges through a multi-port diffuser anchored to the rock wall and extending out into the main body of Herrington Lake 40 feet below winter pool. Before discharging at Outfall BRN006, process water is treated in a new Process Pond and legacy wastewater removed from the Aux Pond is treated using a dedicated temporary treatment system. The diversion of process flows from Outfall BRN001 to Outfall BRN006A should improve surface water quality in Curds Inlet. In addition, mass loading of constituents through Outfall BRN006 will be substantially reduced after dewatering of the Aux Pond is completed (currently anticipated by the end of 2021) and all FGD wastewater flows are discontinued (currently anticipated by July 1, 2023).

In addition to the direct discharges via permitted outfalls, groundwater from beneath E.W. Brown Station flows to Herrington Lake via springs emerging near Curds Inlet and HQ Inlet; locations of these springs are displayed on Figure 2-2A. HQ Spring and Briar Patch Spring are the primary springs that provide flow into HQ Inlet. Springs that previously flowed to Curds Inlet (Dam Toe Left, Middle, and Right) are now captured in the Toe Drain Collection System that was installed in 2016. After construction of the Landfill over the closed Main Ash Pond and installation of the Toe Drain Collection System, Beaver Dam Cave Spring, Ditch Spring, and the South Abutment Spring have had limited flow, or no flow documented. A transient seep, referred to as the North Curd Sink, was observed in 2015 in the inner portion of Curds Inlet near where the Toe Drain Collection System was installed.

Figures 2-2A and 2-2B display the Phase I and Phase II sampling locations and illustrates the extensive sampling coverage in Curds Inlet. The groundwater wells between the Landfill/Main Ash Pond and Aux Pond and Herrington Lake are displayed on Figure 2-2A. The groundwater monitoring data were considered part of the source identification for Herrington Lake. Groundwater that flows beneath the Landfill is potentially influenced by CCR-related constituents in seepage from the former Main Ash Pond. Since 2016, the water from the springs at the toe of the Main Ash Pond (Dam Toe Left, Middle, and Right) has been captured in the Toe Drain Collection System. In addition, a settling pond collects the coal pile runoff. Flows from the TDCS and the coal pile runoff pond were pumped to the Aux Pond until November 2019, when they were re-routed to the TDCPRTS for treatment prior to discharge at Outfall BRN006.

2.2.2.2 Mass Loading Estimates for Selenium and Arsenic

Selenium and arsenic mass loading to Herrington Lake by source was described in the Corrective Action ISARA Report (Ramboll 2019). The mass loading calculations were based on simplifying assumptions and are intended to provide order-of-magnitude estimates for comparing the relative contributions from selected sources. The evaluation provided in the Corrective Action ISARA Report discussed a comparison of conditions (i.e., mass loading) before and after implementation of those IRMs conducted prior to the 2017 to 2018 timeframe when the sampling in Herrington Lake was conducted. The Corrective Action ISARA Report provided estimates of mass loading from:

- Auxiliary Pond Outfall BRN001,
- Springs,
- Groundwater,
- Flux from sediments, and

- Lake-wide upgradient mass loading.

The key findings from the mass loading estimates were:

- The primary input of CCR-related constituents to Curds Inlet was from Outfall BRN001. The estimated discharge of selenium from Outfall BRN001 was slightly lower after the construction IRMs completed by 2018.
- Selenium flux from sediments to water was orders of magnitude lower than selenium mass loading from the Outfall BRN001 prior to elimination of the Aux pond discharge at Outfall BRN001.
- Ditch Spring, Beaver Dam Cave Spring, and the South Abutment Spring have mostly been dry since the installation of the IRMs such as the Toe Drain Collection System. Briar Patch Spring and HQ Spring continue to flow into HQ Inlet. However, flow and thus mass load was reduced for Briar Patch and HQ Springs after the repair of the Aux Pond discharge pipeline in November 2016.
- Mass loading of CCR constituents from groundwater is expected to be *de minimis*.
- The Toe Drain captures groundwater flow from within and below the former Main Ash Pond also captures water from springs (Dam Toe Right, Dam Toe Middle, and Dam Toe Left). It is possible that there is seepage from the Main Ash Pond that is not captured by the Toe Drain Collection System, but detailed analyses presented in the Corrective Action ISARA Report indicate that, if any groundwater with CCR-related constituents is not captured by the Toe Drain Collection System, it would be *de minimis*.
- The amount of selenium and arsenic in pore water was consistent with flux from sediment and does not indicate any mass loading from groundwater upwelling in Curds Inlet.

2.2.2.3 Coal Pile Geology and Hydrogeology

This description of the coal pile geology and hydrogeology is summarized from the Coal Pile Addendum (Ramboll 2020). The Coal Pile Addendum was prepared to supplement the information provided in the Corrective Action ISARA Report and provided an evaluation of potential impacts to Herrington Lake from groundwater migrating from beneath the coal pile and the coal pile retention pond.

The geology around the coal pile and the coal pile retention pond is formed in such a way that migration of groundwater from the coal pile and coal pile retention pond would be more likely to flow in a lateral pathway toward Herrington Lake than a downward path to the lake which could result in groundwater upwelling below the lake surface. This shallow migration pathway would result in visible seeps along the shoreline of either Curds Inlet or of the Dix Dam spillway. As indicated in the Coal Pile Addendum, observations of the near vertical exposed strata on the north, east, and south sides below the coal pile do not show evidence of any significant seeps migrating from the coal pile or retention pond to Herrington Lake.

The Coal Pile Addendum provides an evaluation of potential water migration from beneath the coal pile retention pond to Herrington Lake, using the available geological and hydrogeological data. The Coal Pile Addendum provides conservative estimates for selenium and arsenic loading to Herrington Lake, assuming all rainfall on the coal pile seeps through the pile to groundwater at the maximum detected concentrations in the coal pile retention pond and migrates to the lake. In addition, concentrations of coal-related constituents in the coal pile retention pond water and in lake sampling locations closest to the coal pile were directly compared with water quality criteria for the protection of human health and the environment. These evaluations determined that there is no indication that any coal-related constituents are migrating to Herrington Lake due to possible seepage to groundwater from the coal pile or the coal pile retention pond at concentrations that would pose an unacceptable risk to the environment or human health.

The Coal Pile Addendum also considered iron to evaluate if the concentrations of iron in sediment pore water were likely due to partition from sediment or indicate a potential groundwater upwelling influence. The results of the evaluation indicate that the sediment likely is the source of iron seen in pore water and the results did not indicate that groundwater would be a source of iron to Curds Inlet.

2.2.3 Corrective Action ISARA Report HHRA Findings

The Corrective Action ISARA Report included a human health risk assessment (HHRA) to evaluate the CCR-related constituents detected in water, sediment, and fish tissue. Health protective assumptions were applied to derive risk-based screening levels that were then compared with site data to identify constituents of potential concern (COPCs) in site media.

- No COPCs were identified for surface water based on residential domestic use. In addition, comprehensive drinking water well surveys were conducted in 2018 and 2019 to identify domestic drinking water wells. No drinking water wells were identified within a mile of E.W. Brown Station.
- No COPCs were identified for fish consumption. The measured fish tissue concentrations were below risk-based screening levels for selenium, inorganic arsenic, cadmium, boron, lead, and zinc. The concentrations of methylmercury (the most dominant form of mercury) in fish tissue fillet were below risk-based screening levels for most of the fish samples, with two exceptions. Two flathead catfish had detected fillet tissue concentrations that exceeded the methylmercury risk-based screening criterion based on consuming 50 meals per year. One of these catfish was from LHL4, approximately 3 miles upgradient from E.W. Brown Station. The second catfish was from MHL1, approximately 10 miles upgradient from E.W. Brown Station. These mercury concentrations in the catfish are not considered to be due to discharges from E.W. Brown station because small the home range bluegills did not indicate a pattern of elevated mercury concentrations in Curds Inlet.
- The only COPC identified from the screening analysis for human health risk was arsenic in sediments, using conservative exposure assumptions for recreational visitors (i.e., sediment data were compared with USEPA regional screening levels for arsenic in residential soil which were derived by EPA assuming exposure to soil 350 days per year for 30 years, and calculated using a target excess cancer risk level of $1x10^{-6}$). Arsenic in sediments in each of the investigation areas including those with no influence from E.W. Brown exhibited concentrations in certain samples that exceeded the USEPA RSL for arsenic in residential soil.
- Following the screening level assessment of sediment exposures, a refined assessment of risk from potential human exposures to arsenic in sediment was conducted to account for the fact that there is little potential for human contact with sediments at the frequency assumed in establishing the screening levels for residential soil. For this refined assessment sediments within areas under water 24 feet or less[1] were further evaluated using more realistic exposure assumptions. To determine how frequently people might contact underwater sediments an exposure frequency was developed based on climate data compiled by the US weather service.[2] It was protectively assumed that an older child or adult might swim and contact sediments for three days per week

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[1] The 24-foot depth of water was chosen as a health protective level because the lake can fluctuate by 20 feet and individuals might wade in water 4 feet deep or shallower.

[2] https://www.usclimatedata.com/climate/lexington/kentucky/united-states/usky1079.

(i.e., 65 days per year) and that a young child might visit half as often (i.e. 33 days per year) during the warmer weeks of the year.[3]

  - The highest excess lifetime cancer risk estimate from exposure to arsenic in sediment in Curds Inlet derived using the foregoing conservative exposure assumptions was $1x10^{-5}$ (as shown on Table 4-13 of the Corrective Action ISARA Report). This risk estimate is within the target risk range of $1x10^{-6}$ to $1x10^{-4}$ considered acceptable by USEPA.
  - No hazard quotients were greater than 1, indicating no adverse non-cancer effects would be expected for recreational visitors.

- The results presented in the HHRA were based on conservative health protective sediment exposure assumptions that likely substantially overestimated the actual risks to recreational human receptors in Curds Inlet. Specific examples include:
  - The inclusion of sediments under 24 feet or less of water does not account for the fact that during summer months, when most recreation and potential contact with sediment occurs, most of the deeper areas included in the analysis are not practically accessible by recreators, particularly children. Arsenic concentrations in shallow areas of Curds Inlet are lower than concentrations at depths exceeding 4 feet during the summer months.
  - The assumptions that children under the age of six would be exposed to sediments in Curds Inlet 33 times a year and that older children and adults would be exposed 65 times per year do not account for the limited access to the area by recreational visitors, the steep terrain along the shoreline (which is on KU property), the limited use of the shoreline within Curds Inlet for recreational purposes, and the absence of any observed recreational use other than by adult workers from KU who fish in Curds Inlet from shore. Other recreational visitors would have to come to Curds Inlet by boat, further limiting exposure to sediments.

Based on the foregoing, the potential human health risks from exposure to COPCs in sediment do not exceed target risk levels and do not warrant further consideration for remedial action.

2.2.4 Corrective Action ISARA Report ERA Findings

The Corrective Action ISARA Report included an Ecological Risk Assessment (ERA) that followed Kentucky and USEPA guidance including comparison to relevant available screening levels with the goal of determining whether there is an adverse impact to the environment from CCR-related constituents in Herrington Lake related to the E.W. Brown Station (KDEP 2002, USEPA 1997, 1998, 2018b). The ERA evaluated the following assessment endpoints:

- Survival, growth, and reproduction of fish populations;
- Survival, growth, and reproduction of aquatic-feeding bird and mammal populations;
- Protection and maintenance of aquatic vegetation and water-column invertebrate community; structure and function; and
- Protection and maintenance of sediment dwelling invertebrate community structure and function.

[3] Data compiled by the US weather service indicate that Lexington, Kentucky experiences average daily low temperatures above 50 degrees for five months (roughly equivalent to 21.7 weeks) per year. The number of days having an average low temperature of greater than 50 degrees is a reasonable universe of possible days, since cooler weather generally means people spend less time swimming in the lake or playing in wet areas.

The measurement endpoints (i.e., the methods used in the ERA to determine if potential risks may occur for each assessment endpoint evaluated in the ERA) are provided in Exhibit 2-1 below.

Exhibit 2-1: Summary of Assessment and Measurement Endpoints used in the ERA	
Assessment Endpoint	**ERA Approach (Measurement Endpoints)**
Survival, growth, and reproduction of fish populations	• Comparison of adult whole-body fish tissue concentrations against the Kentucky water quality standard for selenium in fish tissue and other tissue residue reference values for CCR-related constituents other than selenium • Comparison of selenium in ovary/egg tissues to the USEPA ovary/egg water quality standard • Evaluation of YOY bluegill study for selenium concentrations in YOY and a deformities assessment • Comparison of water concentrations to water quality standards for CCR-related constituents
Survival, growth, and reproduction of aquatic-feeding bird and mammal populations	• Comparison of calculated daily dietary intakes against chemical-specific toxicity reference values for birds and mammals
Aquatic vegetation and water-column invertebrate community structure and function	• Comparison of surface water concentrations against water quality criteria
Sediment dwelling invertebrate community structure and function	• Comparison of sediment concentrations against sediment quality criteria • Evaluation of spiked sediment studies • Comparison of sediment pore water concentrations against water quality criteria

Fish Populations

The ERA evaluated the survival, growth, and reproduction of fish populations, based on the following measurement endpoints:

- CCR-related constituent concentrations in adult and YOY fish tissues collected from Herrington Lake sampling efforts in 2017 and 2018 were compared to whole-body tissue protective criteria for fish. The protective criteria used were from the Cabinet, the USEPA, and scientific literature. For selenium, the Kentucky adult fish whole-body criterion and USEPA ovary/egg standard for selenium were used.
- The adult fish whole-body and the adult fish ovary samples had selenium concentrations less than the Kentucky standards and USEPA standards for whole-body tissues and ovary tissues, respectively.

- The adult fish tissues concentrations for CCR-related constituents other than selenium were detected at concentrations less than protective fish tissue criteria with the exception of limited detections of mercury that were in Middle Herrington Lake more than 10 miles upgradient of influence from Curds Inlet.
- YOY bluegills were collected to inspect for deformities (approximately 3,600 fish) and for tissue residue (approximately 700 additional fish) for a total of approximately 4,300 YOY bluegills.
- The 2018 YOY assessment demonstrated that the rate of skeletal, facial, fin, or tail teratogenic deformities was low. Overall, approximately 99% of the YOY fish exhibited no skeletal, facial, fin, or tail teratogenic deformities.
  - The deformity rates in Curds and HQ Inlets (0.38–0.83%) were consistent with the rates observed at other locations, with an observed occurrence at LHL1 of 2.1% and Hardin Inlet at 0.96%.
  - The rate of occurrence at LHL6, approximately 2 miles upgradient from Curds Inlet (outside the influence of E.W. Brown Station), was 0.66%, within a comparable range to that observed in Curds Inlet.
  - These rates of skeletal, facial, fin, or tail teratogenic deformities do not indicate adverse impact to the population of fish in Herrington Lake.
  - The rate of deformities seen in the YOY from within Curds Inlet and the reference areas of Herrington Lake were similar to those seen in other studies of YOY fish (e.g., West Virginia Department of Environmental Protection 2010).
- During the bluegill YOY deformities assessment, a condition called exophthalmia (also known as "popeye") was noticed in approximately 5% of the 3,600 fish evaluated in the assessment. The cause of the popeye was not likely selenium exposure because:
  - Popeye was observed at a similar or lower frequency in Curds Inlet fish compared to the popeye seen in YOY fish collected from reference areas in Herrington Lake.
  - Smaller fish (approximately 1 centimeter) had a higher likelihood of having popeye condition. Small fish are susceptible to popeye from physical stress and findings suggest that the exertion and capture typical of the YOY collection may have contributed to the observed popeye (e.g., Stephens et al. 2002, Hargis 1991; Noor El Deen and Zaki 2012, /2013).

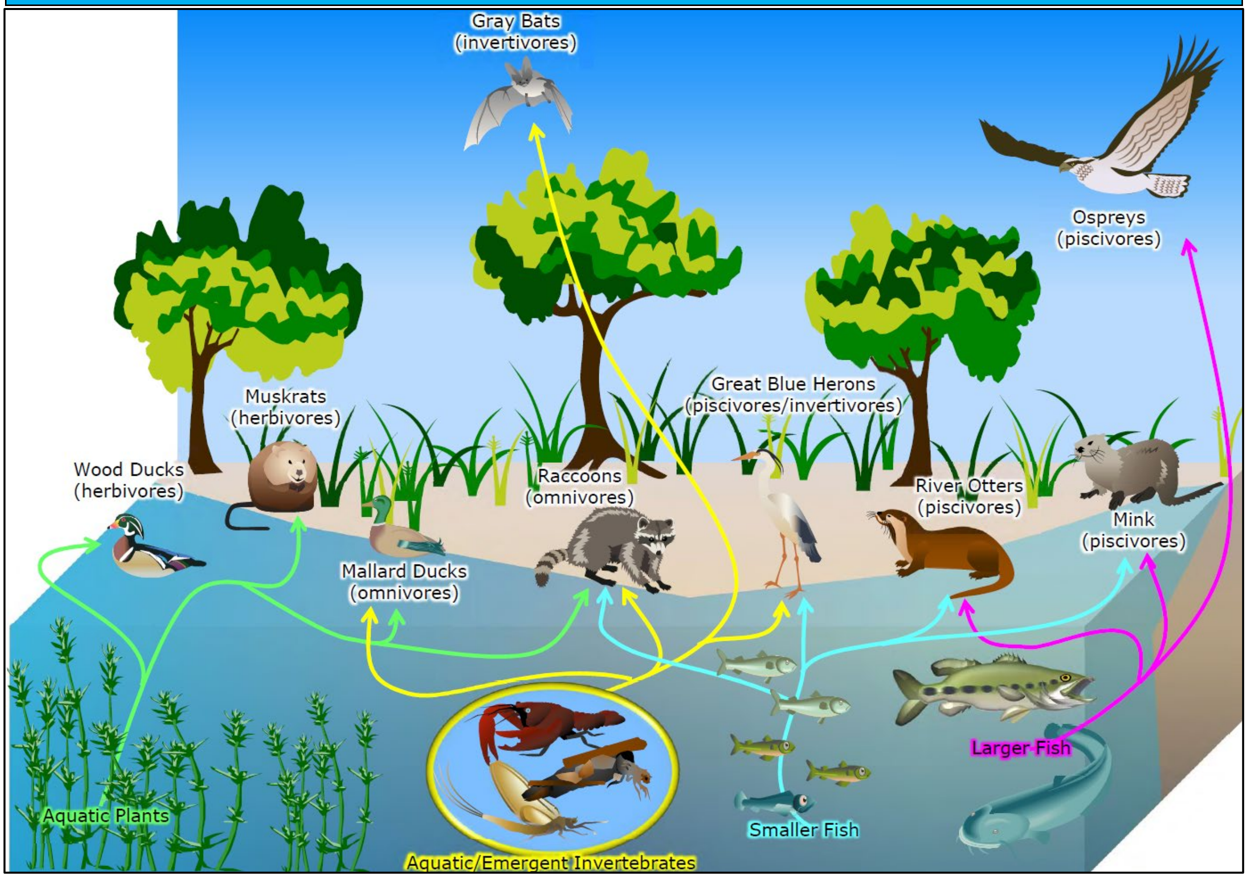
The only finding related to fish that raised any potential ecological concern was elevated selenium tissue concentrations in YOY bluegills collected in Curds Inlet compared to reference locations in other areas of Herrington Lake. The YOY bluegills collected in 2018 from Upper Curds Inlet, nearest to the Outfall BRN001, had the highest selenium tissue levels, and concentrations decreased with increasing distance away from E.W. Brown Station and from Curds Inlet. Neither USEPA nor Kentucky has developed a selenium standard based on YOY fish tissue concentrations, and as noted above, the adult fish tissue sampling results show no indication of adverse effect to the bluegill population in Herrington Lake. Nonetheless, it is possible that the elevated selenium concentrations measured in certain YOY fish in 2018 in upper and middle Curds Inlet may have posed a risk to these individual fish.

As noted above, however, the elimination of process water flows into Curds Inlet as of November 2019 should improve the environmental conditions in this aera, including surface water quality. As a result, it is uncertain whether exposure to selenium currently poses any potential risk to individual YOY fish in Curds Inlet.

Bird and Mammal Populations

The ERA used food web modeling to assess the survival, growth, and reproduction of bird and mammal populations. The species evaluated reflect the various tropic levels (i.e., feeding guilds like insectivore or carnivore) that may be present in Herrington Lake, as indicated in Exhibit 2-2.

Exhibit 2-2: Birds and Mammals Considered in the ERA Food Web Model



The results of the ERA food web model indicated that bird and mammal populations are not adversely impacted by CCR-related constituents in Curds Inlet or elsewhere in Herrington Lake.

Aquatic Plants and Aquatic Invertebrates

- The ERA evaluated community composition and function for aquatic plants and aquatic invertebrates based on the comparison of detected CCR-related constituents in water to protective (chronic) Kentucky surface water quality standards and protective USEPA ecological screening levels.
- Based the comparisons, the conditions in Curds Inlet and Herrington Lake do not pose an unacceptable risk to aquatic plant community or the aquatic invertebrate community exposed to CCR-related constituents from the E.W. Brown Station.

Sediment Dwelling Invertebrates

- The ERA evaluated potential risks to the sediment-dwelling invertebrate community using sediment and pore water concentrations specific to sediment dwelling organisms.

- The ERA concluded that the conditions in Curds Inlet and Herrington Lake are not likely to pose an unacceptable risk to the sediment-dwelling organism community exposed to CCR-related constituents from the E.W. Brown Station because the majority of detected sediment concentrations were less than the USEPA screening levels for sediment.
- Concentrations of selenium, arsenic, and iron in sediment exceeded the USEPA sediment screening levels, but when those concentrations were evaluated in more detail, they were considered unlikely to adversely impact the sediment-dwelling community, as described further below.

Selenium in Sediment and Sediment Pore Water

The selenium sediment concentrations in samples from Curds Inlet and background locations miles away from the influence of Curds Inlet exceeded the 2018 USEPA ecological screening levels (Figure 2-3B).

- The fact that concentrations of selenium in sediment both within Curds Inlet and well upstream of Curds Inlet (e.g. LHL6) exceeded the 2018 USEPA screening levels indicated that these values may not be useful for screening purposes given the naturally occurring conditions in Herrington Lake.
- For this reason, the basis of the USEPA Region 4 selenium sediment criteria was closely considered as part of the Corrective Action ISARA Report and, as explained in that document, the prior USEPA Region 4 sediment ecological screening levels were deemed more useful for assessing potential risk in Herrington Lake.
  - The prior USEPA Region 4 sediment selenium ecological screening levels are based on "no effects" and "low effects" from Washington state regulations (Washington State Department of Ecology. 2013).
  - The majority of selenium sediment concentrations in Curds Inlet were below the ecological "no effects" value. The detected selenium concentrations from 3 locations within Curds Inlet exceeded the Washington state "no effects" value (Figure 2-3B).
  - The remainder of the detected concentrations of selenium in sediments in Curds Inlet had concentrations less than low effect and many less than no effect.
  - Therefore, adverse impacts to the sediment dwelling community was considered unlikely to occur, but some isolated potential impacts to individual sediment dwelling organisms could not be definitively ruled out.
- Speciated selenium concentrations in pore water (selenate and selenite, the toxic forms of selenium) were compared to Kentucky chronic water quality standard and a selenium risk-based criterion from the USEPA ECOTOX database for sediment dwelling organisms (Figure 2-3C).
  - Selenate exceeded the Kentucky water quality standard at only a single location (CI1A) and none of the concentrations of selenate or selenite in sediment pore water exceeded the additional risk-based criterion from the USEPA ECOTOX database.
  - These results support the conclusion that selenium in sediment pore water does not pose an unacceptable risk to sediment dwelling organisms.

Arsenic in Sediment and Sediment Pore Water

- Most of the detected concentrations of arsenic in sediment within Curds Inlet and some of the detected concentrations of arsenic in sediment from other locations in Lower Herrington Lake exceeded the USEPA ecological screening levels for arsenic. none exceeded risk-based screening levels that are based on spiked sediment studies that evaluated the specific toxicity of arsenic for sediment-dwelling organisms similar to those likely to be present in Herrington Lake (Figure 2-4A).
- Speciated arsenic (arsenate and arsenite, the toxic forms of arsenic) concentrations in pore water samples exceeded the USEPA Region 4 screening level at several locations within Curds Inlet (Figure 2-4B).
    - The concentrations of arsenic, arsenite, and arsenate in pore water were also compared to a risk-based-criterion based on the USEPA ECOTOX database specific for sediment-dwelling organisms.
    - Arsenite and arsenate exceeded the risk-based criterion at four locations within Curds Inlet.
    - Based on these findings, some isolated areas along the thalweg in Curds Inlet may pose risk to sediment-dwelling organisms. Given the isolated locations, however, it is not likely that these conditions adversely impact the sediment-dwelling organism community.

Iron in Sediment and Sediment Pore Water

- The Corrective Action ISARA Report ERA discussed iron concentrations in sediment and pore water from Curds Inlet and Herrington Lake, and the sampling results for iron were graphically presented in the Coal Pile Addendum.
    - As explained in the Corrective Action ISARA Report and the Coal Pile Addendum, most of the detected concentrations of iron in sediment within Curds Inlet and Herrington Lake exceeded the lower USEPA ecological screening level for iron and 11 of the detected concentrations in Curds Inlet exceed the upper USEPA ecological screening level. The USEPA Region 4 screening levels for iron are based on an Ontario Ministry of the Environment (1993) study that brackets background values. These are not concentrations that have been observed to be toxic to sediment-dwelling organisms exposed to iron.
    - The Coal Pile Addendum and Figure 2-5 of this SRAA Report show that none of the detected concentrations of iron in sediment exceed the USEPA threshold value for iron toxicity in sediment and sediment-dwelling organisms (188,000 mg/kg, Ingersoll et al. 1996).Therefore, iron in sediment from Curds Inlet and Herrington Lake outside of Curds Inlet are not expected to cause adverse impacts to sediment-dwelling organisms.
    - The iron concentrations in sediment pore water exceed the upper Kentucky water quality standards of 1 mg/L and 3.5 mg/L at 5 locations within Curds Inlet (Figure 2-5). These five locations are within the central portion of Curds Inlet, where elevated arsenic concentrations were also observed and are illustrated on Figure 2-5 of this SRAA Report.
    - The Corrective Action ISARA Report evaluated iron in sediment pore water and noted that some of the pore water concentrations exceeded the Kentucky water quality standard for iron. However, the report did not identify iron as an issue for sediment dwelling organisms for a variety of reasons related to the geochemistry of iron, the natural occurrence of iron, and bioavailability of iron bound to the sediment matrix.

- The iron in sediment pore water is considered further in this SRAA Report because some potential impacts to some individual sediment-dwelling organisms cannot be definitely ruled out based on the sediment pore water concentrations at the five highest concentrations that exceed both the Kentucky water quality standards of 1 mg/L and 3.5 mg/L.
- Based on these findings, it is possible that some isolated impact to sediment dwelling organisms could occur where concentrations exceed the higher of the iron water quality standards. Because these isolated locations represent only a small portion of the sediment habitat, however, it is unlikely that iron would adversely impact the overall sediment-dwelling organism community.

2.3 Summary of Risk-Based Conditions Warranting Consideration for Supplemental Remedial Action

As discussed above and in the HHRA, there are no human health risks that warrant consideration of remedial action. The ERA did not identify any population level impacts to fish, birds, or mammals, and did not identify any likely risk to the sediment dwelling invertebrate community. Based on these findings, it is reasonable to conclude that no supplemental remedial actions are warranted to address ecological risk.

Some isolated risk may exist for individual fish in upper Curds Inlet based on elevated selenium concentrations measured in YOY bluegills in 2018, and some localized risk may exist for the sediment-dwelling community in middle Curds Inlet due to exposure to selenium in sediment, and arsenic and iron in sediment pore water. Absent impacts at the population or community level, these kinds of isolated risks to particular ecological organisms typically do not warrant the need for remedial action. However, in the event that the Cabinet chooses to pursue a greater level of ecological protection, the assessment of supplemental remedial alternatives is focused on determining if these potential localized risks to ecological organisms currently exist and, if so, how to address them.

3. REMEDIAL ACTION OBJECTIVES

3.1 Herrington Lake Remedial Alternative Objectives (RAOs)

Based on the findings of the investigation and risk assessments presented in the Corrective Action ISARA, the following RAOs are defined to address potential ecological risks for Herrington Lake and Curds Inlet:

- RAO 1: Sustain the applicable standards for protection of aquatic life in Curds Inlet and Herrington Lake for selenium.
- RAO 2: Reduce selenium concentrations in young-of-the-year (YOY) fish in Curds Inlet compared to the 2018 YOY selenium tissue concentrations.
- RAO 3: Demonstrate an acceptable level of diversity and abundance of the sediment-dwelling invertebrate community in Curds Inlet or reduce concentrations of selenium in sediment and arsenic and iron in sediment pore water to achieve acceptable levels of diversity and abundance.

3.2 Potential Supplemental Remedial Action Alternatives

Potential supplemental remedial action alternatives are considered for each of the RAOs considering the expected effects of the IRMs.

- RAO 1: Aquatic Life Water Quality Criteria
  - Based on the most recent and most comprehensive sampling data, aquatic life water quality standards for selenium are currently being met in Herrington Lake and Curds Inlet.
  - Moreover, the IRMs that have been implemented since the last round of sampling in 2018 as described in Section 1.2 above are expected to reduce overall selenium loading, thus increasing the confidence that the aquatic life criteria for selenium will continue to be met.
  - As a result, the only supplemental remedial action warranted for this RAO at this time is a monitoring program to confirm that the criteria continue to be met and that aquatic life continues to be protected.
  - The elements of an appropriate monitoring program are described in Section 4 of this report.
- RAO 2: Reduce Selenium Concentration in YOY Fish Compared to the 2018 YOY Selenium Tissue Concentrations
  - The Corrective Action ISARA Report concluded that the primary source of selenium detected in YOY fish tissue was the permitted discharge from the Aux Pond through Outfall BRN001 to Curds Inlet.
  - The highest concentrations of selenium in both fish tissue and surface water were measured in upper Curds Inlet closest to Outfall BRN001.
  - As noted, this discharge from the Aux Pond into Curds Inlet was eliminated as of November 2019, subsequent to the most recent YOY tissue sampling.
  - The only remaining potential source of selenium loading to Curds Inlet is flux from sediment or upwelling of groundwater, but the Corrective Action ISARA Report showed that any

contributions from either source are negligible compared to the average flow of approximately 5 million gallons per day formerly discharged to Curds Inlet from Outfall BRN001.

  - As a result, the only supplemental remedial action warranted for this RAO at this time is a monitoring program to determine whether YOY fish tissue concentrations are declining following the elimination of the Aux Pond discharge into Curds Inlet.
  - The elements of an appropriate monitoring program are described in Section 4 of this report.

- RAO 3: Diversity and Abundance of Sediment-Dwelling Organism Community
  - Remedial options considered to address elevated concentrations of selenium in sediment and arsenic and iron in sediment pore water include removal of contaminated sediments, capping of contaminated sediments, and enhanced natural attenuation following the elimination of the Aux Pond discharge to Curds Inlet.
  - To date, however, there has been no direct assessment of the diversity and abundance of the sediment-dwelling organism community in Curds Inlet to confirm whether these elevated concentrations are having any unacceptable adverse effects on that community.
  - Such an assessment will inform any decision about the need for supplemental remedial action to address sediment or pore water. The elements of an appropriate assessment program for this RAO are described in Section 4 of this report.

Depending on the results of this community assessment, further remedial action may be considered on a contingent basis, as discussed in Section 5 of this report.

4. SUPPLEMENTAL PERFORMANCE MONITORING

This section describes the proposed supplemental performance monitoring programs to meet the RAOs. In each case, the performance criteria identify when monitoring may be discontined and the RAO considered met (i.e., these monitoring elements are independent of one another and any particular monitoring element may be discontinued when performance criteria are met).

4.1 Monitoring Adult Fish (RAO 1)

RAO 1: Sustain the applicable standards for protection of aquatic life in Curds Inlet and Herrington Lake for selenium.

Measurements: Selenium concentrations in (1) adult whole-body bluegills, (2)bluegill ovary/egg tissues; and (3) adult whole-body largemouth bass.

Overview of Monitoring: Adult whole-body bluegills and largemouth bass will be collected from Curds Inlet and Middle Herrington Lake to address RAO 1 with samples collected from locations shown on Figures 4-1A and 4-1B and summarized on Table 4-1. Adult bluegills and largemouth bass samples will be collected consistent with the Quality Assurance Project Plan (Ramboll 2017b) and following the methodology provided in Appendix A-1 for the collection of adult fish tissues as part of the performance monitoring program in Herrington Lake. Efforts will be made to collect bluegills and largemouth bass. If those species are unavailable at the time of sampling, other sunfish and Kentucky bass will be considered reasonable substitutes.

Adult fish will be collected in Curds Inlet as well as locations in lower Herrington Lake (LHL 1, LHL 2, and LHL 6) and Middle Herrington Lake, consistent with the locations sampled as part of the Phase I and II investigations in 2017 and 2018.

- Adult bluegills and largemouth bass collection will occur prior to spring spawning in March/early April to facilitate collection of gravid females, if available. As summarized in Table 4-1, thirteen adult bluegill composite samples will be collected from six sampling stations. Each composite sample will be comprised of 2 to 5 adult bluegills, which equates to approximately 26 to 55 individual bluegills. Eleven adult bass composite samples will be collected from five sampling stations. Each composite sample will be comprised of 2 to 3 largemouth bass, which equates to approximately 22 to 33 individual bass.
- Efforts will be made to collect ovary/egg tissues from gravid female bluegills. If gravid bluegills are collected, ovaries will be removed, and the ovaries, including egg tissue, will be submitted for analysis separately from the remaining carcass. Ovary and carcass concentrations will be recombined to provide whole-body concentrations, as done for the Corrective Action ISARA Report.
- Ovary/egg tissues will be collected for bluegills only. Adult largemouth bass ovary tissues are not planned for RAO 1 because ovary tissues were analyzed for largemouth bass and catfish in 2017 and the results did not exceed the USEPA ovary criterion (Ramboll 2019). In addition, studies indicate that bluegills are more sensitive to selenium exposure than largemouth bass (USEPA 2016c).
- The adult fish samples (whole-body and ovary tissues) will be analyzed for selenium (bluegills and largemouth bass).

RAO 1 Performance Criteria:

- The adult fish whole-body dry weight tissue analytical results will be compared to the Kentucky Surface Water Quality Standard for Warm Water Habitat for selenium in whole body fish tissues (Source: KDOW 2020, 401 KAR 10:031,).
- Bluegill ovary/egg concentrations will be compared to the USEPA ovary/egg criterion (USEPA 2016).
- Monitoring will be considered complete after the first monitoring event (i.e., RAO 1 achieved) if the following criteria are met:
  - Selenium concentrations in adult bluegills and largemouth bass whole-body fish tissues are less than the Kentucky Water Quality Standard for selenium (8.6 mg/kg).
  - Selenium concentrations in bluegill ovary/egg tissues from Curds Inlet are less than the USEPA ovary/egg criterion (15.1 mg/kg).
- Additional monitoring events will be conducted if any whole-body fish tissue samples from Curds Inlet or LHL exceed the Kentucky water quality standard for selenium in whole-body fish tissues or any ovary/egg tissues from Curds Inlet exceed the USEPA ovary/egg criterion. The timing of the sampling will be determined based on consultation with the Cabinet. If the applicable standards are met during each of two consecutive additional monitoring events, performance monitoring will be considered complete.
- If performance monitoring does not demonstrate that RAO 1 continues to be met, KU will confer with the Cabinet regarding possible further remedial action.
- Once performance monitoring is completed, additional fish tissue testing will continue to be conducted in accordance with the 2019 KPDES permit if effluent sampling for outfall BRN006 exceeds the trigger value for selenium.

4.2 Monitoring YOY Bluegill Fish Tissues (RAO 2)

RAO 2: Reduce selenium concentrations in young-of-the-year (YOY) bluegills from Curds Inlet compared to the 2018 YOY tissue concentrations.

Measurement: Selenium concentration in YOY bluegill whole-body tissues.

Overview of Monitoring: YOY whole-body fish will be collected from Curds Inlet and a reference area in Lower Herrington Lake as displayed in Figures 4-2A, 4-2B and summarized on Table 4-1. Two monitoring events are anticipated to identify whether there is a trend of reduced YOY bluegill selenium tissue concentrations observed when compared to selenium concentrations observed in YOY bluegills in 2018. As summarized in Table 4-1, twelve bluegill YOY composite samples will be collected from four sampling stations. Each composite sample will be comprised of approximately 20 to 100 YOY bluegills, which equates to approximately 240 to 1200 individual YOY bluegills.

YOY bluegill composite fish samples will be collected consistent with the Quality Assurance Project Plan (Ramboll 2017b) and following methodology provided in Appendix A-1 for the collection of YOY fish tissues as part of the performance monitoring program in Herrington Lake.

YOY fish will be collected during the summer, to allow for sufficient development of young fish. The collected individual whole-body YOY fish will be combined to form composite samples. The number of individual fish per sample will be determined by the volume requirements of the analytical laboratory (approximately 5 to 10 grams of fish tissue). The composite YOY samples will be analyzed for selenium.

For consistency and to allow direct comparison to the summer 2018 YOY study results reported in the Corrective Action ISARA Report, the proposed YOY bluegill monitoring locations include:

1. Curds Inlet (Upper, Middle, and Lower); three YOY regions located adjacent to E.W. Brown Station). The lower Curds Inlet area can extend into HQ Inlet because these areas are very close and the 2018 data show that lower Curds Inlet and HQ Inlet YOY fish had similar selenium concentrations.
2. The target reference area will be Hardin Inlet (located approximately 3/4 of a mile upstream from Curds Inlet). Other reference areas, LHL 1 and LHL 6, will only be sampled if insufficient fish can be collected from Hardin Inlet at the time of sampling.

Surface water samples will also be collected from each area where YOY samples are collected. Selenium in surface water will be analyzed as supporting information to understand the selenium concentrations in YOY fish. It is not a direct measurement of performance, as the selenium in fish tissues supersedes water concentrations according to the Kentucky water quality standards. The final determination of the locations for collection of the YOY fish and surface water will be determined at the time of sampling based on where the YOY fish are found.

RAO 2 Performance Criteria:

- The YOY composite whole-body dry-weight tissue analytical results for Curds Inlet will be compared to the 2018 YOY sampling results.
- At least two monitoring events are considered necessary to confirm tissue concentration trends. The results from the first YOY monitoring event will be used to inform the timing of the next YOY sampling event. The timing of the sampling will be determined based on consultation with the Cabinet.
- Monitoring will be considered complete if the first and second sampling events show an overall declining trend in YOY selenium concentrations compared with the 2018 YOY sampling.
- Additional sampling events will be conducted if the results of the initial two performance monitoring sampling events from Curds Inlet does not show a trend of selenium reduction compared to 2018 results. If the YOY tissue concentrations show an overall declining trend over two additional monitoring events, performance monitoring will be considered complete.
- If the performance monitoring does not demonstrate that RAO 2 is met, KU will confer with the Cabinet regarding possible further remedial action.

4.3 Assessment of Monitoring Sediment-Dwelling Organism Community Health (RAO 3)

RAO 3: Demonstrate the diversity and abundance of the Curds Inlet sediment-dwelling invertebrate community, considering the presence of selenium in sediment, arsenic in sediment pore water, and iron in sediment pore water.

Measurements: Sediment dwelling organism community composition, based on taxonomic identification of diversity, abundance, and other community metrics.

Overview of Monitoring: To address RAO 3, a benthic invertebrate community assessment will be completed in Curds Inlet and at a reference area in the lower Herrington Lake area (see Figure 4-3). Sampling areas will include three areas in Curds Inlet (Upper Curds Inlet, Middle Curds Inlet, and Lower Curds Inlet), and a reference location from one of the following areas, to be selected based on the conditions at the time of sampling: Hardin Inlet, LHL1 or LHL6.

Benthic community samples will be collected using an artificial substrate, such as a multi-plate sampler (e.g., Hester-Dendy arrays) or rock baskets. Examples of multi-plate and rock basket samplers are provided in Appendix A-2. Artificial substrates will be deployed in multiple sets (3 replicates per location) and then retrieved approximately six weeks later, depending on the time of year, to allow for benthic invertebrate colonization of the substrate. As indicated in Table 4-1, 36 benthic community assessment samplers will be deployed in four sampling areas – three within Curds Inlet and one reference area. The final selection of the artificial substrate sampling device and the placement of artificial substrate samplers will be based on:

- Areas with highest concentrations of selenium in sediment (Figure 2-3B), arsenic in sediment pore water (Figure 2-4B), and iron in sediment pore water (Figure 2-5).
- Sub-bottom profile and side scan sonar imagery that will be conducted for insight into the size and locations of sediment deposits and the presence of debris within Curds Inlet. Areas of debris that could entangle the artificial substrate samplers will be avoided. t. The SOP for sub-bottom profile and side scan sonar imagery is provided in Appendix A-3.
- The selected artificial substrate will be positioned and secured approximately three to six inches above the surface of the sediment to be elevated enough to avoid getting the sampler filled with sediment, but close enough to the sediment surface to attract sediment-dwelling organisms.
- The same artificial substrate samplers will be used in Curds Inlet and the reference area(s).

The number of proposed benthic community samples with the first monitoring event is shown in Table 4-1. General sampling methodology will be consistent with the relevant KDOW guidance (e.g., KDOW 2002, 2003, 2015) and USEPA Guidance (1989, 1999, 2001, 2006, 2009). The sampling will be timed for spring or summer of 2022, subject to the Cabinet's approval. . Upon retrieval, the artificial substrates will be collected and placed in sample containers with 10 percent ethanol for shipment to a taxonomic laboratory for processing. Following the taxonomic identification and enumeration of the benthic community samples, the benthic community health assessment metrics may include:

- Species richness
- Abundance
- Ephemeroptera, Plecoptera, Trichoptera richness
- Community similarity index
- Hilsenhoff Biotic Index
- Species diversity (Shannon diversity)
- Dominance
- Non-chironomid/oligochaete richness
- Chironomid mouthpart deformities
- Ratio of various feeding guilds (e.g., shredders, scrapers, filter-feeders)

Appendix A-2 provides a Benthic Community Assessment SOP, which explains each metric and the KDOW and USEPA calculation methodologies that will be used.

RAO 3 Performance Criteria:
The results of benthic community assessment for Curds Inlet will be compared to results from the reference area selected at the time of sampling (from Hardin Inlet, LHL1 or LHL6) (Figure 4-3). The USEPA metrics and scoring approach for non-wadeable streams (2006) will be used to evaluate the benthic community in Curds Inlet for RAO 3. The final list of metrics most appropriate to Herrington Lake will be identified based on the benthic community observed at the Herrington Lake reference area(s) selected for the assessment, as described in Appendix A-2. The USEPA lake indices will also be calculated in accordance with USEPA 2009 and 2001, with comparisons made to the reference area(s) selected for Herrington Lake. In accordance with scoring described in Appendix A-2, multi-metric scoring and indices will be considered for Curds Inlet compared to Herrington Lake reference area(s) for RAO 3, as follows:

- Conditions greater than or equal to 80% in Curds Inlet relative to reference area(s) in Herrington Lake will be considered comparable;
- Conditions between 50 and 79% in Curds Inlet relative to reference area(s) in Herrington Lake will be considered slightly impaired;
- Conditions between 21 and 49% in Curds Inlet relative to reference area(s) in Herrington Lake will be considered moderately impaired; and,
- Conditions less than 20% in Curds Inlet relative to reference area(s) in Herrington Lake will be considered severely impaired.
- Performance monitoring will be considered complete if the assessment demonstrates that the community composition between Curds Inlet and the reference area are designated "comparable," defined as multi-metric scoring within 80% between Curds Inlet and the reference location.
- Depending upon the results of the monitoring:
  - Additional monitoring events will be conducted if the benthic community assessment does not meet the foregoing criterion of comparable conditions. The timing of the sampling will be determined based on consultation with the Cabinet.
  - If the additional monitoring shows that the benthic community in Curds Inlet is comparable to the Herrington Lake reference area(s)Curds Inlet, performance monitoring will be considered complete.
  - If the results of the sediment-dwelling invertebrate community assessment for areas of Curds Inlet with elevated pore water arsenic and iron are not shown to be comparable to the community in the reference area, and if the Cabinet concludes that additional monitoring of the invertebrate community is not expected to yield different results, additional remedial measures will be considered as discussed in Section 5 of this report.

4.4 Performance Monitoring Reports

Performance Monitoring Report(s) will be provided to the Cabinet, for each monitoring event following completion of the field sampling, analytical testing, data validation, and assessment.

5. CONTINGENT SUPPLEMENTAL REMEDIAL ACTION ASSESSMENT FOR RAO 3

This section evaluates contingent remedial action alternatives to address selenium in sediment and arsenic and iron in sediment pore water in Curds Inlet if the performance monitoring discussed in Section 4.3 does not demonstrate that RAO 3 is met.

This preliminary evaluation applied to the criteria defined in 401 KAR 100:030, as well as the considerations of "sustainability" in accordance with USEPA's April 2008 Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (USEPA 2008b) and the Interstate Technology and Regulatory Council's (ITRC) November 2011 Green and Sustainable Remediation: A Practical Framework (ITRC 2011). The results of this preliminary comparative analysis will serve as the basis for further evaluation and recommendations to the Cabinet for selection of an appropriate remedy should performance monitoring identify conditions warranting supplemental actions.

5.1 Spatial Distribution of CCR Constituents in Curds Inlet Warranting Consideration in this SRAA

The potential area of selenium in sediment, arsenic in sediment pore water, and iron in sediment pore water that may be considered for contingent remedial action depending on the outcome of proposed performance monitoring (see Section 4) have been estimated based on a range of risk-based criteria. As described in Appendix B, the following three remedial footprints are defined for the purpose of this contingent remedial action assessment:

- Footprint 1 is illustrated in Figure 5-1A. This is the smallest remedial footprint of 0.75 acres, based on the highest risk-based criteria. This footprint is based on selenium in sediment exceeding 20 milligrams per kilogram (mg/kg), arsenic in pore water exceeding 0.34 milligrams per liter (mg/L), and iron in pore water exceeding 3.5 mg/L.
- Footprint 2 is illustrated in Figure 5-1B. This remedial footprint of 1.5 acres is based on selenium in sediment exceeding 11 mg/kg, arsenic in pore water exceeding 0.15 mg/L, and iron in pore water exceeding 1.0 mg/L.
- Footprint 3 is illustrated in Figure 5-1C. This is the largest remedial footprint of 2.14 acres, based on selenium in sediment exceeding 2.9 mg/kg, arsenic in pore water exceeding 0.15 mg/L, and iron in pore water exceeding 1.0 mg/L.

Each of the estimated areas of sediment remediation is evaluated in this SRAA for consideration by the Cabinet should any contingent supplemental remedial alternatives be considered necessary for RAO 3. To inform the Cabinet's review, the reduction in ecological risk was evaluated for each of the three contingent remedy alternatives (described further in Section 5.2) under each of the remedial Footprints compared to the existing conditions in Curds Inlet. Hazard quotients can be used to represent potential ecological risks, as was discussed in the Corrective Action ISARA Report (Ramboll 2019). Hazard quotients less than or equal to a value of 1 indicate that no unacceptable risks are expected. Hazard quotients between 1 and 3 indicate conditions where risks cannot be definitively ruled out but are not expected to adversely impact the sediment dwelling organism community. The hazard quotients for Curds Inlet presented in Figure 5-2 are based on measured concentrations of selenium in sediment, arsenic in sediment pore water, and iron in sediment pore water under existing conditions and the conditions following completion of remedial action within each footprint compared to ecological screening values associated with Footprint 1 as specified above. Under existing conditions, only one location within Curds Inlet had hazard quotients greater than 3 (location CI3.1A, associated with the highest arsenic concentration in sediment pore water).

As shown on Figures 5-2, for each of the three Contingent Remedial Alternatives, the level of risk reduction is comparable across all three footprints. This indicates that there would be little if any meaningful reduction in ecological risks to be gained from expanding the remedial footprint beyond Footprint 1.

5.2 Identification of Contingent Remedial Alternatives

As described in USEPA guidance, there are three primary approaches considered for reducing risk from contaminated sediment (or pore water): (1) monitored natural recovery (MNR), (2) in-situ capping, and (3) sediment removal by dredging or excavation (USEPA 2005). These general approaches are considered herein for Curds Inlet. Specifically, conceptual approaches for three contingent remedial alternatives have been evaluated as described in the following subsections, considering the remediation target concentrations and associated areas of potential impact defined as Footprints 1 through 3.

5.2.1 Contingent Alternative 1: Enhanced Monitoring Natural Recovery (EMNR)

MNR is defined by the National Research Council (1997) as a remediation practice that relies on natural processes to protect the environment and receptors from unacceptable exposures to contaminants. As discussed in Section 4, monitoring within Curds Inlet is proposed to assess improvements resulting from source control measures that have been implemented in accordance with the GWRAP as well as other facility operational changes that have reduced mass loading to Herrington Lake and Curds Inlet. Enhanced MNR (EMNR) applies material or amendments to enhance these natural recovery processes (such as the addition of a thin-layer cap or a carbon amendment). Parallel natural or enhanced processes, taken together with observed and predicted reductions of contaminant concentrations in fish tissue, sediments, and water, provide multiple lines of evidence to support the selection of MNR/EMNR.

Contingent Alternative 1 would consist of the placement of a thin layer cover over impacted sediments in Curds Inlet. For all three remedial footprint scenarios, the thin layer cap would consist of 6 inches of sand which would serve to accelerate, or *enhance*, ongoing natural recovery processes. Table 5-1 summarizes the remedial quantities estimated for Alternative 1 for this evaluation.

It is anticipated that the thin layer cover would be spread hydraulically or mechanically using equipment staged on floating barges that can be positioned within Curds Inlet using a small tug or work boat. Sand would be delivered to and stockpiled in a centrally-located material-staging area located upland and proximate to Curds Inlet, from where materials would be transferred to water-based scows to supply the barge operation.

5.2.2 Contingent Alternative 2: Capping

Contingent Alternative 2 consists of placement of clean isolation cap materials over impacted sediments in Curds Inlet. For the purposes of this evaluation, the proposed sediment cap consists of a 4.5-foot layer of sand in arsenic-impacted areas to address potential migration of arsenic in pore water up through the cap material, and a 1-foot layer of sand in non-arsenic-impacted areas.[4] In addition, the proposed sediment cap includes a 6-inch layer of armor stone, which would protect the underlying isolation sand layer. Table 5-1 summarizes the remedial quantities estimated for Alternative 2 for this evaluation.

It is anticipated that sand and armor cap materials would be placed hydraulically or mechanically using equipment staged on floating barges that can be positioned around Curds Inlet using a small tug or work boat. Capping materials would be delivered to and stockpiled in a material-staging area located upland and proximate to Curds Inlet, from where materials would be transferred to water-based scows to supply the barge operation.

5.2.3 Contingent Alternative 3: Sediment Removal

Contingent Alternative 3 consists of removal of impacted sediments from Curds Inlet. For the purposes of this evaluation, the proposed removal depths for all three remediation footprints are two feet.[5] Table 5-1 summarizes the remedial quantities estimated for Alternative 3 for this evaluation.

Sediment removal in Curds Inlet would involve mechanical dredging using a barge-mounted crane with clamshell bucket attachment, and sediment placement in a scow for transport to an upland temporary material processing area. Sediments would then be dewatered for offsite disposal.[6] Material processing will also likely include mixing the sediment with stabilization reagents prior to offsite transport. Water recovered from dewatering would be collected for onsite treatment prior to discharge. It is assumed that this alternative does not require backfilling of the sediment removal areas because any underlying sediment that remains in place is not expected to have elevated contaminant concentrations, but this assumption would need to be confirmed prior to implementation of this alternative.

5.2.4 Elements Common to all Alternatives

All the contingent alternatives would be supported from upland areas adjacent to Curds Inlet. Prior to starting any in-water remediation activities, turbidity curtains would be installed across the eastern end of Curds Inlet to prevent the re-deposition of suspended sediment outside the target remediation areas. The turbidity curtains would be removed at the conclusion of construction activities. All support operations would be dismantled, and the disturbed areas restored with topsoil and seeding, following the conclusion of construction activities.

5.3 Contingent Remedial Alternatives Evaluation Criteria

As specified in the CAP, each contingent remedy alternative was evaluated according to the criteria in 401 KAR 100:030. Alternatives must meet the threshold criteria to be considered viable. The eight

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[4] As detailed in Appendix C, the different sand cap layer thicknesses defined for arsenic-impacted and non-arsenic-impacted areas are based on preliminary cap modeling calculations involving median sediment-porewater partitioning coefficients for arsenic and selenium (Allison and Allison 2005).

[5] The two-foot target removal depth represents an estimated average sediment thickness in Curds Inlet based on limited available measurements. Additional investigation (e.g., sub-bottom profiling) would be required to refine this estimate.

[6] For the purposes of this evaluation, it has been assumed that dredged sediments would be disposed offsite at a permitted facility. Disposal of sediments in the onsite landfill may be a viable alternative subject to regulatory and permitting approvals.

evaluation criteria defined in 401 KAR 100:030 are described below in terms of threshold criteria, balancing criteria, and modifying criteria.

Threshold Criteria

1. Overall Protection of Human Health and the Environment: This criterion is used to evaluate whether the alternative achieves adequate protection for human and ecological receptors (i.e., the overall ability of the alternative to achieve the RAOs developed for the site).
2. Compliance with Any Other Applicable Requirements:
    i. The cleanup must be consistent with current and potential future land use; and
    ii. The alternative must be compliant with Kentucky and USEPA regulations.

Primary Balancing Criteria

3. Long-Term Effectiveness and Permanence: This criterion is used to evaluate the adequacy and reliability of the alternative to maintain acceptable risk conditions over time. It also considers the extent to which the alternative and its effects are irreversible, providing an assessment of the potential need to replace technical components of the alternative and the potential exposure pathways and risks posed should the remedial action require replacement.
4. Reduction of Toxicity, Mobility, or Volume through Treatment: This criterion is used to evaluate the extent to which the alternative reduces toxicity, mobility, and volume of contaminants of concern through treatment. It also provides a quantification of risks from residual materials left onsite post-remedy implementation.
5. Short-Term Effectiveness: This criterion is used to evaluate the potential impacts to site workers and the community during implementation of the alternative until the RAOs are achieved. It also considers the potential positive and/or negative environmental impacts of the alternative, including temporary physical disturbance of the environment.
6. Implementability: This criterion is used to evaluate the technical challenges associated with constructing and maintaining the alternative, including availability of necessary equipment and personnel and the ability to monitor remedy effectiveness. It also considers the availability of treatment, storage, and disposal services. In addition, the ability to obtain necessary permits and agency approvals is assessed.
7. Cost: This criterion includes an evaluation of the total estimated present worth of indirect (e.g., engineering design, permitting, and contingencies) and direct (e.g., equipment, labor, materials, and disposal) capital costs to implement the alternative.[7]

Modifying Criteria

8. Community Acceptance: This criterion is used to evaluate the expected level of acceptance from community stakeholders and the degree to which the alternative addresses the general public's issues and concerns. It also considers whether the alternative adequately addresses the technical and administrative issues raised by the community.

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[7] In accordance with USEPA guidance, the cost evaluation for alternatives typically also includes costs for post-construction, as well as long-term operation and maintenance (O&M) activities required to demonstrate and ensure the continued effective performance of the remedy. However, O&M costs have not been developed for the contingent remedial alternatives identified in this SRAA. Development of these costs would be included in future evaluations, should performance monitoring identify conditions warranting supplemental remedial actions.

In addition to the eight criteria defined in 401 KAR 100:030 and consistent with USEPA and ITRC (2011) guidance, the sustainability/overall environmental impact of the identified contingent remedial alternatives has been considered in this preliminary evaluation (USEPA 1998, 1999, 2000, 2002, 2005, 2008, 2016a, 2020a, 2020b; ITRC 2011). As discussed in the 2017 CAP, in selecting a remedial action, it is important to understand the potential benefits (i.e., gains in ecosystem service value) and costs (i.e., losses in ecosystem value) associated with the implementation of each alternative and the relationship to predicted ecosystem service injury that is suggested by a risk assessment. Consideration of green cleanup assessment elements (e.g., energy and resource use, air emissions, waste reduction, and land management) may assist in the overall evaluation, selection, and implementation of protective remedial strategies.

5.4 Evaluation of Contingent Remedial Alternatives

As discussed in Section 5.3, the criteria specified in 401 KAR 100:030 were used to complete the preliminary evaluation of the three contingent remedial alternatives identified in Section 5.2. As discussed above, it is expected that the completed IRMs and other facility operational changes will be sufficient to achieve the RAOs. However, to the extent that performance monitoring described in Section 4 indicates that supplemental remedial measures are needed to achieve RAO 3, all three alternatives, in combination with the previously implemented IRMs, are expected to achieve the threshold criteria of overall protectiveness of human health and the environment and compliance with other applicable requirements. Therefore, this preliminary evaluation of these alternatives focuses primarily on the balancing criteria. Consideration of the modifying criteria and the anticipated sustainability of the alternatives is also provided. A qualitative summary of the following evaluation is presented in Table 5-2.

5.4.1 Long-Term Effectiveness and Permanence

Contingent Alternatives 1 through 3 will provide varying degrees of long-term effectiveness and permanence.

- Contingent Alternative 1, EMNR (thin layer cover placement), will immediately enhance ongoing natural recovery processes and prevent direct contact with impacted sediment within the bioactive zone (i.e., the upper six inches of sediment), thereby reducing potential exposure risks and impacts to the environment. However, Contingent Alternative 1 is less effective and permanent than Contingent Alternatives 2 (capping) and 3 (sediment removal) because the remaining underlying impacted sediments will continue to present a potential source for exposures should the thin cover layer be disturbed or from seepage of contaminated pore water from sediments below the thin cover.

- Also, in comparison, Contingent Alternatives 2 (capping) and 3 (sediment removal) do not rely on ongoing natural recovery processes. Placement of a thicker sediment cap (as compared with the EMNR thin layer cover) will better isolate the impacted sediments, further reducing potential ecological exposures. However, a higher level of long-term effectiveness will be achieved through removal of impacted sediments since the source of potential exposure risks and impacts to the environment will be permanently eliminated. Contingent Alternative 3 would require post-removal confirmation sampling to ensure effective implementation of the remedy.

A comparison of risk reduction for Curds Inlet after 10 years for each Footprint is presented on Figure 5-2. Figure 5-2 shows the risk reduction for each of the three Footprints following implementation Continent Remedial Alternatives 1 (EMNR), 2 (capping), and 3 (dredging) compared to existing conditions. Figure 5-2 indicates that each Alternative would achieve approximately the same level of risk reduction across all three Footprints.

- As shown on Figure 5-2, hazard quotients are less than 1 for each of the Footprints for all three Alternatives at 10 years following Contingent Alternative implementation.
- Beyond 10 years, the model indicates that continued seepage expected over time for Alternative 1 for arsenic and iron in pore water could result in hazard quotients greater than 1, but the model does not account for deposition in Curds Inlet over time. Given the significantly reduced water flows in Curds Inlet following the relocation of process water discharges to Outfall BRN006, it is anticipated that deposition rates in Curds Inlet will increase and may offset any effects from seepage beyond 10 years.

For all alternatives, long-term monitoring and maintenance requirements are generally expected to be limited to monitoring the recovery process in Curds Inlet. There are no technical components of Contingent Alternative 3 that would require repair or replacement. For Contingent Alternatives 1 and 2, the potential need to replace the alternatives is low assuming that the cover/cap systems for the ash ponds, along with the previously implemented IRMs, are properly maintained. Institutional controls will be required to maintain permanence of the remedy by restricting activities that could result in disturbance of the caps.

5.4.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

None of the contingent alternatives evaluated in this SRAA incorporates a *treatment* component. Contingent Alternatives 1 and 2 involve placement of layers of clean material to isolate contaminants from ecological receptors, which is not considered a form of treatment. Contingent Alternative 3 assumes sediment removal with direct disposal in an offsite landfill with no treatment (other than dewatering).

Contingent Alternative 2 will provide the largest reduction in contaminant mobility. As discussed in Section 5.2.2, preliminary cap modeling of arsenic and selenium transport from the contaminated sediment was conducted. The modeling indicated that a sand cap placed over the sediments can meet target cleanup levels. The preliminary modeling for the sediment cap conducted as part of this SRAA Report provides the minimum thicknesses required to establish a sufficient isolation layer to prevent the existing arsenic and selenium contamination to reach the cap surface at concentrations exceeding target cleanup levels. In comparison, while Contingent Alternative 1 will enhance ongoing natural recovery processes by providing a clean cover layer within the bioactive zone, it will not significantly reduce toxicity or mobility of contaminants from the underlying sediments to pore water. Contingent Alternative 3 will provide a substantial reduction in contaminant volume. However, given the anticipated challenges posed by conditions in Curds Inlet (i.e., the potential presence of large debris, substantial water depths, and relatively shallow sediment depth above bedrock), there is a greater potential for mobilizing contaminated sediments through the water column during dredging and debris removal, and potential challenges for achieving complete removal.

5.4.3 Short-Term Effectiveness

The contingent remedial alternatives provide varying degrees of short-term effectiveness when considering the potential adverse impacts on human health and the environment during implementation of remedy construction. Short-term risks, including risks to human health and the environment (onsite and in the surrounding community), injury or fatality, nuisance conditions (e.g., odor, dust, runoff, noise), and greenhouse gas emissions are generally proportional to the amount of material transport handling required and the time required to complete construction. These risks will generally increase with the size of the remedy footprint as the duration of remedial activities increases and material management increases.

Short-term exposure risks are expected to be similar in kind for Contingent Alternatives 1 and 2, as these require the import and placement of clean materials. However, given the multiple cap layers (sand and armor) and greater cap thickness for Alternative 2, a substantially higher material volume (see Table 5-1) and longer construction duration are anticipated for Alternative 2 compared to Contingent Alternative 1. This will result in additional truck traffic and associated energy consumption, air emissions, dust, noise, and risk of injury and accidents.

The more intrusive Contingent Alternative 3 (dredging) will have even greater potential short-term impacts to site workers, ecological receptors, and the local community. The equipment that will be required to excavate contaminated sediments and potentially remove large subsurface debris is expected to generate substantially greater air emissions and noise than the other two alternatives. Upland dewatering and stabilization activities and transportation of removed sediments for offsite disposal will also result in greater truck traffic and associated energy consumption, nuisance conditions, and injury/accident risk. In addition, as noted above, there is a greater potential for mobilizing contaminated sediments through the water column during dredging and debris removal, resulting in increased short-term exposures and risks.

Worker safety is an important concern for all three contingent alternatives. It is well-documented that workers in a water environment are at higher risk than land-based construction workers; the National Institute for Occupational Safety and Health (NIOSH) Center for Maritime Safety and Health Studies have documented that workers in the water industry have a fatality rate 4.7 times higher than the rate for all US workers (NIOSH 2020). While Curds Inlet is not a marine environment, it is an open water body with significant water depths that will pose greater risk for injury and fatality during construction to workers than associated with similar upland construction activities. In particular:

- On-water work areas (i.e., equipment staged on barges or flexi-floats) will be less stable;
- There is increased risk for accident and injury due to reduced mobility associated with the use of upgraded levels of PPE (e.g., personal floatation devices); and
- Offshore workers will be physically and potentially visually isolated from land, which will increase access challenges and response time for emergency crews, if needed.

Given the above concerns, it is anticipated that Contingent Alternative 3 represents the highest short-term risk to onsite workers, the local community, and ecological receptors. With the shortest duration and smallest volume of material to be managed, Contingent Alternative 1 presents the least short-term risk.

5.4.4 Implementability

Typically, implementability scales inversely with the intrusiveness of the remedy. In aquatic environments, larger, more intrusive remedies create unique implementability challenges that must be addressed. In Curds Inlet, existing site conditions, including the steep terrain in Curds Inlet, the water depth in the proposed work areas, and the steep shore rock walls, pose significant challenges for implementing all three of the contingent remedial alternatives. These alternatives will require the use of specialized equipment (e.g., amphibious, or barge-mounted construction equipment). However, thin layer cover, capping, and removal are commonly used at comparable sites and have a proven performance; it is expected that an experienced and qualified contractor will be able to provide the equipment and perform the work required.

Another potentially significant challenge, especially with respect to the implementability of Contingent Alternative 3, is the presence of remnant trees, tree stumps and debris in or on the sediment surface. The size and number of tree trunks and other woody vegetative debris that may be present in the work area and require removal prior to remedy implementation is currently unknown and could greatly limit the technical feasibility of Contingent Alternative 3. By comparison, the vegetative debris may also interfere with completing complete coverage by a thin layer cover for Alternative 1. This concern would be less for Contingent Alternative 2 which involves significantly thicker material placement to blanket the area. A sub-bottom profile survey will provide more information of the sediment surface conditions that could interfere with implementation of the contingent alternatives.

Contingent Alternative 3 will also require significant waste material management, both offsite for dredged sediments and debris, and onsite for water generated from sediment dewatering. Comparatively, Contingent Alternatives 1 and 2 are moderately to highly implementable and technically feasible, although will still require similar mobilization efforts, as well as post-remedy monitoring (and potentially maintenance) to demonstrate and ensure the continued effective performance of the remedy.

For all alternatives, further evaluation will be needed to determine implementability and identify permits that will be required where improvements are to take place within regulated areas.

5.4.5 Cost

Appendix C presents preliminary cost estimates for each contingent remedial alternative. The ranges of estimated capital costs (i.e., design, permitting, and construction) to implement the alternatives for each of the three remedial Footprints are summarized as follows (expressed in millions (MM) of US dollars):

- Alternative 1: $2.2 MM to $2.5 MM
- Alternative 2: $2.9 MM to $3.9 MM
- Alternative 3: $4.0 MM to $7.4 MM

These cost estimates were prepared using feasibility study level-of-detail with the basic intention to establish a reasonable basis for comparison of alternatives and not to direct the means and methods of construction. This level of detail is typically associated with accuracy of +50% to -30% (USEPA 1988; USACE and USEPA 2000). Factors such as actual labor and material costs, and competitive market conditions at the time of remediation, will control actual cost.

The above cost estimates assume that there is no equipment available on site for use in the implementation, and also assume the requirement of importation of all capping materials.

little if any meaningful reduction in ecological risks to be gained from expanding the remedial footprint beyond Footprint 1.

5.5 Summary

The findings of this preliminary comparative analysis of the potentially applicable contingent remedial alternatives for Curds Inlet sediments indicate that the less intrusive alternatives (Alternatives 1 and 2) are technically more feasible and can be more effectively implemented, while providing effective reduction in exposure to impacted sediments should that be necessary. The benefit of eliminating the source of exposure risks and environmental impact associated with sediment removal (Alternative 3) is outweighed by the higher risks to workers and disturbance of the surrounding community during implementation, as well as higher costs, compared to capping (Alternative 2). This is illustrated on Table 5-2 where the long-term permanence associated with sediment removal (Alternative 3) provides the best long-term solution but Alternative 3 is not as effective as other alternatives in any of the other balancing criteria categories. Also, sediment removal is the least sustainable because it has the largest overall environmental impact of the remedial alternatives discussed.

As indicated on Table 5-2, the preliminary remedy analysis indicates similar attributes for Alternatives 1 and 2. Alternative 1 scores better in some categories (e.g., short-term effectiveness and sustainability) and Alternative 2 scores better in other categories (e.g., long-term effectiveness and permanence as well as reduction of toxicity, mobility, or volume through treatment). As a result, additional evaluation and consultation with the Cabinet would be needed to select a final preferred alternative. Given the current uncertainty with respect to the presence of remnant timber and stumps within the remedy footprint, at this preliminary stage of the evaluation, Alternative 2 would provide greater coverage of the sediments contributing to better long-term effectiveness of this remedy. The final selection between Alternatives 1 and 2 can be informed by the results of the sub-bottom profile survey to be conducted in connection with performance monitoring for RAO 3 to better assess the sediment surface conditions that could interfere with thin layer cap placement.

In summary, should the ongoing performance monitoring identify conditions warranting supplemental actions in order to the meet the RAOs, further evaluation of the contingent remedial alternatives would be conducted, taking into account the results of the post-IRM performance monitoring, in order to make final recommendations to the Cabinet for approval of the remedy.

Path Forward and Schedule

The path forward is for the Cabinet to review and approve this SRAA Report and approve the elements of the performance monitoring program. The performance monitoring program will be implemented during the first spring/summer field season following Cabinet approval of this SRAA Report. The performance monitoring report(s) for each RAO will be provided to the Cabinet following the completion of the field sampling, analytical testing, data validation, and assessment for each monitoring event.

The need for and timing of implementation of contingent supplemental remedial alternatives and the selection between EMNR, sediment capping, and sediment removal will depend upon the results of the performance monitoring to document that the IRMs and facility operational changes implemented by KU achieve the RAOs identified in this report.

6. References

AECOM. 2019. Draft Assessment of Corrective Measures Under the CCR Rule for the Auxiliary Pond and CCR Landfill - Multi-Unit for E.W. Brown Generating Station

AMEC. 2013. Groundwater Assessment Report. E.W. Brown Generating Station. Mercer County, Kentucky. September 27.

AMEC. 2014. Main Ash Pond Closure Plan. E.W. Brown Generating Station. Mercer County, Kentucky. April 25.

AMEC Foster Wheeler. 2015a. Sitewide Groundwater Remedial Action Plan. E.W. Brown Generating Station. Mercer County, Kentucky. Agency Interest #3148. February 27.

AMEC Foster Wheeler. 2015b. Groundwater Assessment Report Update. E.W. Brown Generating Station. Mercer County, Kentucky. Solid Waste Permit SW84000010. June 2.

AMEC Foster Wheeler. 2017. Sediment Data. E.W. Brown Generating Station. Mercer County, Kentucky. February 2017.

AMEC Foster Wheeler. 2018a. First Annual Groundwater Monitoring and Corrective Action Report (2016-2017): E.W. Brown Generating Station Mercer County, Kentucky.

Blocksom, K. A., and Johnson, B. R. 2009. Development of a regional macroinvertebrate index for large river bioassessment. Ecological Indicators, 9(2), 313–328. doi:10.1016/j.ecolind.2008.05.005

Downstream Strategies. 2016. Herrington Lake Phase II Sampling Report, June 6–7, 2016. Downstream Strategies, Morgantown, WV.

Flotemersch, J., Stribling, J., and Paul, M. 2006. Concepts and Approaches for the Bioassessment of Non-Wadeable Streams and Rivers. EPA/600/R-06/127.

Hargis, W.J. 1991. Disorders of the eye in finfish. Annual Review of Fish Diseases, (1)95-117.

Ingersoll, C.G., P.S. Haverland, E.L. Brunson, T.J. Canfield, F.J. Dwyer, C.E. Henke, N.E. Kemble, and D.R. Mount. 1996. Assessment and remediation of contaminated sediments (ARCS) program: Calculation and evaluation of sediment effect concentrations for the amphipod Hyalella azteca and the midge Chironomus riparius.

Lewis, Philip A.; Klemm, Donald J.; Thoeny, William T. (2001). Perspectives On Use Of A Multimetric Lake Bioassessment Integrity Index Using Benthic Macroinvertebrates. Northeastern Naturalist, 8(2), 233–246. doi:10.1656/1092-6194(2001).

National Biological Service Final Report for the U.S. Environmental Protection Agency, Great Lakes National Program Office, Assessment and Remediation of Contaminated Sediment Project. EPA 905-R96-008. September.

ITRC. 2011. Green and Sustainable Remediation: A Practical Framework.

KDFWR 2004-2020. Statewide Annual Sportfish Lake Performance Reports District Fisheries Management, Lake and Tailwater Sampling (yearly reports). Available at: https://fw.ky.gov/Fish/Pages/Statewide-Annual-Fish-Sampling-Reports.aspx

KDOW. 2002. Methods for Assessment Biological Integrity of Surface Waters in Kentucky. Commonwealth of Kentucky, Natural Resources and Environmental Protection Cabinet, Division of Water, Water Quality Branch. July.

KDOW. 2003. The Kentucky Macroinvertebrate Bioassessment Index: Derivation of Regional and Narrative Ratings for Assessing Wadeable and Headwater Streams. Kentucky Department for Environmental Protection, Division of Water, Water Quality Branch. September.

KDOW. 2015. Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters. Commonwealth of Kentucky, Energy and Environment Cabinet, Department for Environmental Protection, Division of Water. March.

KDOW. 2016a. Fish Study for Dix Dam and Residential Cove. Data provided by KU September 2017.

KDOW. 2016b. Kentucky Administrative Record 401 KAR 10:031. Surface Water Standards. Section 4. Aquatic Life. http://www.lrc.ky.gov/kar/401/010/031.htm. Accessed December 2020.

KDOW. 2018a. Fish Tissue Sampling for Herrington Lake. Kentucky Energy and Environment Cabinet, Department for Environment Protection. Division of Water.

KDOW. 2018b. Kentucky Departments for Environmental Protection, Public health and Fish and Wildlife Resources jointly issued fish consumption advisories. https://eec.ky.gov/Environmental-Protection/Water/Monitor/Pages/Fish-Advisories.aspx

KDOW 2018c. Kentucky Administrative Regulations (KAR) Section 401 KAR 100:030. Available at https://apps.legislature.ky.gov/law/kar/TITLE401.HTM

Kentucky Division of Environmental Protection (KDEP). 2002. Kentucky Risk Assessment Guidance. June 8.

Kentucky Energy and Environment Cabinet. 2020. Comments dated January 31, 2020 Kentucky Energy and Environment Cabinet Department for Environment Protection (Cabinet) comments on the Corrective Action ISARA Report for the Kentucky Utilities Company (KU) E.W. Brown Station.

Kentucky Energy and Environment Cabinet. 2021a. Corrective Action ISARA Report Review Completion and Approval Letter addressed to the Kentucky Utilities Company (KU) E.W. Brown Station. May 31st, 2021.

Kentucky Energy and Environment Cabinet. 2021b. Corrective Action ISARA Report: Cabinet's Responses to Public Hearing and the Public Comment Period comments. Letter addressed to the Kentucky Utilities Company (KU) E.W. Brown Station. May 31st, 2021.

Kentucky Utilities. 2021a. E.W. Brown Generating Station Permit Modification Request: January 7th, 2021 Letter to Kentucky Division of Water (KDOW), Agency Interest# AI 3148. KPDES Permit No. KY0002020. January 2021.

Kentucky Utilities. 2021b. E.W. Brown Generating Station Permit Modification Request: April 26th, 2021 Letter to Kentucky Division of Water (KDOW) - Supplemental Information, Agency Interest# AI 3148. KPDES Permit No. KY0002020. April 2021.

KPDES 2019a. Draft Authorization to Discharge Under the Kentucky Pollutant Discharge Elimination System (Permit Number KY0002020). Pending Approval. http://dep.gateway.ky.gov/eSearch/Search_Pending_Approvals.aspx?Program=Wastewater=30

KDPES 2019b. KPDES Fact Sheet KY0002020. October 2019.

http://dep.gateway.ky.gov/eSearch/Search_Pending_Approvals.aspx?Program=Wastewater&NumDaysDoc=30

National Research Council (NRC). 1997. Contaminated Sediments in Ports and Waterways – Cleanup Strategies and Technologies, National Academy Press, Washington, DC.

National Institute for Occupational Safety and Health (NIOSH) Center for Maritime Safety and Health (2020). Water Industry Fatality Rates for US Workers. Data retrieved July 15th, 2021 from: https://www.cdc.gov/niosh/programs/cmshs/default.html

Noor El Deen, A.I. and M.S. Zaki. 2012. Eye Affection Syndrome Wild and Cultured Fish. Life Science Journal 9(3)2568-2575. January.

Noor El Deen, A.I. and M.S. Zaki. 2013. Eye Affection Syndrome Wild and Cultured Fish. Life Science Journal 10(1)643-650. January.

Ontario Ministry of Environment and Energy. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of Environment and Energy, Standards Development Branch and Environmental Monitoring and Reporting Branch.

Ramboll. 2017a. Corrective Action Plan. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. August.

Ramboll. 2017b. Quality Assurance Project Plan. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. October.

Ramboll. 2017c. Standard Operating Procedures: Fish Sampling and Analysis. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. October.

Ramboll. 2017d. Standard Operating Procedures: Surface Water Sampling and Analysis. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. October.

Ramboll. 2017e. Standard Operating Procedures: Sediment Pore Water and Sediment Sampling and Analysis. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. October.

Ramboll. 2017f. Standard Operating Procedures: Aquatic Vegetation and Aquatic Invertebrate Sampling and Analysis. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. October.

Ramboll. 2018a. QAPP Addendum: Herrington Lake Young-of-the-year (YOY) Fish Assessment. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. May.

Ramboll. 2018b. Standard Operating Procedures: SOP: Young-of-the-Year (YOY) Fish Assessment Sampling and Fish Tissue Sampling. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. May.

Ramboll. 2018c. Standard Operating Procedures: SOP: Young-of-the-Year (YOY) Fish Assessment Sampling and Fish Tissue Sampling. Herrington Lake, E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. May.

Ramboll 2018d. Standard Operating Procedures: SOP: Selenium Analysis for Young-Of-The-Year (YOY) Preserved Bluegill Whole-Body Tissues, E.W. Brown Station, Mercer County Kentucky. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. May.

Ramboll 2019. Corrective Action Investigation Source Assessment, and Risk Assessment (ISARA) Report for E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. June.

Ramboll 2020. E.W. Coal Pile Addendum to the Response to the Cabinets Comments on the Corrective Action Investigation Source Assessment, and Risk Assessment Report for E.W. Brown Station. Prepared For: Kentucky Utilities Company for Submittal to KDOW Agreed Order No. DOW - 17001. March.

Stephens, F. J.; Cleary, J. J.; Jenkins, G.; Jones, B.; Radial, S. R. and Thomas, J. B. 2002: Pathogenesis and epidemiology of spontaneous exophthalmos in the West Aust. dhufish, Glaucosoma hebaraicum Richardson. Journal of Fish Disorders 24(9):515-522.

USEPA. 1977. National Eutrophication Survey: Report on Herrington Lake Boyle, Garrard, and Mercer Counties Kentucky EPA Region IV. Working Paper No. 353.

USEPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Washington, DC. EPA 540-R-97-006. June.

USEPA. 1998. Guidelines for Ecological Risk Assessment. Federal Register 63(93):26845-26924. May 14.

USEPA. 1999. Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites. OSWER Directive 9285.7-28 P. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington DC. October 7.

USEPA. 2000. Amended Guidance on Ecological Risk Assessment at Military Bases: Process Considerations, Timing of Activities, and Inclusion of Stakeholders. Memorandum from Simon, Ted. W., Ph.D., Office of Technical Services. http://risk.lsd.ornl.gov/homepage/ecoproc2.pdf

USEPA. 2001. Perspectives On Use Of A Multimetric Lake Bioassessment Integrity Index Using Benthic Macroinvertebrates. Northeastern Naturalist, 8(2), 233–246. Also cited as Lewis et al. 2001.

USEPA. 2006. Concepts and Approaches for the Bioassessment of Non-Wadeable Streams and Rivers. EPA/600/R-06/127. Also cited as Flotemersch et al. (2006).

USEPA. 2009. Development of a regional macroinvertebrate index for large river bioassessment. Ecological Indicators, 9(2), 313–328. Also cited as Blocksom and Johnson (2009).

USEPA 2002. Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites. OSWER Directive 9285.6-08. Memo to Superfund National Policy Managers, Regions 1 - 10 RCRA Senior Policy Advisors, Regions 1 - 10. February.

USEPA 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. EPA-540-R-05-012 Office of Solid Waste and Emergency Response OSWER 9355.0-85 December 2005.https://www.epa.gov/superfund/superfund-contaminated-sediments-guidance-and-technical-support

USEPA. 2008. Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites. (EPA/542/R/08/002).

USEPA. 2015 Effluent Limitations Guidelines (ELGs) for Steam Electric Coal-fired Utilities and the Disposal of Coal Combustion Residuals (CCRs) from Electric Utilities Rule Available at: https://www.epa.gov/eg/steam-electric-power-generating-effluent-guidelines-2015-final-rule

USEPA. 2016a. Corrective Measures Selection Process: Interim Measures as the Final Remedy, Koppers, Inc., Guthrie, KY , Inc., Guthrie, KY. SESSION 3 Presentation by James Smith – EPA Region 4.

USEPA. 2016b. Module 5. Presentation with this stated objective: "Discuss the definition of a remedial action and explain the major steps and activities performed in conducting remedial actions under CERCLA. Available at: https://archive.epa.gov/epawaste/hazard/web/pdf/sf-rem-a.pdf

USEPA. 2016c. Technical Support for Fish Tissue Monitoring for Implementation of EPA's 2016 Selenium Criterion – Draft Report. EPA 820-F-16-007. September

USEPA. 2018b. Supplemental Guidance to ERAGS: Region 4, Ecological Risk Assessment. Originally published November 1995 and updated March 2018. Scientific Support Section, Superfund Division, EPA Region 4. https://www.epa.gov/risk/regional-ecological-risk-assessment-era-supplemental-guidance.

USEPA. 2020a. Superfund Cleanup Process. Online Resources found at: https://www.epa.gov/superfund/superfund-cleanup-process

USEPA. 2020b. How Superfund Cleans Up Sediment Sites. Online Resources found at: https://www.epa.gov/superfund/how-superfund-cleans-sediment-sites

USEPA. 2021. ECOTOX User Guide: ECOTOXicology Knowledgebase System. Version 5.3. Available: http:/www.epa.gov/ecotox/ (data retrieval performed July 2021)

USGS. Crain et al., 2000. Modeling Hydrodynamics and Water Quality in Herrington Lake, Kentucky. Water- Resources Investigations Report 99-4281.

Washington State Department of Ecology. 2013. Sediment Management Standards Chapter 173-204 WAC. Revised February 2013, Effective September 2013. Publication no. 13-09-055. https://fortress.wa.gov/ecy/publications/documents/1309055.pdf

West Virginia Department of Environmental Protection. 2010. Selenium-Induced Development Effects Among Fishes in Select West Virginia Waters.

TABLES

5.4.6 Community Acceptance

For this SRAA, the contingent remedial alternatives have not been evaluated against this criterion. However, should performance monitoring identify conditions warranting supplemental actions, community preferences and concerns (technical and administrative) will be identified as part of the detailed evaluation to support recommendations to the Cabinet for selection of an appropriate remedy. This evaluation will determine the extent to which the alternatives minimize impacts on the following:

- Community safety during implementation,
- Quality of life, such as the generation of odors, light, diesel emissions, and noise during construction; and,
- Ease of access to and use of areas in the vicinity of the remediation.

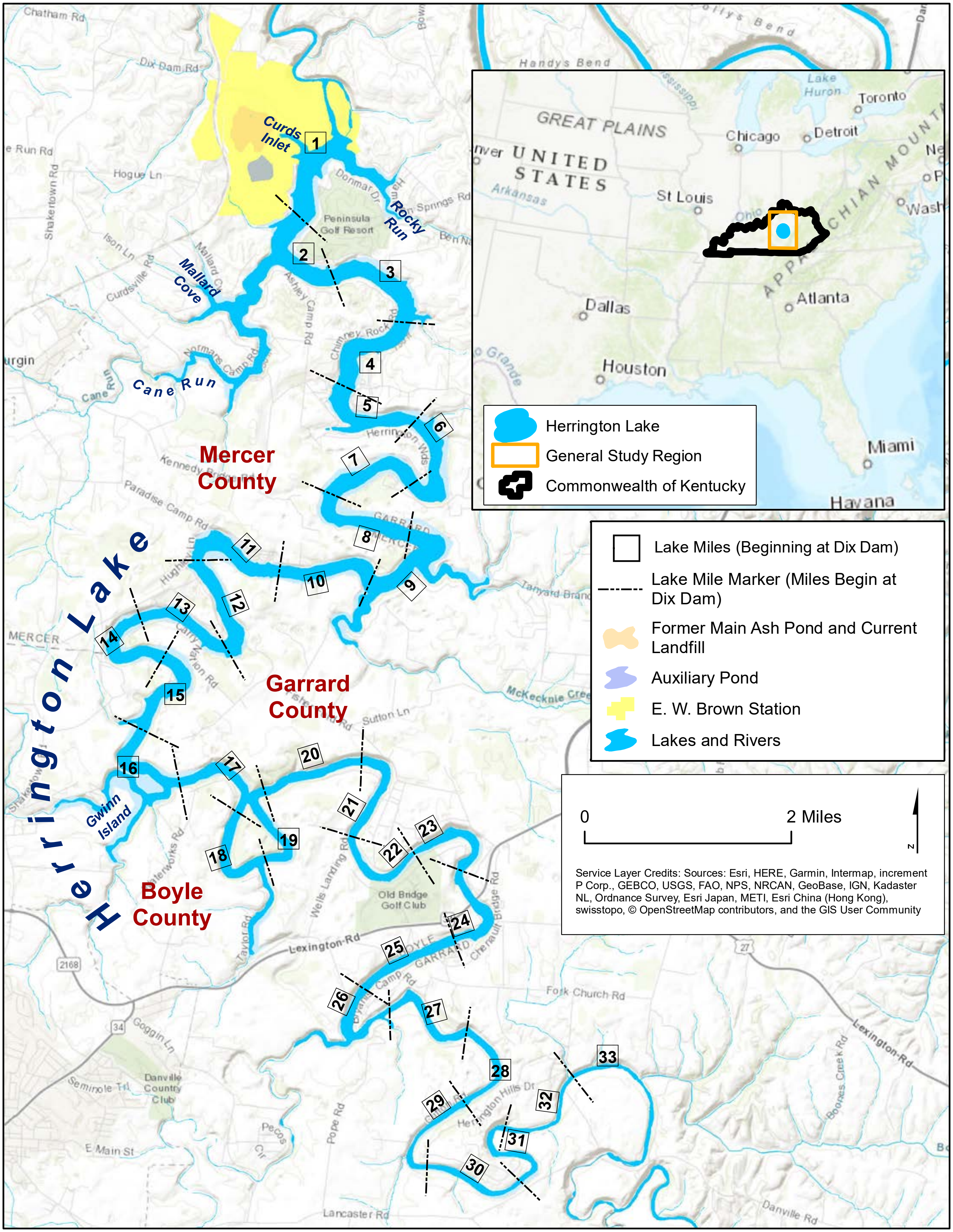
5.4.7 Sustainability/Overall Environmental Impact

The sustainability and overall environmental impacts of the contingent remedial alternatives were evaluated and compared. The results are qualitatively presented in Table 5-2 and Figure 5-2. Evaluation of sustainability and overall environmental impacts includes consideration of habitat disturbance, resource requirements, injury/fatality risk, and air emissions increase with greater remedial footprint, extent of disturbance to the existing sediment environment, and construction duration. Since Contingent Alternative 1 relies primarily on natural restoration processes, Alternative 1 has the shortest construction duration and requires fewer resources to implement compared to Contingent Alternatives 2 and 3, and thus represents the most sustainable alternative among the contingent remedial alternatives. While Alternative 1 is shown in Table 5-2 to score lower on two of the primary balancing criteria (long-term protectiveness and permanence as well as reduction of toxicity, mobility, or volume through treatment), Alternative 1 is still considered a viable, long-term effective option because:

- As was discussed in the Corrective Action ISARA Report, Kentucky does not have water quality standards for sediment pore water.
- The concentrations for speciated selenium in sediment pore water only slightly exceeded the Kentucky ecological chronic surface water chronic water quality standard for selenium, as shown on Figure 2-3C of this SRAA Report. The flux of selenium from sediment to the water column was demonstrated to be very low. The primary source of selenium to the water column of Curds Inlet was former Outfall BRN001 rather than sediment flux to the water column.
- Arsenic and iron in sediment pore water from Curds Inlet exceeded the Kentucky ecological chronic surface water quality standards as shown in Figures 2-4B (arsenic) and 2-5 (iron). However, arsenic and iron did not exceed the chronic ecological Kentucky water quality standards in the water column of Curds Inlet.
- Therefore, Alternative 1 is considered to provide long-term effectiveness and permanence for addressing potential risks from sediments to the water column of Curds Inlet. Alternative 1 is less effective than Alternatives 2 and 3 as it pertains to potential impacts to sediment dwelling organisms only.

Contingent Alternative 3 is expected to be least sustainable of the three alternatives, as removing all impacted sediments from Curds Inlet will require greater resources and result in more significant environmental disturbance during implementation. As shown on Figure 5-2, all three remedial Footprints result in a hazard quotient less than 1 for all locations. This indicates that there would be

FIGURES



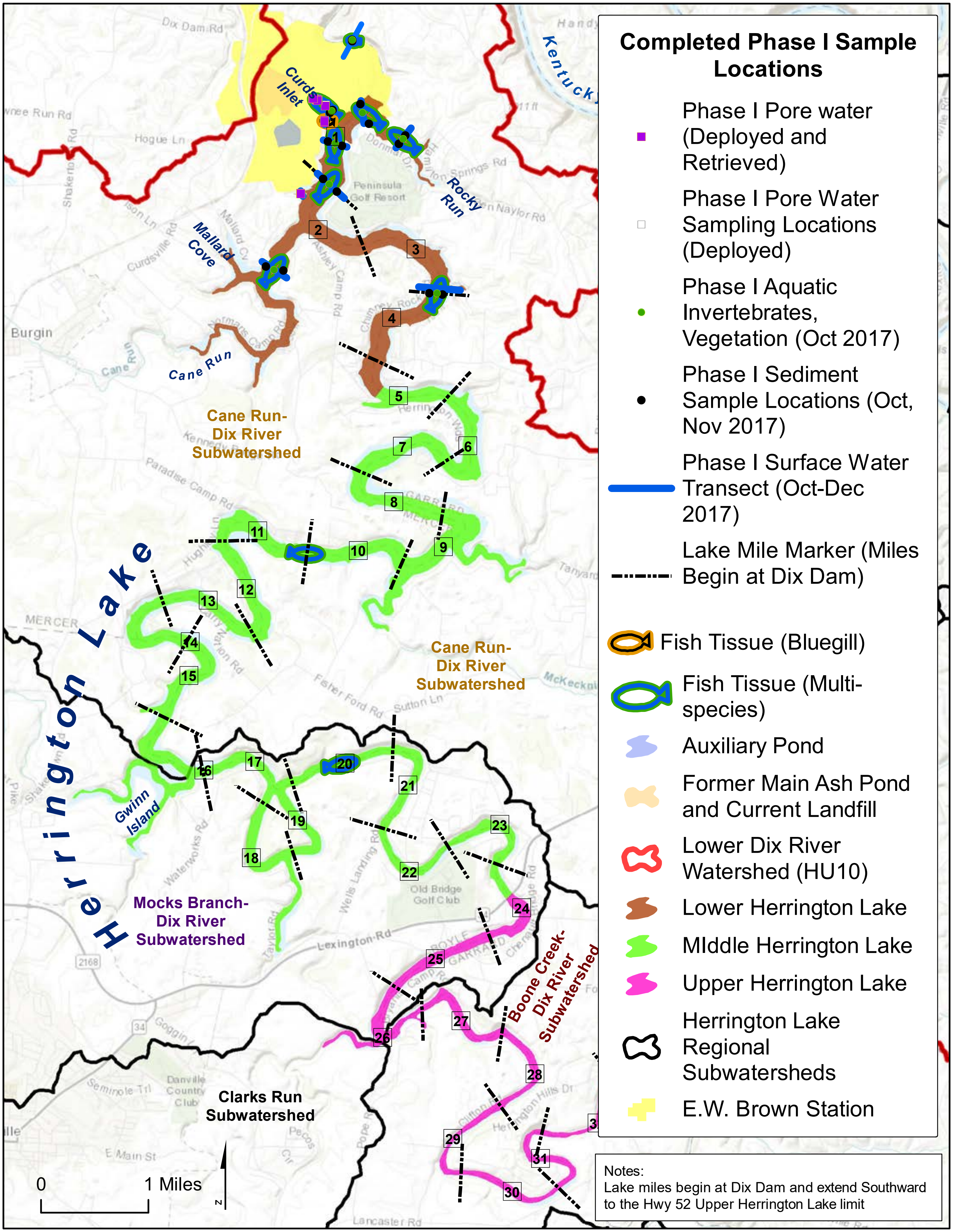
Map Design: AJS, Date: Jan 16, 2019

E.W. Brown Station Location Map

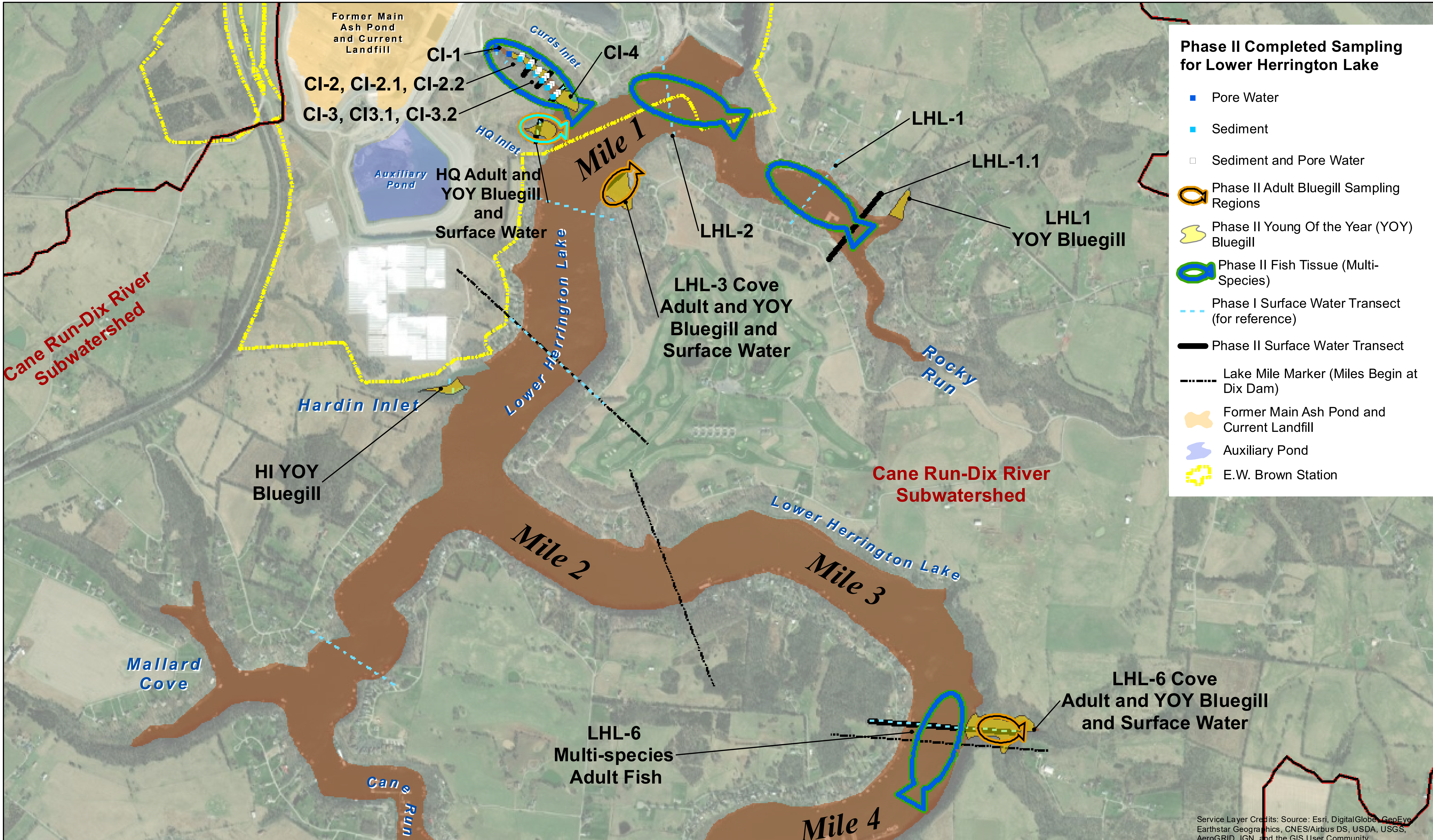
Supplemental Remedial Alternatives Assessment
Mercer County, Kentucky

FIGURE 1-1

Project Code:



RAMBOLL Map Design: AJS, Date: Jan 23, 2019	Phase I Sample Collection Overview Supplemental Remedial Alternatives Assessment E.W. Brown Station Mercer County, Kentucky	FIGURE 2-1A Project Code:



RAMBOLL

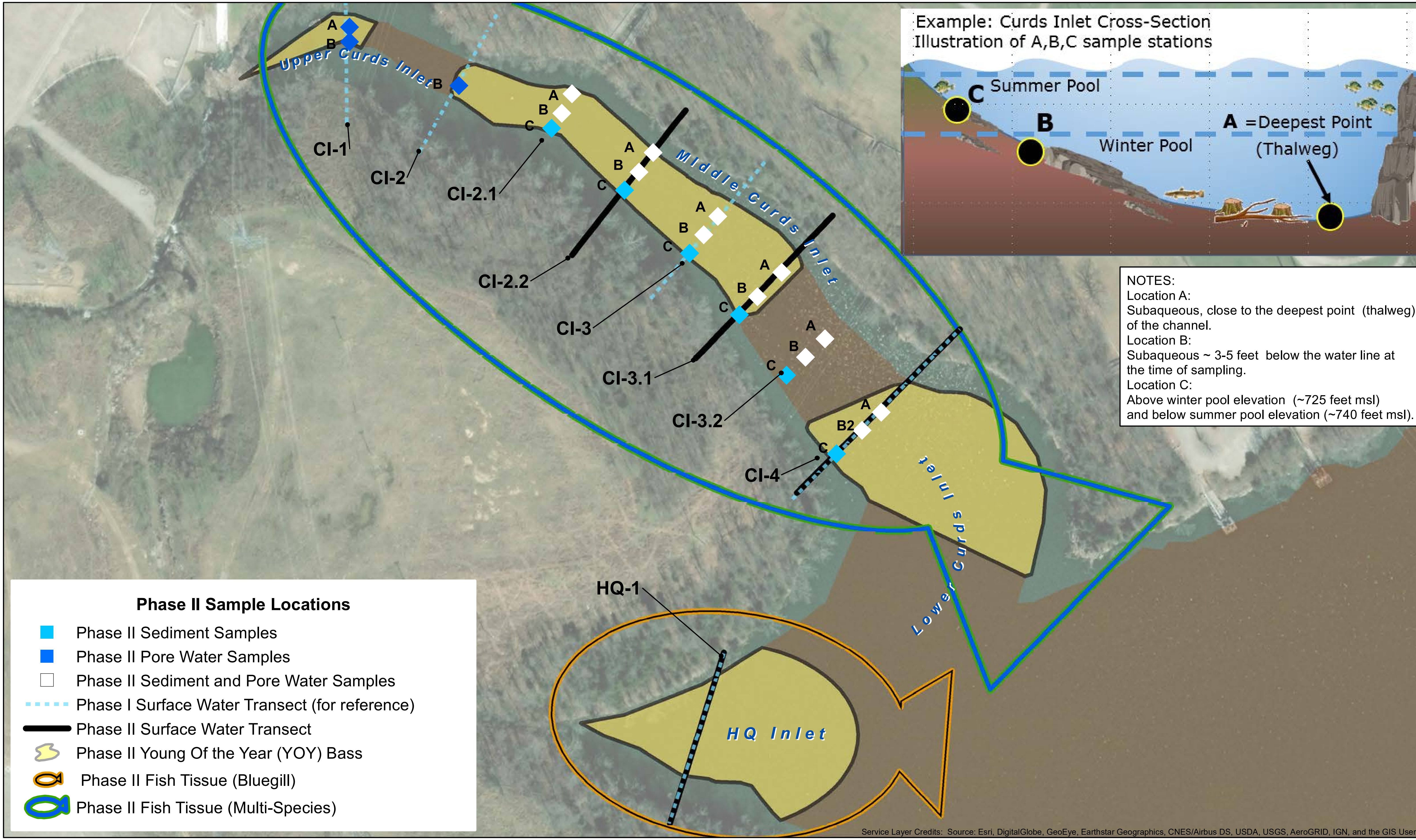
Map Design: AJS, Date: Jan 14, 2021

Notes:
Lake miles begin at Dix Dam and extend Southward to the Hwy 52 Upper Herrington Lake limit

Phase II Completed Sampling for Lower Herrington Lake
Supplemental Remedial Alternatives Assessment
E. W. Brown, Herrington Lake, Mercer County, Kentucky

FIGURE
2-1B

Project:



RAMBOLL

Map Design: AJS, Date: Jan 21, 2019

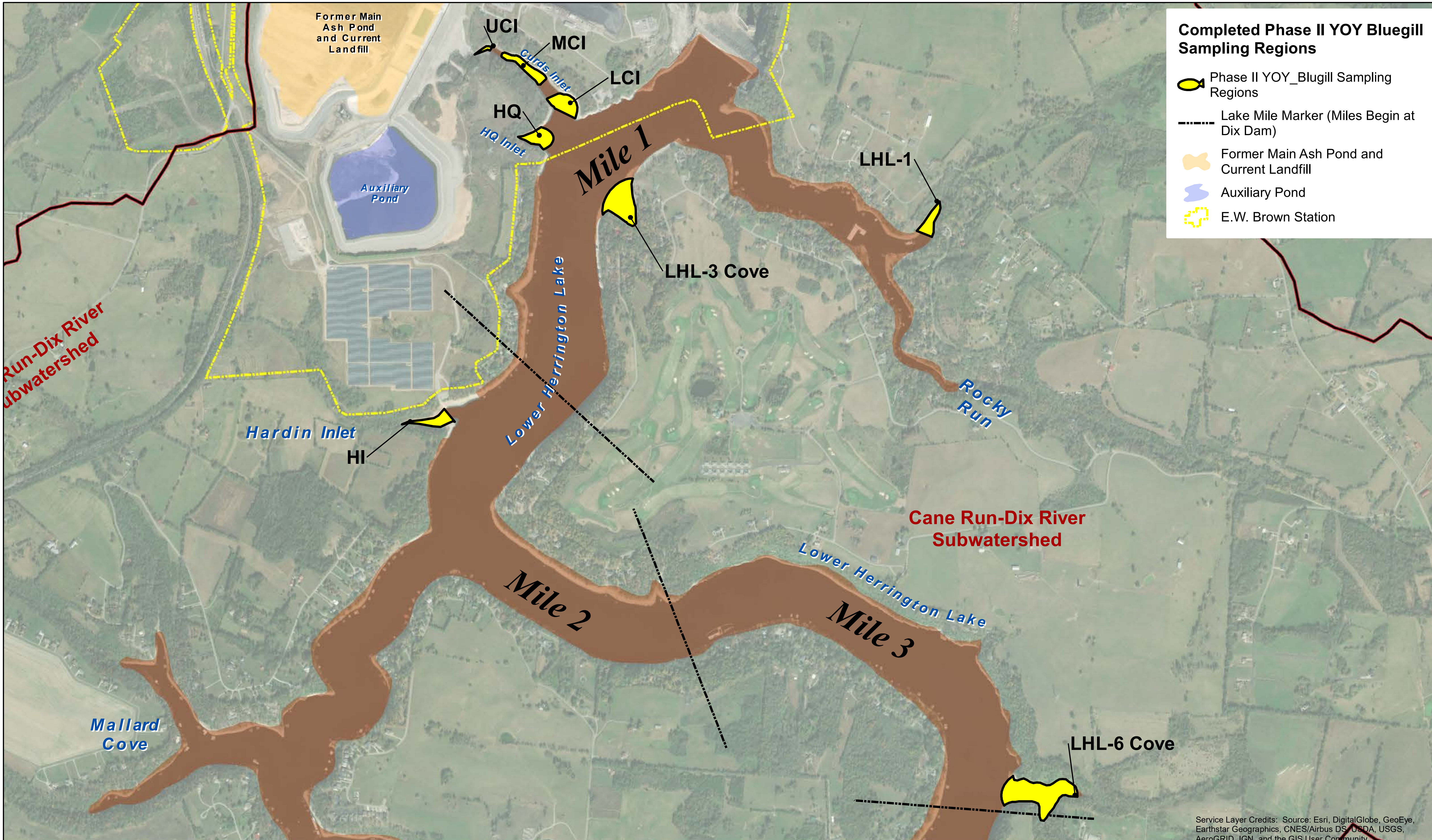
0 200 Feet

N

Phase II Completed Sampling for Curds Inlet and HQ Inlet
Supplemental Remedial Alternatives Assessment
E. W. Brown, Herrington Lake, Mercer County, Kentucky

FIGURE 2-1C

Project:



Map Design: AJS, Date: Jan 22, 2019

0 1,000 Feet

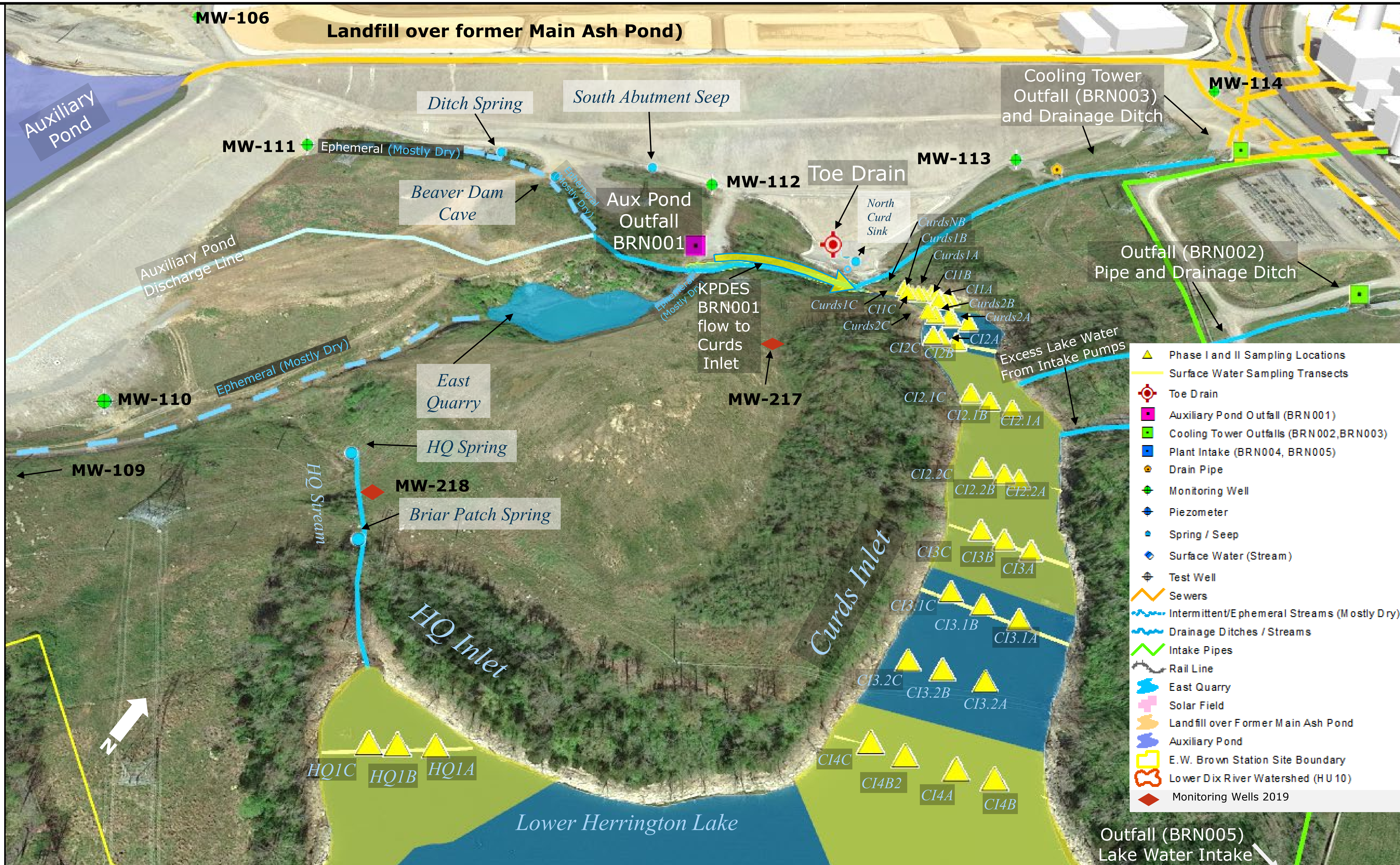
N

Notes:
Lake miles begin at Dix Dam and extend Southward to the Hwy 52 Upper Herrington Lake limit

Phase II Young-of-the-Year Bluegill Sampling Regions Herrington Lake
Supplemental Remedial Alternatives Assessment
E.W. Brown Mercer County, Kentucky

FIGURE
2-1D

Project:



RAMBOLL

Figure Created by: AJS

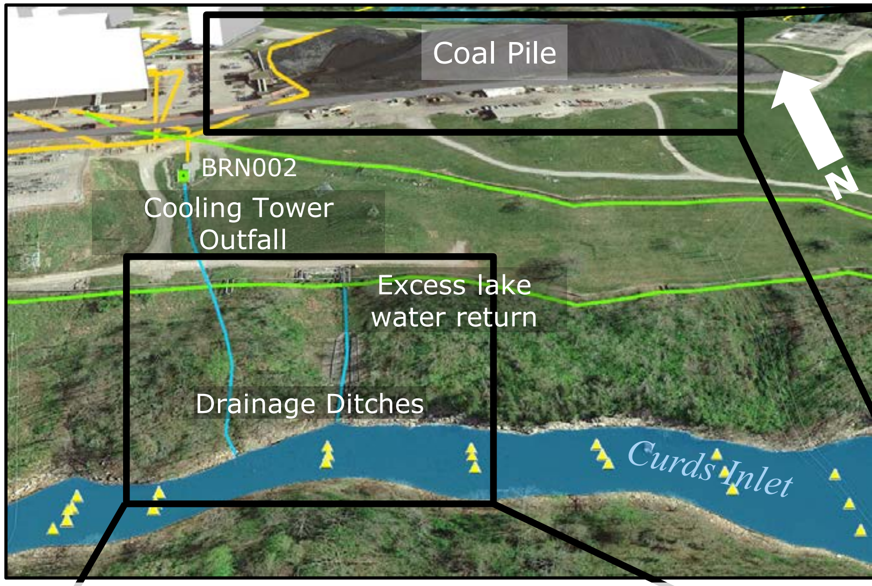
DATE: 01/14/2021

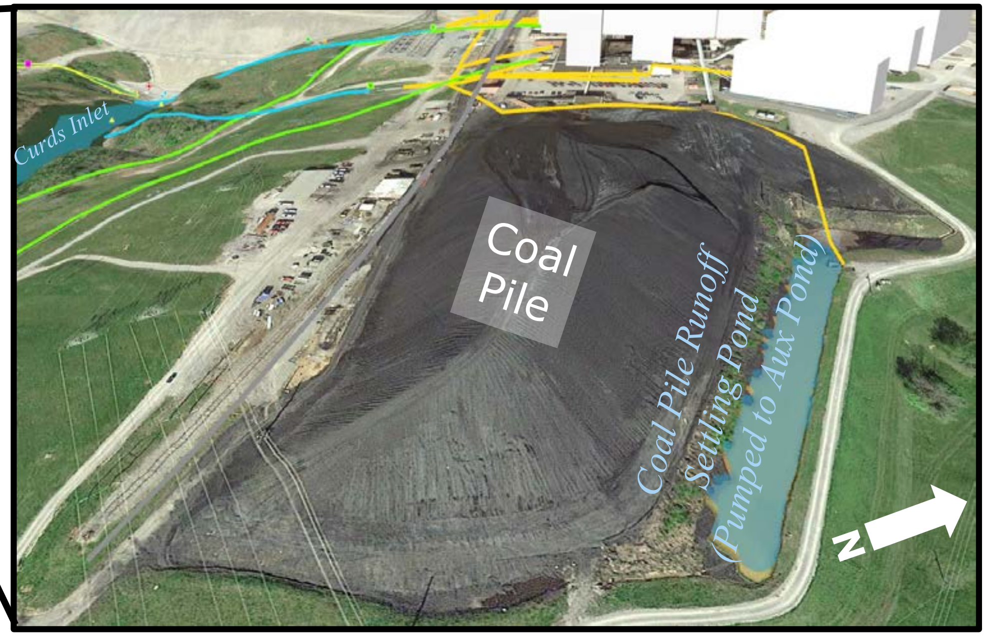
CONCEPTUAL SITE MODEL FOR SOURCE IDENTIFICATION: CURDS AND HQ INLETS WITH SPRINGS AND GROUNDWATER MONITORING WELLS

Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Herrington Lake, Mercer County, Kentucky

FIGURE

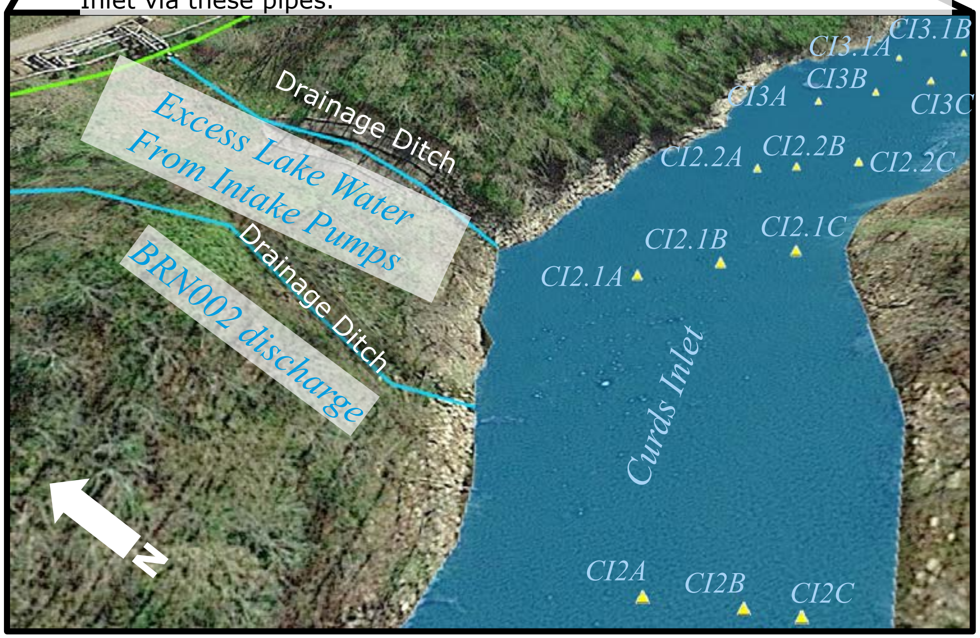
2-2A





Notes: Cooling tower Units 1 and 2 were retired in February 2019, so non-contact cooling water is no longer discharged from KPDES Outfall BRN002. The pipe parallel to BRN002 returns excess lake water from intake pumps. Water from the coal pile does not discharge to Curds Inlet via these pipes.

Notes:
Drainage from the coal pile is collected in the coal pile runoff and settling pond and is pumped to the Auxiliary Pond. Water from the Auxiliary Pond is now discharged via KPDES Outfall 006.



- Phase I and II Sampling Locations
- Surface Water Sampling Transects
- Auxiliary Pond Outfall (BRN001)
- Cooling Tower Outfalls (BRN002,BRN003)
- Plant Intake (BRN004, BRN005)
- Drain Pipe
- Monitoring Well
- Piezometer
- Spring / Seep
- Surface Water (Stream)
- Test Well
- Toe Drain
- Sewers
- Intermittent/Ephemeral Streams (Mostly Dry)
- Drainage Ditches / Streams
- Intake Pipes
- Rail Line
- East Quarry
- Solar Field
- Landfill over Former Main Ash Pond
- Auxiliary Pond
- E.W. Brown Station Site Boundary
- Lower Dix River Watershed (HU10)

Notes:
Drainage from the coal pile is pumped to the Auxiliary Pond.

RAMBOLL

Figure Created by: AJS

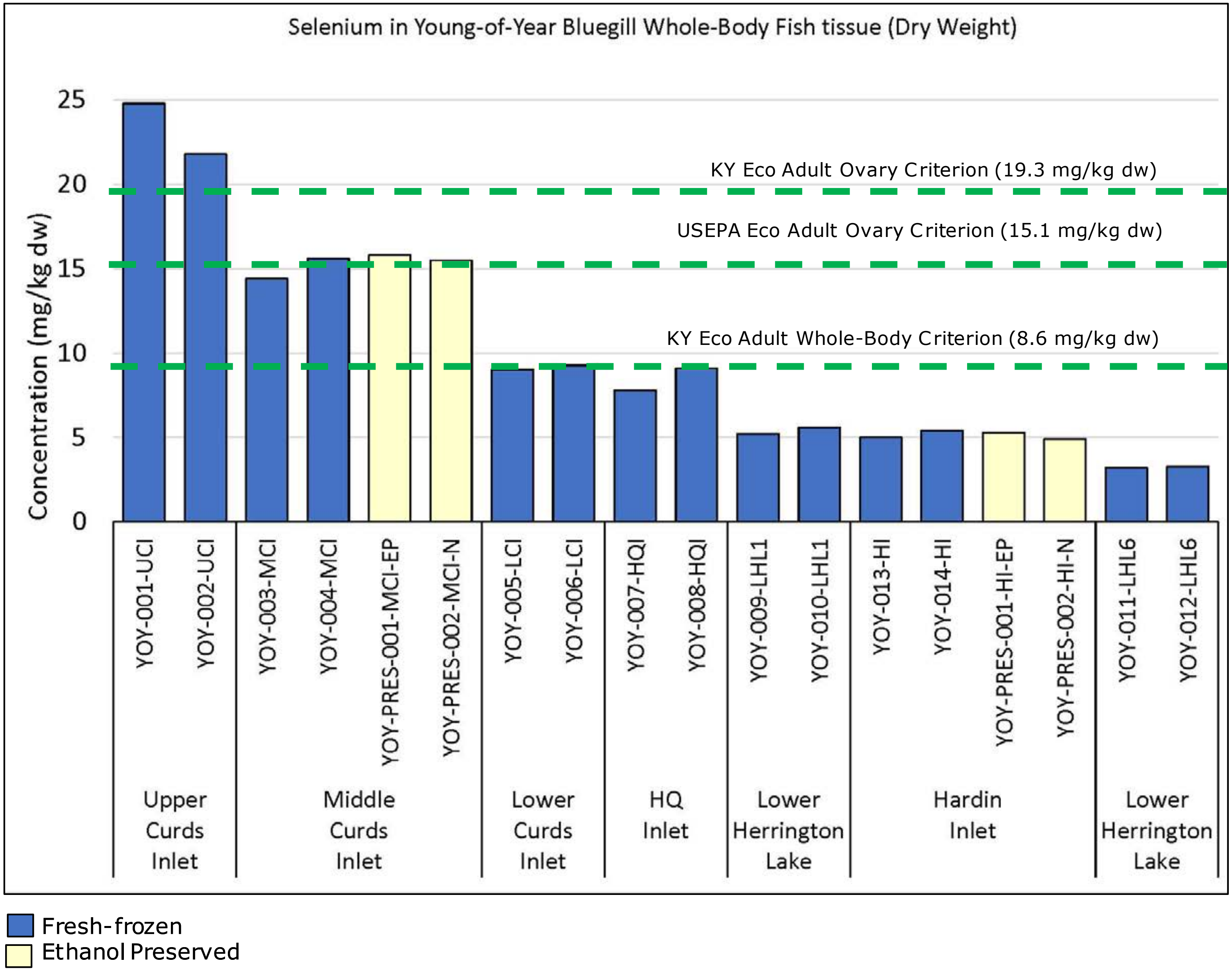
DATE: 03/01/2019

CONCEPTUAL SITE MODEL FOR SOURCE IDENTIFICATION: CURDS INLET AND COAL PILE DRAINAGE VIEW

Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Herrington Lake, Mercer County, Kentucky

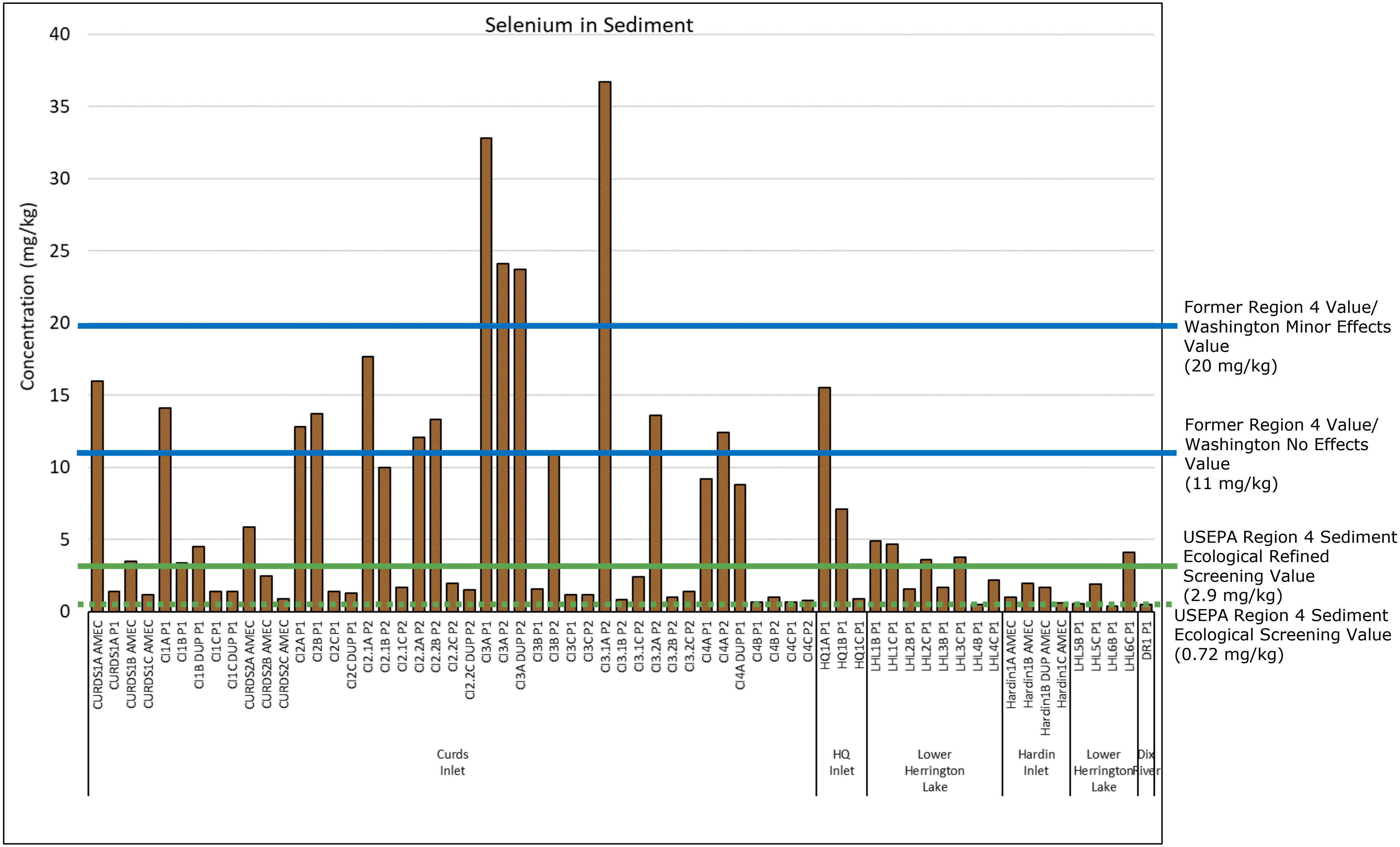
FIGURE

2-2B



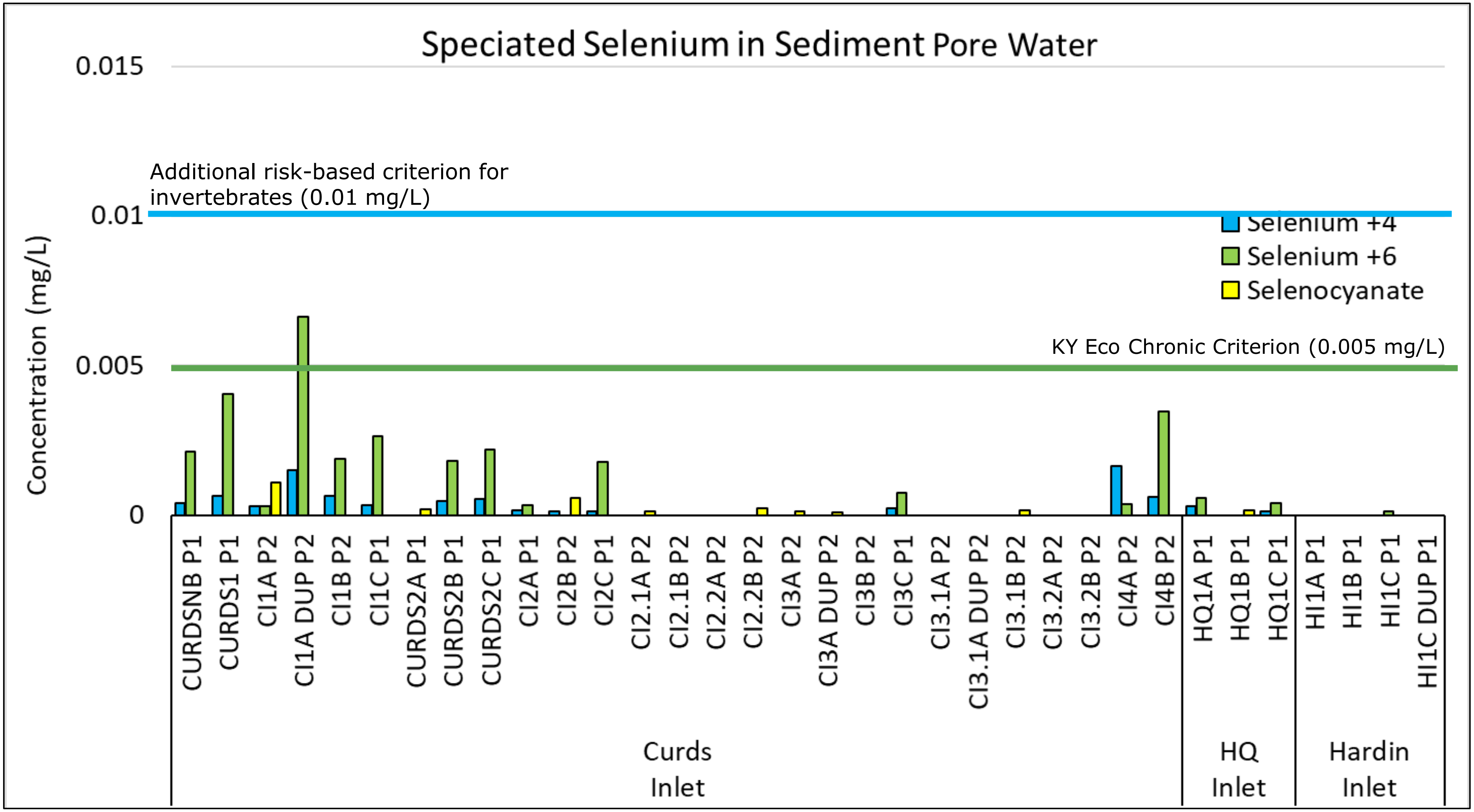
Hardin Inlet (HI), HQ Inlet (HQ), Kentucky Ecological (KY Eco), Lower Curds Inlet (LCI), Lower Herrington Lake 1 (LHL1), Lower Herrington Lake 6 (LHL6), Middle Curds Inlet (MCI), Milligrams per kilograms dry weight (mg/kg dw), Upper Curds Inlet (UCI), United States Environmental Protection Agency Ecological (USEPA Eco), Young-of-the-Year (YOY)

RAMBOLL	**SELENIUM CONCENTRATIONS FOR YOUNG-OF-YEAR FISH** Suppplemental Remedial Alternatives Assessment E.W. Brown Station, Herrington Lake, Mercer County, Kentucky	FIGURE 2-3A
DRAFTED BY: PAL	DATE: 3/3/2019	



Data from AMEC (AMEC), Curds Inlet (CI), Duplicate sample (DUP), HQ Inlet (HQ), Lower Herrington Lake (LHL), Dix River (DR), Milligrams per kilogram (mg/kg), Phase I (P1), Phase II (P2)

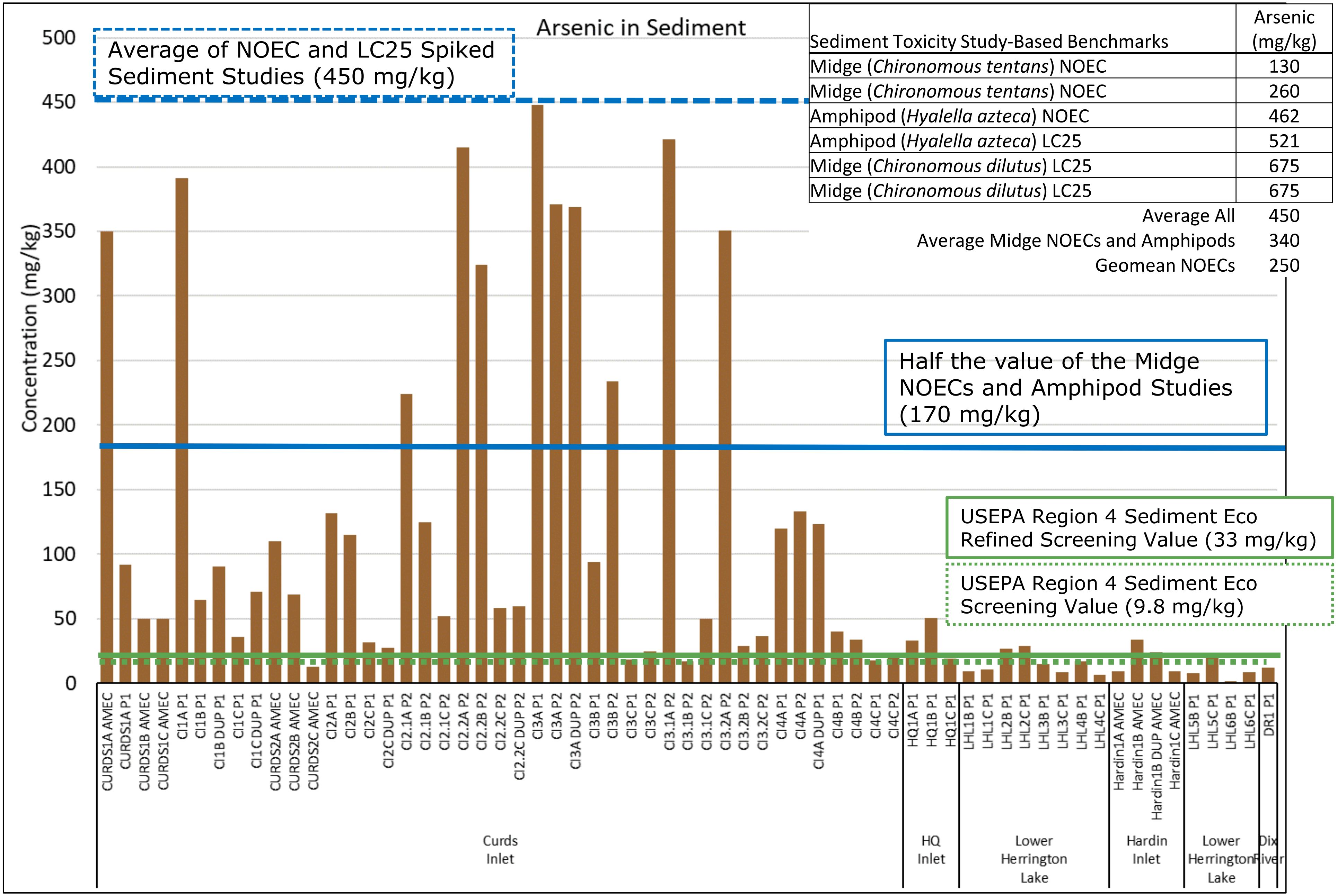
RAMBOLL	**SELENIUM IN SEDIMENT WITH ADDITIONAL RISK-BASED CRITERIA FOR CONSIDERATIONS** Supplemental Remedial Alternatives Assessment Mercer County, Kentucky	FIGURE 2-3B
DRAFTED BY: PAL — DATE: 02/01/2019		



Curds Inlet (CI), Duplicate (DUP), Hardin Inlet (HI), HQ Inlet (HQ), Kentucky Ecological Chronic Criterion (KY Eco Chronic Criterion), micrograms per liter (µg/L), milligrams per liter (mg/L), Phase I (P1), Phase II (P2), United States Environmental Protection Agency (USEPA)

Additional risk-based criterion for invertebrates (0.01 mg/L) is based on selenium USEPA ECOTOX data for low/no-effect data in 7 day studies for crustaceans, insects, and worms shows that 95% of the 98 species are protected by a selenium concentration of 0.01 mg/L. This is detailed in Appendix I2.

RAMBOLL	SPECIATED SELENIUM IN SEDIMENT PORE WATER WITH ADDITIONAL RISK-BASED CRITERIA FOR CONSIDERATIONS Supplemental Remedial Alternatives Assessment E.W. Brown Station, Herrington Lake, Mercer County, Kentucky	FIGURE 2-3C
DRAFTED BY: PAL DATE: 02/01/2019		



Data from AMEC (AMEC), Curds Inlet (CI), Data from AMEC (AMEC), Dix River (DR), Duplicate (DUP), HQ Inlet (HQ), Lower Herrington Lake (LHL), Milligrams per kilogram (mg/kg)

RAMBOLL

DRAFTED BY: PAL

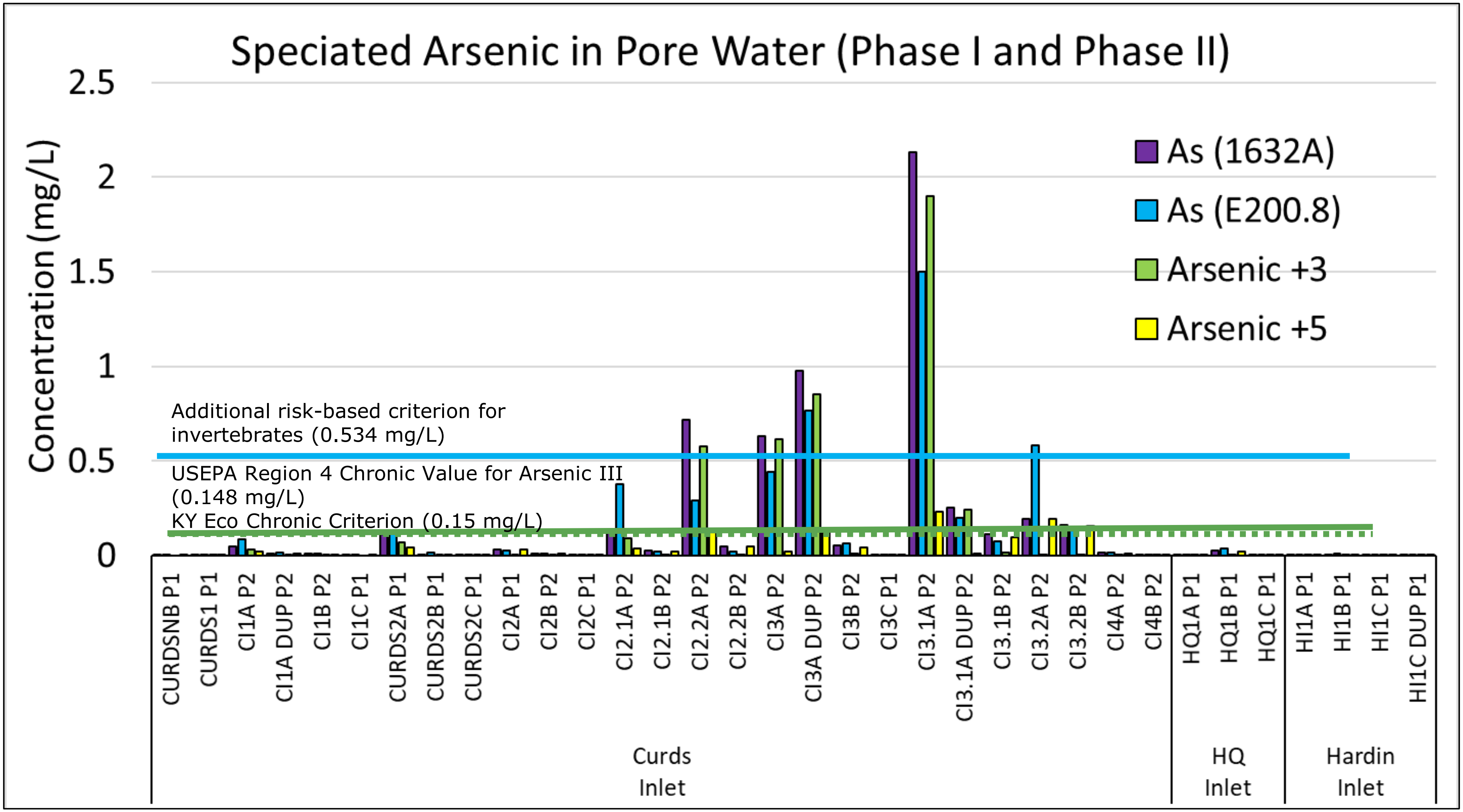
DATE: 02/01/2019

ARSENIC IN SEDIMENT WITH ADDITIONAL RISK-BASED CRITERIA FOR CONSIDERATION

Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Herrington Lake, Mercer County, Kentucky

FIGURE

2-4A



Arsenic (As), Curds Inlet (CI), Dissolved (D), Duplicate (Du), Environmental Protection Agency (EPA), EPA Method 1632A (1632A), EPA Method 200.8 (E200.8), Hardin Inlet (HI), HQ Inlet (HQ), Kentucky Ecological Chronic Water Quality Criterion (Kentucky Eco Chronic Criterion), milligrams per liter (mg/L), Phase I (P1), Phase II (P2), United States Environmental Protection Agency (USEPA)

A species sensitivity distribution for arsenic based on ECOTOX data for As3+ shows the most sensitive 4-day test (which used *Gammarus pseudolimnaeus*, a freshwater, sediment-dwelling amphipod) has a LC50 of 875 ug/L. Comparing the geometric mean values for acute and chronic tests for similar invertebrates yields an acute-to-chronic ratio of about 1.6, which suggests a chronic value of 534 ug/L (0.534 mg/L) as an alternate risk-based criterion. This is detailed in Appendix I2.

RAMBOLL

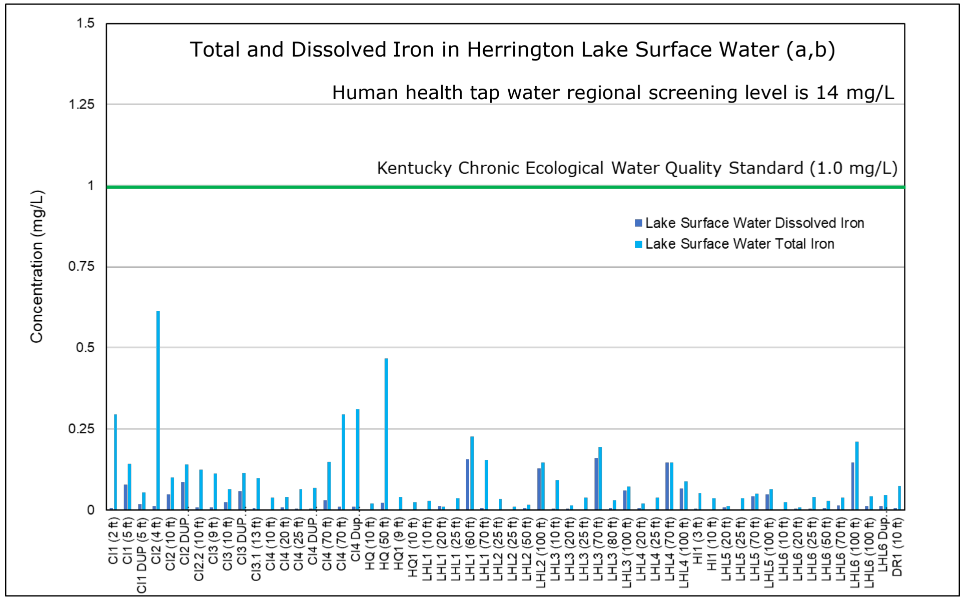
DRAFTED BY: AJS | DATE: Nov 2020

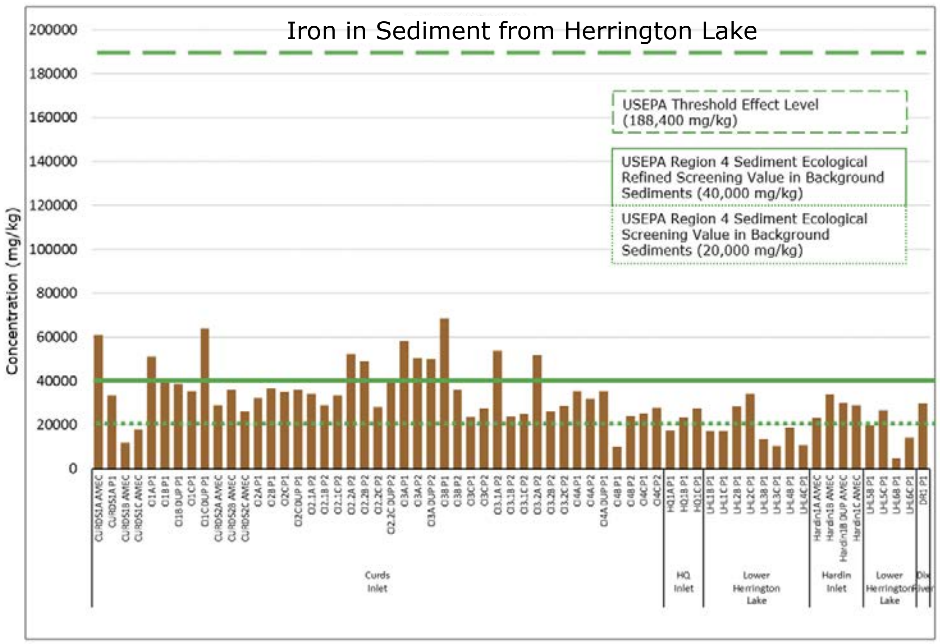
SPECIATED ARSENIC IN SEDIMENT PORE WATER WITH ADDITIONAL RISK-BASED CRITERIA FOR CONSIDERATION

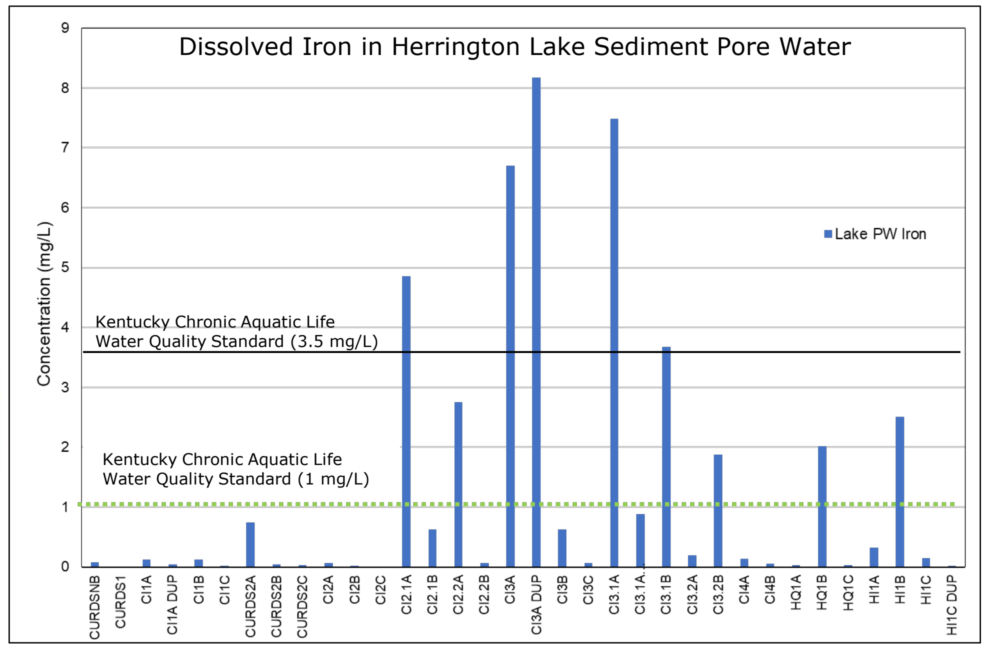
Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Herrington Lake, Mercer County, Kentucky

FIGURE

2-4B







Dissolved (D), Total (T), United States Environmental Protection Agency (USEPA), milligrams per liter (mg/L), milligrams per kilogram (mg/kg), Porewater (PW)

This figure is an addendum to the Corrective Action Investigation, Source Assessment, Risk Assessment (ISARA) Report, Ramboll June 2019

RAMBOLL	**IRON IN HERRINGTON LAKE SURFACE WATER, SEDIMENT PORE WATER, AND SEDIMENT** Supplemental Remedial Alternatives Analysis E.W. Brown Station, Herrington Lake, Mercer County, Kentucky	FIGURE 2-5
DRAFTED BY: CDB / DATE: 10/29/2019		

Map Design: AJS, Date: Jan 16,2019

0 2,000 Feet

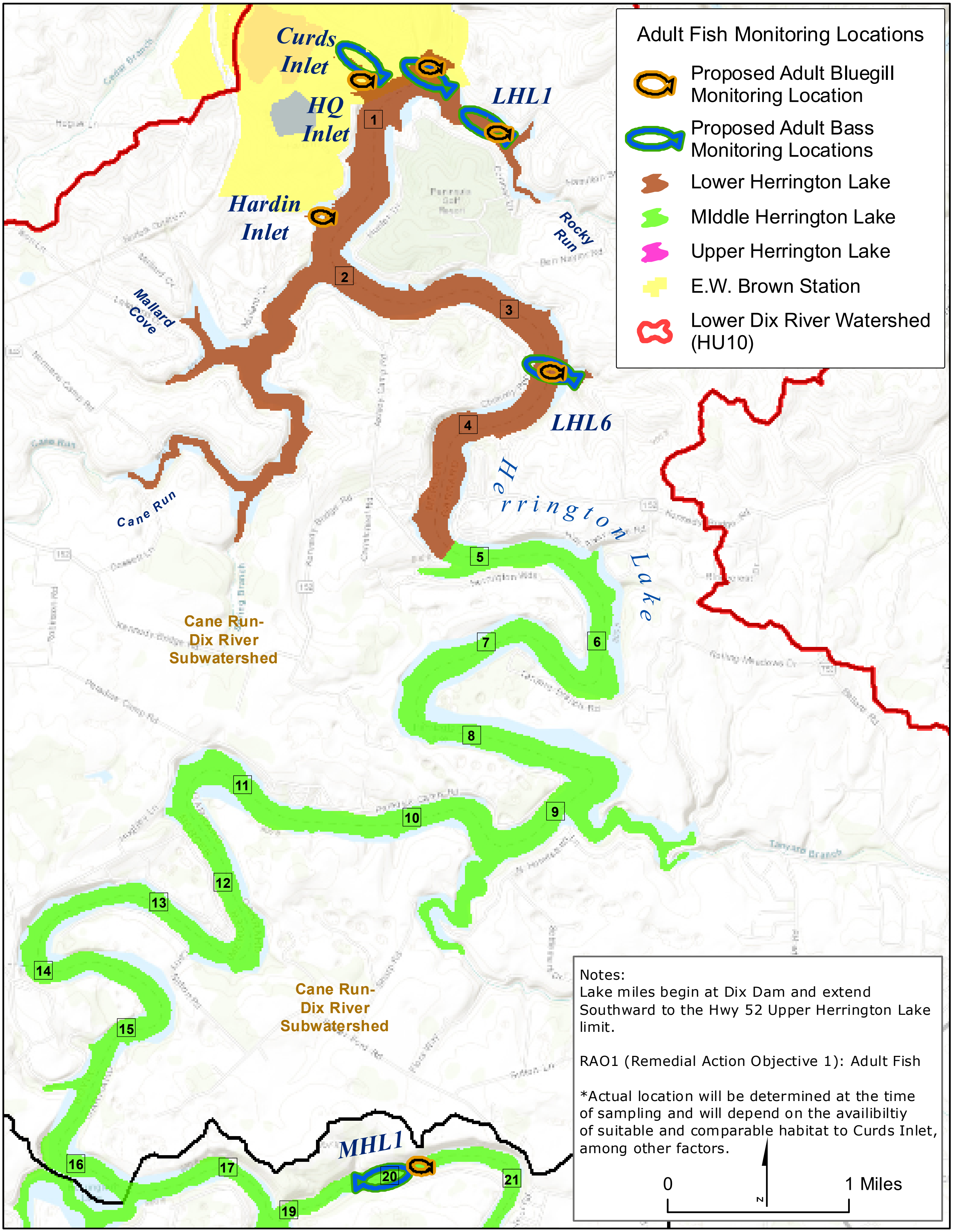
N

Proposed Adult Fish Monitoring Locations in Lower Herrington Lake (RAO 1)

Supplemental Remedial Alternatives Assessment Report E.W. Brown Station,
Herrington Lake, Mercer County, Kentucky

FIGURE
4-1A

Project:



RAMBOLL

Map Design: AJS, Date: Jan 2021

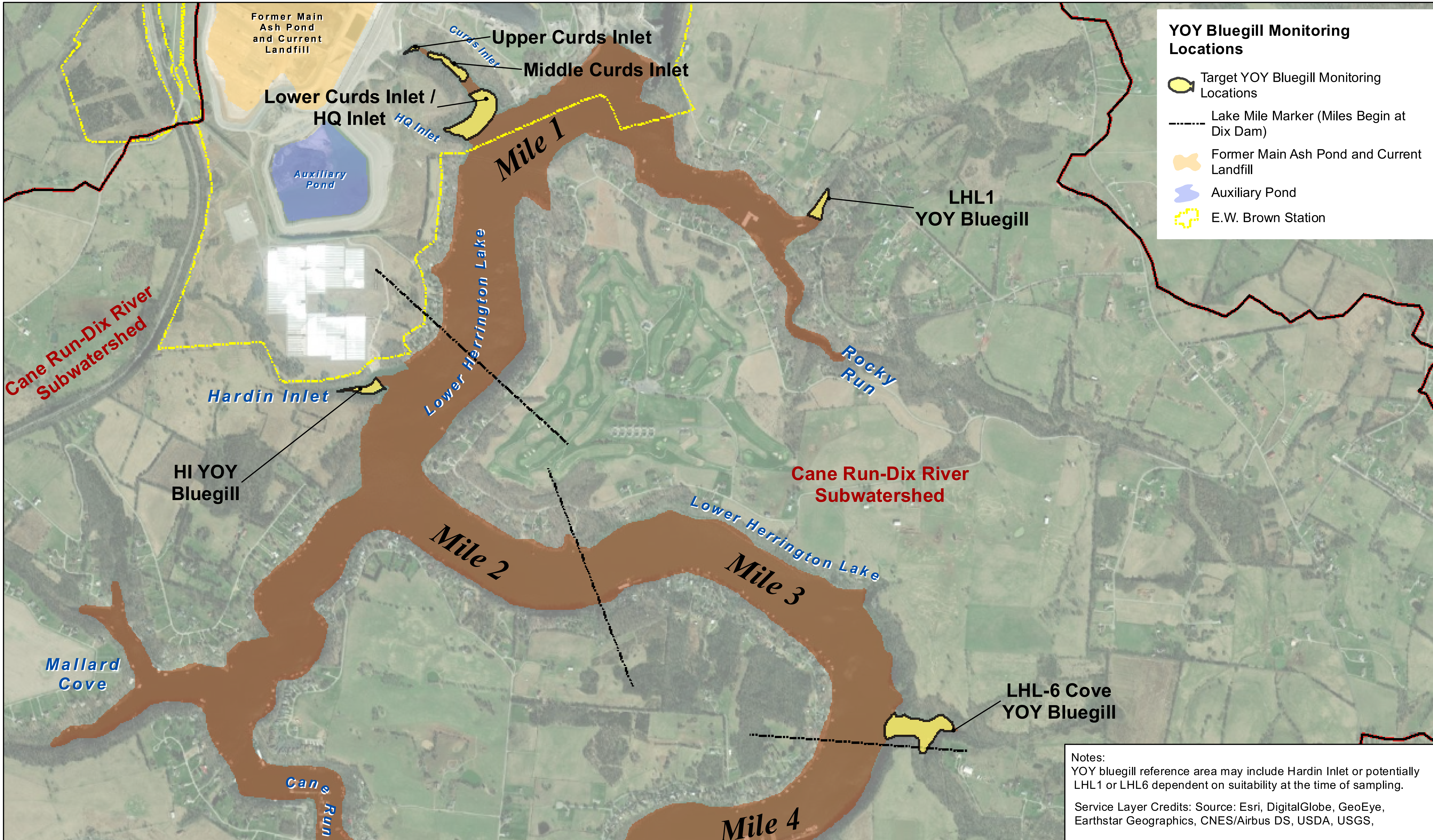
Proposed Adult FIsh Monitoring Locations (RAO1)

Supplemental Remedial Alternatives Assessment

E. W. Brown, Herrington Lake, Mercer County, Kentucky

FIGURE 4-1B

Project Code:



Notes:
YOY bluegill reference area may include Hardin Inlet or potentially LHL1 or LHL6 dependent on suitability at the time of sampling.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS,

RAMBOLL

Map Design: AJS, Date: Jan 16, 2021

0 1,000 Feet

N

Proposed Young-of-Year Bluegill Monitoring Locations in Lower Herrington Lake (RAO 2)
Suppplemental Remedial Alternatives Assessment
E.W. Brown Station, Mercer County, Kentucky

FIGURE 4-2A

Project:

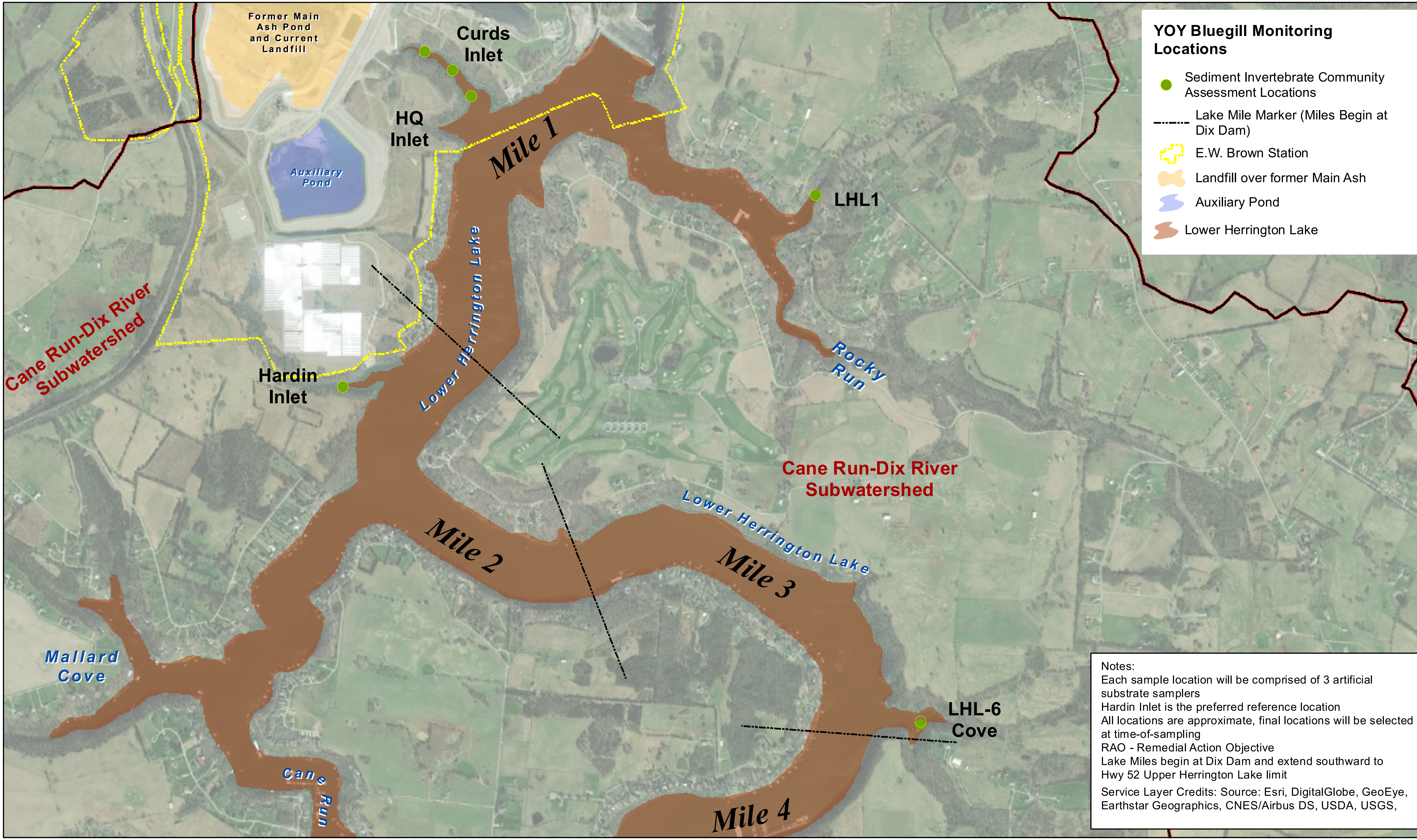
RAMBOLL

Map Design: AJS, Date: Nov 2020

Proposed Young-of-Year Bluegill Monitoring for Curds Inlet and HQ Inlet
Supplemental Remedial Alternatives Assessment
Mercer County, Kentucky

FIGURE 4-2B

Project:



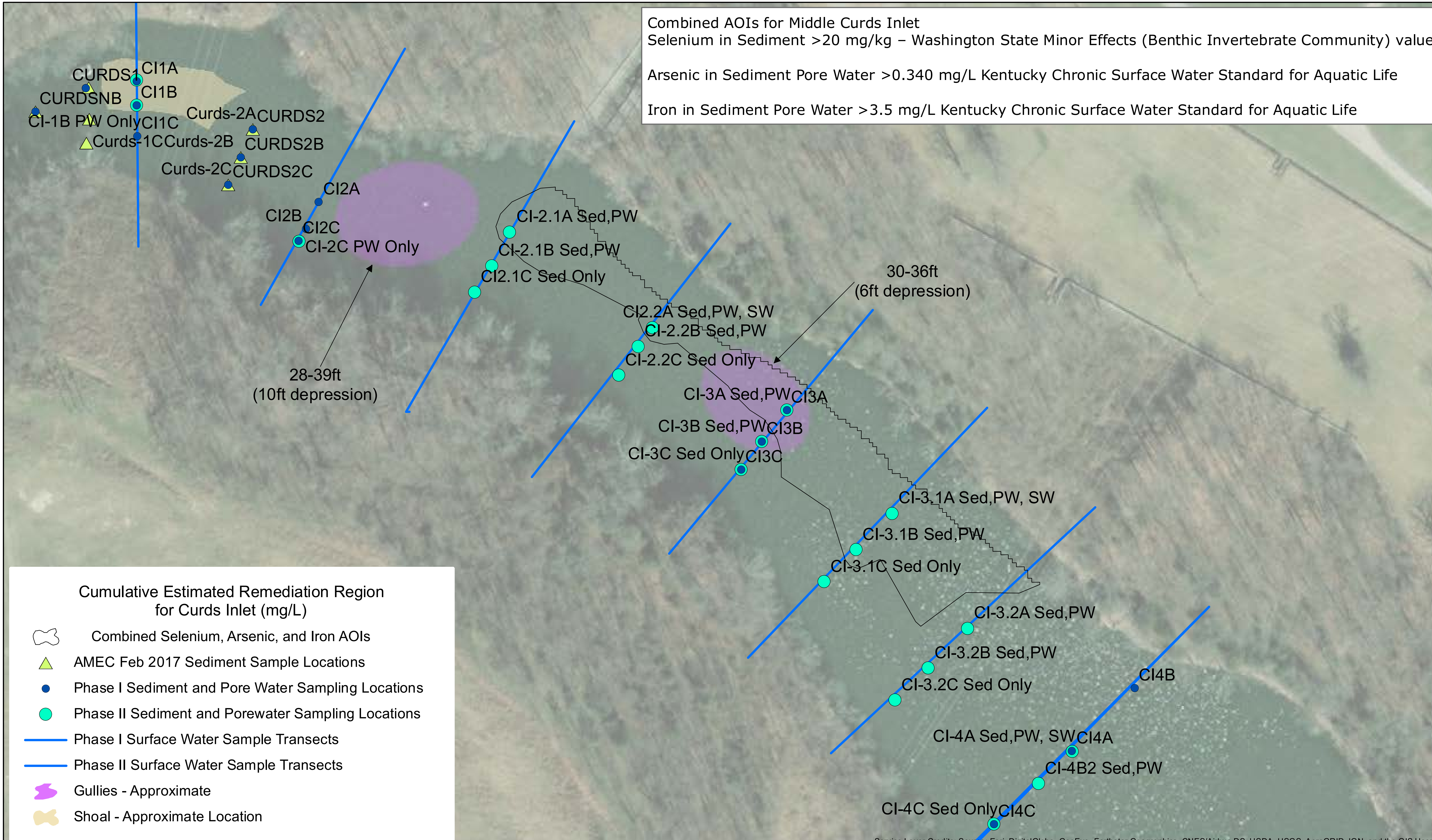
RAMBOLL

Map Design: AJS, Date: Jan 16, 2021

Proposed Sediment Dwelling Invertebrate Community Assessment Locations, Lower Herrington Lake (RAO3)
Suppplemental Remedial Alternatives Assessment
E.W. Brown Station, Mercer County, Kentucky

FIGURE 4-3

Project:



RAMBOLL

Map Design: AJS, Date: Nov, 2020

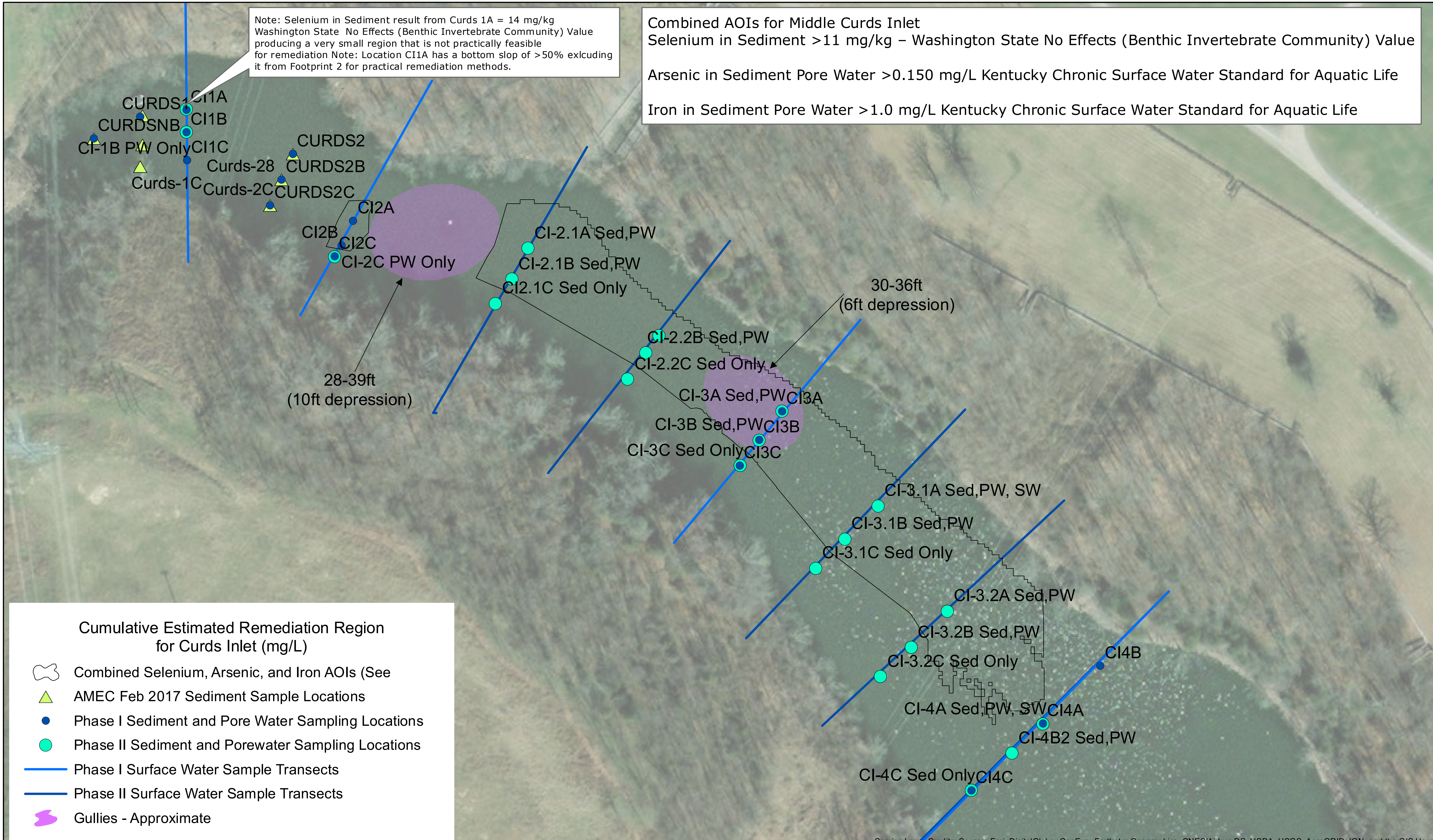
0 100 Feet

N

Footprint 1 - Combined Cumulative Estimated Remediation Region
Curds Inlet, Herrington Lake Corrective Action Plan,
Mercer County, Kentucky

FIGURE
5 - 1 A

Project:



RAMBOLL

Map Design: AJS, Date: Nov, 2020

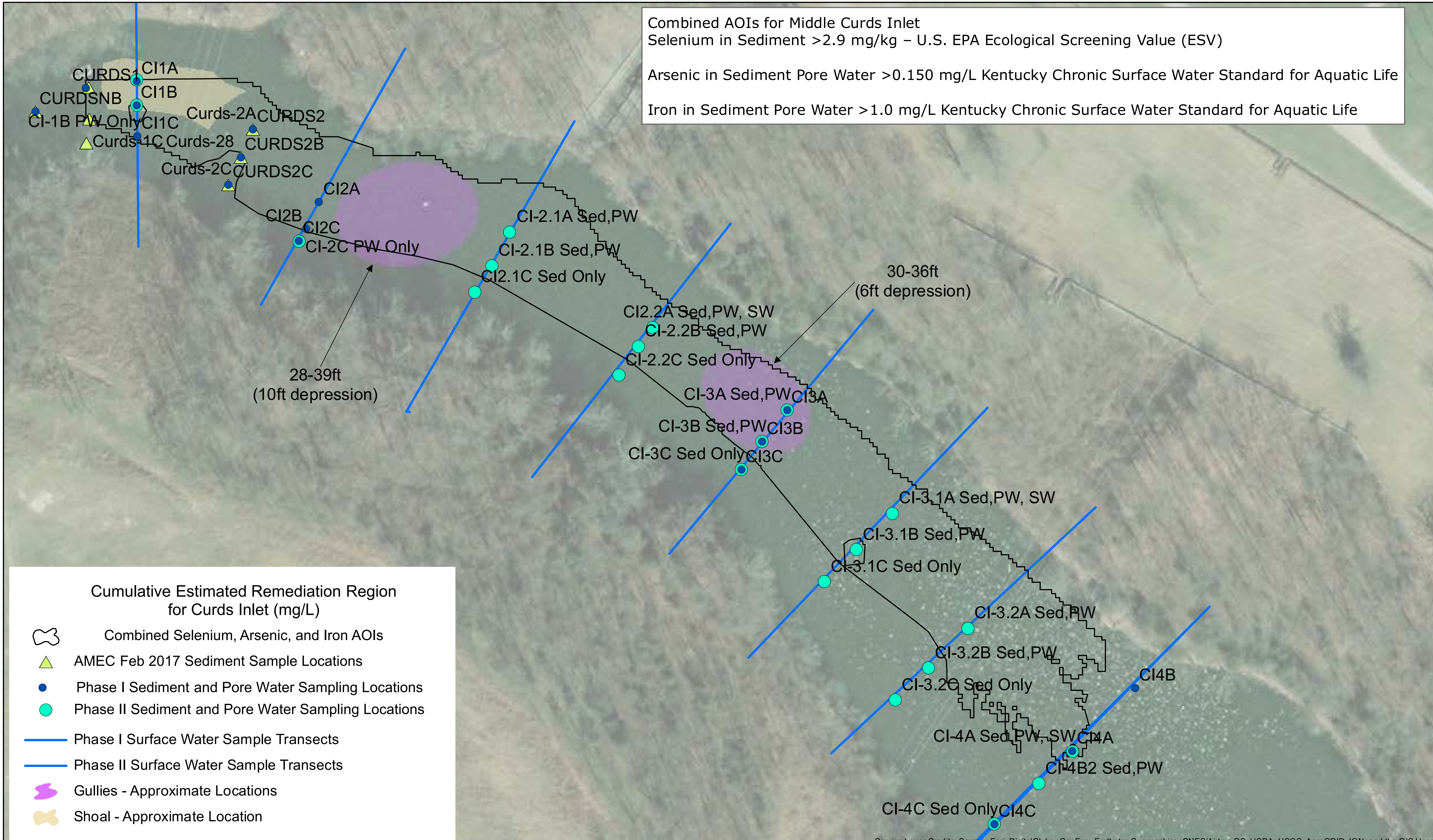
0 100 Feet

N

Footprint 2 - Combined Cumulative Estimated Remediation Region - Curds Inlet, Herrington Lake Corrective Action Plan, Mercer County, Kentucky

FIGURE 5-1B

Project:



RAMBOLL

Map Design: AJS, Date: Nov, 2020

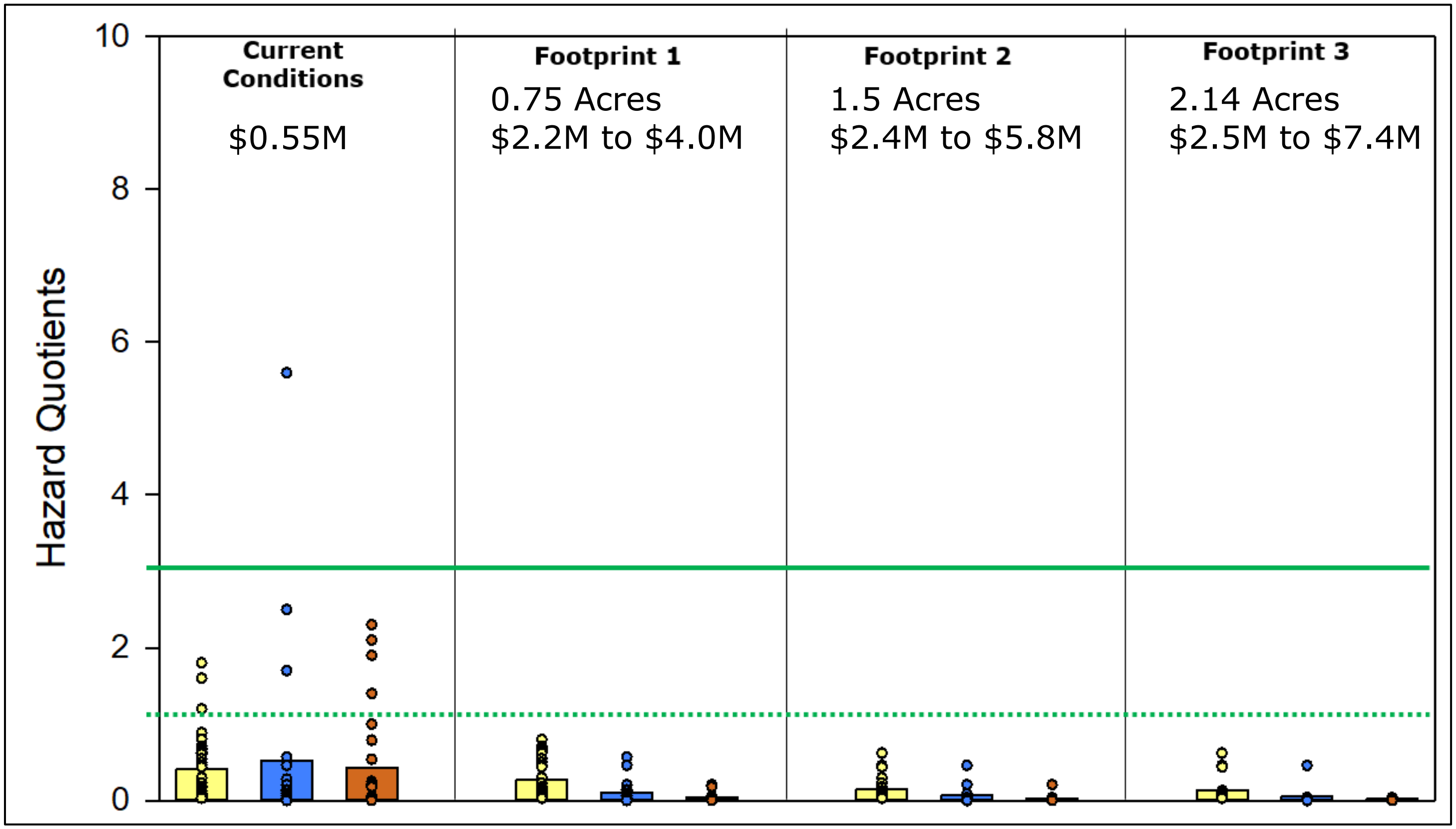
0 100 Feet

N

Footprint 3 - Combined Cumulative Estimated Remediation Region
Curds Inlet, Herrington Lake Corrective Action Plan,
Mercer County, Kentucky

FIGURE
5-1C

Project:



Footprint 1 Risk Based Criteria (a)	
Constituent and Medium	Criterion
Se SD (mg/kg)	20
As PW (mg/L)	0.34
Fe PW (mg/L)	3.5

(a) The same criteria are used for each Footprint in this graphic for comparative purposes.

- This figure shows the comparison of risk reduction for the three footprints, calculated using the same risk-based criteria for Current Conditions and conditions following implementation Continent Remedial Alternatives 1 (EMNR), 2 (Capping), and 3 (Dredging). This comparison is made to illustrate the differences from one footprint to the next in terms of risk reduction.
- This figure indicates that there would be little if any meaningful reduction in ecological risks to be gained from expanding the remedial footprint beyond Footprint 1. Seepage of arsenic and iron in pore water through the thin cover cap for Contingent Alternative 1 is expected to be low enough for HQs to remain less than 1 for at least 10 years. Deposition of clean sediment over the thin cover cap for Contingent Alternative 1 is also expected to further limit future pore water seepage.
- Hazard quotients less than a value of 1 indicate that no unacceptable risks are expected. Hazard quotients between 1 and 3 are locations where risks are not definitively ruled out but are not expected to adversely impact the sediment dwelling organism community.

Alternative	Footprint 1	Footprint 2	Footprint 3
1. EMNR	$2.2	$2.4	$2.5
2. Capping	$2.9	$3.6	$3.9
3. Sediment Removal	$4.0	$5.8	$7.4

All costs are presented in Millions of US dollars.

HQ of 1.
HQ of 3.

Se SD – Selenium in sediment.
As PW – Arsenate/arsenite in sediment pore water.
Fe PW – Iron in sediment pore water.

Risk Reduction Profile at ~10 years after remedy implementation, EMNR, Capping, Dredging

RAMBOLL

DRAFTED BY: AJS | DATE: 11/20/2020

ECOLOGICAL RISK REDUCTION IN CURDS INLET FOR EACH FOOTPRINT AND ALTERNATIVES 1 (EMNR), 2 (CAPPING) AND 3 (DREDGING)

Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Herrington Lake, Mercer County, Kentucky

FIGURE 5-2

TABLES

Table 1-1. E.W. Brown Station Completed, Underway, and Planned Remedial Measures
Corrective Action Plan Supplemental Remedial Alternatives Assessment
Herrington Lake, Mercer County, Kentucky

Site Area	Remedial Measure	Status and Timeline	Descriptions of the Completed, Underway, and Planned Remedial Measures
Herrington Lake	Redirection of process water flows from Outfall BRN001 to new Outfall BRN006	Completed: November 2019	- Per the 2019 renewed KPDES permit, treated wastewater from the plant no longer discharges to Curds Inlet via Outfall BRN001. - Flow from the Aux Pond now discharges through BRN006, located in main lower Herrington Lake, at 40 feet below winter pool. - Outfall BRN006 discharges through a multi-port diffuser anchored to the rock wall and extending out into the main body of Herrington Lake. - The new Process Pond handles dewatering of the Aux Pond and other plant process wastewater prior to discharge via Outfall BRN006. - Mass loading of constituents through Outfall BRN006 will also be substantially reduced after dewatering of the Aux Pond is completed (expected in 2021). - The flows to Outfall BRN001 now consist solely of stormwater drainage and are required to be monitored in accordance with the 2019 renewed KPDES permit. - These changes should improve environmental conditions in Curds Inlet, including surface water quality.
Former Main Ash Pond	CCR Capping	Completed: Phase I, II, and III	- Final Capping of Pond.
			- Cap installation was phased to integrate it into the construction of the new lined landfill over top of the covered existing CCRs. - Construction of a special waste landfill over the top of the Main Ash Pond was permitted in 2015 and completed in 2016 . - The special waste landfill is currently receiving plant-generated CCRs including bottom ash, fly ash, and gypsum. - The constructed landfill also serves as a remedial cap for the Main Ash Pond.
			- See the Main Ash Pond Closure Plan (AMEC 2014) for final design details.
	Abutment Drain Collection System (ADCS)	Completed: July 2014	- Discharges from the Abutment Drain Collection System (ADCS) were redirected to the Aux Pond as a short-term IRM. - Per the 2019 renewed KPDES permit, all discharges from ADCS are treated in the new Process Pond prior to final discharge to Herrington Lake via new Outfall BRN006.
	North Abutment Drain Pump Station	Completed: April 2016	- Installed pumping station to capture the north abutment drain discharge and transfer it to the Aux Pond; per the 2019 renewed KPDES permit, discharge, all discharges from north abutment drain are treated in the new Process Pond prior to final discharge to Herrington Lake via new Outfall BRN006
	Toe Drain Collection System (TDCS) (Part of TDCPRTS)		- Part of the approved Toe Drain and Coal Pile Runoff Treatment System (TDCPRTS). - TDCS captures flows at the toe of the Main Pond Dam (Dam Toe Springs Left, Middle, and Right); per the 2019 renewed KPDES permit, all discharges from TDCS are treated in the new Process Pond prior to final discharge to Herrington Lake via new Outfall BRN006.
	Cut-Off Wall Construction		- Constructed a cut-off wall across the valley downstream of the TDCS.
Auxiliary Pond	Redirection of Aux Pond Flow from BRN001 to Newly Constructed BRN006	Completed: November 2019	- Per the 2019 renewed KPDES permit, all flows from the Aux Pond were redirected from Outfall BRN001 to new Outfall BRN006 located in main lower Herrington Lake, at 40 feet below winter pool. - Outfall BRN006 discharges through a multi-port diffuser anchored to the rock wall and extending out into the main body of Herrington Lake.
	Convert Wet to Dry Handling of CCRs	Completed: November 2019	- Replace wet handling of CCRs in Auxiliary Pond with dry handling in the landfill.
	Discharge Pipeline Maintenance	Completed: November 2016	- Replaced existing sections of the HDPE pipeline and manholes based on 2014 evaluation by AMEC. - Reduced the number of manholes. - Tightness tested system on completion.
	Dewatering and Treatment System	Started: December 2019	- Dewatering of the Aux Pond commenced upon the effective date of the renewed 2019 KPDES permit. - Free water and interstitial water removed from the Aux Pond is pumped to a dewatering treatment system. - After treatment, the water is then pumped to a storage basin from where it is pumped to the Process Pond and then discharged through Outfall BRN006. - Auxiliary Ash Pond Dewatering flows, which are addressed in Outfall BRN006A conditions and limits, have been substantially reduced and are expected to be discontinued by the end of 2021.
	Aux Pond Closure	Planned Completion: Dec 2021	- Aux Pond closure activities are substantially complete and full completion is expected by the end of 2021. - Cover soil and storm water runoff management channel construction will continue into mid-2021.
Coal Pile	Coal Pile Runoff Treatment Enhancement (Part of TDCPRTS)	Initial System Start: December 2019	- Part of the approved Toe Drain and Coal Pile Runoff Treatment System (TDCPRTS); - Provides enhanced physical/chemical treatment of coal pile runoff system water. - Initial system start-up commenced in late 2019.

Table 1-1. E.W. Brown Station Completed, Underway, and Planned Remedial Measures

Corrective Action Plan Supplemental Remedial Alternatives Assessment

Herrington Lake, Mercer County, Kentucky

Site Area	Remedial Measure	Status and Timeline	Descriptions of the Completed, Underway, and Planned Remedial Measures
Gypsum Processing Pond	Liner Installation	Completed Late 2015	- Installation of a liner under the Gypsum Processing Pond (GPP) and the area draining to the pond (55,600 SF total) to prevent infiltration of gypsum-impacted water in the area of the GPP. - The Gypsum Pond liner system consists of the following three layers ordered from bottom to top: - Bottom Layer: A 4-inch-layer of dense graded aggregate (DGA) over grade (rough rock surface) to support the membrane liner. - Middle Layer: A 60-millimeter LLDPE flexible membrane liner between two geotextile layers. - Top Layer: A 6-inch fabric form concrete mat.
West Quarry	Drained, Filled, and Covered	Completed: April 2016	- Drained accumulated storm water. - Filled the quarry with inert structural fill of soil and rock. - Graded surface to promote drainage. - Covered surface with topsoil and vegetated to minimize erosion.
Process Pond	New Construction	Completed	- The new Process Pond replaces the Aux Pond for treatment of plant process flows including treated FGD wastewater, TDCPRTS flows, plant sumps, coal/limestone piles runoff waters, landfill leachate/CCR-contact runoff flow, incidental fractions of bottom ash recycle water flows, and other low volume wastewaters.
E.W. Brown Station Facility Waste Ash and Water	Dry Handling of Fly Ash	Completed: Prior to Nov 2019	- Conversion to dry handling for all fly ash systems to eliminate the discharge of fly ash sluice waters.
	Bottom Ash Transport Water (BATW) Management System	System in operation as of 2015; upgrades planned by July 2023	- Since 2015, the Bottom Ash Transport Water (BATW) management system recirculates the Unit 3 bottom ash sluice water. - Two remote submerged flight conveyors were installed in 2015 at Unit 3 to manage bottom ash, coal mill rejects/pyrites, and any boiler air-heater wash water flows. - As of the renewal of the KPDES permit in November of 2019, wastewater from the BATW management system discharges to the new Process Pond, and then ultimately to Herrington lake via Outfall BRN006. - In addition, KU will be upgrading the existing BATW management system to meet the requirements for recirculation of BATW flows under the applicable USEPA ELGs. - KU recently submitted an application to modify the permit to specify an ELG compliance date of July 1, 2023 for operation of the BATW high recycle rate management system and allow for a purge rate of up to 10% in accordance with recent revisions to the ELGs. - Purge flows from the BATW system will be treated in the Process Pond prior to final discharge to Herrington Lake through Outfall BRN006 high-rate multiport diffuser.
	Flue Gas Desulfurization Wastewater Recirculation and Treatment	2019	- As of late 2019, most process waters from the Unit 3 Flue Gas Desulfurization (FGD) system are recycled to supply FGD system makeup water. - Any surplus FGD process water is treated in a new Process Water System (PWS) using physical-chemical systems. - The PWS is a physical-chemical water treatment system consisting of two reaction tanks, one clarifier, filter system, and an effluent tank. - Within the PWS, the influent is treated with caustic, organosulfide, ferric chloride, and polymer. - This treatment system removes suspended solids, adjusts pH, and removes metals by chemical reactions with organosulfide compounds. - The effluent is then pumped from the effluent tank to the process pond and then discharged through Outfall BRN006. - Kentucky Division of Water designed the KPDES permit limits for wastewater discharges to ensure compliance with the applicable Kentucky surface water quality standards (401 KAR 10:031). - KU submitted an application to modify the Brown plant KPDES permit to reflect its plans to install additional equipment to convert the FGD wastewater system to fully zero liquid discharge (ZLD) to meet FGD wastewater requirements under the applicable USEPA ELGs. - Currently, completion of the FGDWW system conversion to ZLD is estimated for July 1, 2023; at which point no further FGD wastewater discharges will flow to the PWS or to Outfall BRN006.

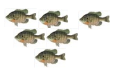
Acronyms:

%	Percent
ADCS	Abutment Drain Collection System
AMEC	Amec Foster Wheeler
Aux	Auxiliary
BATW	BATW Bottom Ash Transport Water
BRN	Brown (as in E.W. Brown Station)
CCR	Coal Combustion Residuals
DGA	Dense Graded Aggregate
ELG	Effluent Limitation Guideline
FGD	Flue Gas Desulfurization
FGDWW	Flue Gas Desulfurization Wastewaters
GPP	Gypsum Processing Pond
HDPE	High-density polyethylene
IRM	Interim Remedial Measure
KAR	Kentucky Administrative Regulation

Acronyms (Cont'd):

KPDES	Kentucky Pollution Discharge Elimination System
KU	Kentucky Utilities Company
Ky	Kentucky
LLDPE	Linear low-density polyethylene
pH	potential Hydrogen
PWS	Process Water System
SF	Square feet
SWQS	Kentucky Surface Water Quality Standards (KAR (401 KAR 10:031)
TDCS	Toe Drain Collection System
TDCPRTS	Toe Drain and Coal Pile Runoff Treatment System
USEPA	United States Environmental Protection Agency
WWTP	Waste Water Treatment Plant
WWTS	Waste Water Treatment System
YOY	Young-of-the-Year
ZLD	Zero Liquid S Discharge System

Table 4-1: Post-Interim Remedial Measures Performance Monitoring Plan for Herrington Lake
Corrective Action Plan, Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Mercer County, Kentucky

EVENT	RAO Performance Measure	Sampling Media	Sampling Season	# of Samples: Curds Inlet: Upper	Curds Inlet: Middle	Curds Inlet: Lower	HQ Inlet	Hardin Inlet	LHL1 (Dix Dam)	LHL6 (Near Sunset Marina)	LHL2 (Rocky Run)	Middle Herrington Lake	Total # of Composite Fish Samples and Benthic Samplers	Total # of Individual Fish per Composite Fish Sample	Total Individual Fish Collected	Target Analyte/ Metrics	Sample Descriptions
MONITORING EVENT 1 (After BRN001 Retirement)	RAO 1	 Adult Fish Bluegill [a,b]	Spring (prior to spawn)	3*				2	2	2	2	2	13	2 to 5[c]	26 to 65[d]	Selenium	Three composite adult bluegill samples 2-5 bluegills per sample, gravid females preferred). Separate ovaries and combine mathematically to estimate whole-body concentrations.
	RAO 1	 Adult Fish Bass[b]		2				–	2	2	2	2	11	2 to 3[c]	22 to 33[d]	Selenium	Two composite largemouth bass samples (2-3 bass per sample) in Curds Inlet and Two composite largemouth bass samples (2-3 bass per sample) from Lower and Middle Herrington Lake. Kentucky bass may be collected if largemouth bass are unavailable.
	RAO 2	 YOY Fish	Summer	3	3	3[e]		3[f]			–	–	12	20 to 100	240 to 1200[f]	Selenium	Resampling of the 2018 YOY regions but with smaller sample sizes (20-100 YOY Bluegills)
	RAO 3	 Benthic Community Assessment[g]	Late Spring	9	9	9	–	9					36			Species Diversity and Abundance	Benthic community assessment using artificial substrates e.g. Hester Dendy. Three samples per sampling region.

Abbreviations:
BCA - Benthic Community Assessment
CI - Curds Inlet
HQ - HQ (Rumored to have previously been HeadQuarters but no information found for this acronym)
LCI - Lower Curds Inlet
LHL - Lower Herrington Lake
MHL - Middle Herrington Lake
RAO - Remedial Alternative Objective
Se - Selenium
YOY - Young-of-the-year

Adult Fish Notes:
Lower Curds Inlet and HQ Inlet will be sampled together due to the close proximity of the two locations is within the adult fish ranges.
(a) Adult bluegill sampling will include extraction of ovaries from gravid females for separate laboratory analysis.
(b) Adult bass and bluegill reference locations will remain consistent with those sampled for the 2017 and 2018 Phase I and II studies.
(c) Estimated 2 to 5 adult bluegill per composite sample and 2 to 3 bass per composite, where possible. A single fish may suffice for a sample if multiple fish cannot are not captured.
(d) Estimated number of individual fish from all sample locations.

YOY Bluegill Notes:
(e) For the monitoring phase, Lower Curds Inlet and HQ Inlet will be sampled together for YOY bluegill sampling, for the following reasons:
1. The close proximity of the two locations has no barriers for fish movement
2. The results from the Phase II 2018 YOY study for LCI and HQ inlet are similar

(f) Due to their very small size (weight), the minimum number of individual YOY fish required to complete one composite YOY bluegill whole-body tissue sample relies on the individual weights of the sample members, sometimes requiring up to approximately 20 to 100 small fish to meet minimum weight requirement for the laboratory test minimum weight (typically 5 to 10g for analysis of selenium). Depending on conditions at the time of sampling, including availability of sufficient numbers of YOY bluegills, Hardin Inlet will serve as the YOY bluegill reference location. Locations LHL1 or LHL6 will serve as alternative references, if needed.

Benthic Community Assessment Notes:

(g) BCA locations in Curds Inlet and reference areas will be determined at the time-of-sampling based on many variables including practicality (some very deep drop-off shelf locations will not be suitable) and to ensure maximum likelihood of retrieval. Hardin Inlet will be the target reference area. Locations outside Hardin Inlet will be considered if Hardin Inlet is not comparable to Curds Inlet. For the BCA, three replicate samplers will be placed at each sampling location.

Table 5-1: Estimated Remedial Quantities for Contingent Alternatives 1, 2 and 3
Corrective Action Plan, Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Mercer County, Kentucky

		Footprint 1	Footprint 2	Footprint 3
Alternative 1 Enhanced MNR	EMNR Area (SF)	32,700	64,700	93,400
	Sand Depth (inch)	6	6	6
	Thin Layer Cover Volume (CY)[1]	700	1,300	1,900
	Estimated Duration (months)	1	1	1
Alternative 2 Capping	Total Cap Area (SF)	32,700	64,700	93,400
	Arsenic-Impacted Area (SF)	23,500	37,000	37,000
	Sand Layer Depth (in) Arsenic Impacted Area (ft)	4.5	4.5	4.5
	Sand Layer Depth (in) Non-Arsenic-Impacted Area (ft)	1	1	1
	Sand Layer Volume (CY)[1]	4,700	7,900	9,000
	Armor Layer Depth (ft)	0.5	0.5	0.5
	Armor Layer Volume (CY)[1]	700	1,300	1,900
	Estimated Duration (months)	3	4	5
Alternative 3 Dredging	Removal Area (SF)	32,700	64,700	93,400
	Target Removal Depth (ft)	2	2	2
	Removal Volume (CY)[2]	3,400	6,500	9,400
	Sediment Tonnage (ton)	4,300	8,300	12,000
	Debris Tonnage (ton)[3]	700	1,400	2,000
	Estimated Duration (months)	2	2	3

Notes:

1 - Volumes include 10% for material loss, over-placement, and/or overlap.

2 - Removal volume includes target volume, plus overdredge and slope back assumptions.

3 - Debris volume estimated at 15% sediment removal volume. It does not include large tree trunks which may be present on the sediment surface and require removal prior to remedy implementation.

Table 5-2: Preliminary Comparative Evaluation of
Contingent Supplemental Remedial Alternatives for Curds Inlet

Supplemental Remedial Alternatives Assessment
E.W. Brown Station, Herrington Lake, Mercer County, Kentucky

Remedial Assessment Criteria		1 Enhanced MNR:Thin Layer Cover	2 Capping	3 Sediment Removal
Threshold Criteria	Overall Protection of Human Health and the Environment	+	+	+
	Compliance with any other Applicable Requirements	+	+	+
Primary Balancing Criteria	Long-Term Effectiveness and Permanence	Moderate	Better	Best
	Reduction of Toxicity, Mobility, or Volume Through Treatment	Low	Better	Moderate
	Short-Term Effectiveness	Better	Moderate	Low
	Implementability	Moderate	Moderate	Low
	Cost	$2.2 to 2.5MM	$2.9 to 3.9MM	$4.0 to 7.4MM
Modifying Criteria	Community Acceptance	To be determined		
Sustainability/Overall Environmental Impact		Better	Moderate	Least

Legend
"+" Satifies Criterion
- Least
- Low
- Moderate
- Better
- Best

MM - Millions of U.S. Dollars
MNR - Monitored Natural Recovery