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Kingston Ash Recovery Project
Non-Time-Critical Removal Action
for the River System
Sampling and Analysis Plan (SAP)

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List of Acronyms

°C	degree Celsius
°F	degree Fahrenheit
AdH	adaptive hydraulics
ASTM	American Society of Testing Materials
AVS	acid volatile sulfides
BERA	Baseline Ecological Risk Assessment
$CACO_3$	calcium carbonate
CERCLA	Comprehensive Environment Response, Compensation, and Liability Act
CoC	chain-of-custody
CRM	Clinch River Mile
cy	cubic yard
DOE	U.S. Department of Energy
DO	dissolved oxygen
DOC	dissolved organic carbon
DOT	U.S. Department of Transportation
DQO	data quality objective
DWS	Drinking Water Standards
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
ERDCWES	Engineering Research and Development Center at Waterways Experiment Station
ERM	Emory River Mile
ft	foot
GPS	global positioning system
ID	identification
IDW	investigation-derived waste
KIF	Kingston Fossil Plant
mi	mile
msl	mean sea level
ORP	oxidation-reduction potential
NOAEL	no-observed-adverse-effects-level
LOAEL	lowest-observed-adverse-effects-level
PAH	polynuclear hydrocarbon
PCB	polychlorinated biphenyl
PLM	polarized light microscopy
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RSL	regional screening level
SAP	Sampling and Analysis Plan
SEM	simultaneously extracted metal
SC	specific conductivity
SOP	Standard Operating Procedure
SPM	Sample Planning Module
TBD	to be determined
TDEC	Tennessee Department of Environment and Conservation
TDS	total dissolved solids
TOC	total organic carbon
TRM	Tennessee River Mile

TRV	toxicity reference value
TSS	total suspended solids
TVA	Tennessee Valley Authority
WQC	water quality criteria

1. SITE BACKGROUND

This Sampling and Analysis Plan (SAP) details the data gathering efforts to support a Preliminary Assessment of the Emory River and other river areas impacted by the spilled fly ash at the Tennessee Valley Authority (TVA) Kingston Fossil Plant (KIF) release site in Roane County, Tennessee.

On Monday, December 22, 2008, just before 1 a.m., a coal fly ash spill occurred at TVA's KIF, allowing a large amount of fly ash to escape into the adjacent waters of the Emory River. Shortly after the ash spill, on January 12, 2009, the Tennessee Department of Environment and Conservation (TDEC) issued a Commissioner's Order, Case No. OGC09-0001 (TDEC 2009), requiring action be taken as necessary to respond to the emergency under Tennessee Code Annotated §69-3-109(b)(1), the Water Quality Control Act. The TDEC Order required a plan for the comprehensive assessment of soil, surface water, and groundwater; remediation of impacted media; and restoration of all natural resources damaged as a result of the coal ash release.

On May 11, 2009, an Administrative Order and Agreement on Consent (U.S. Environmental Protection Agency [EPA] 2009a) was signed between EPA and the TVA providing the regulatory framework for the restoration efforts. EPA's Administrative Order directed the restoration work to be conducted under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and more specifically, under the removal program. A significant portion of the restoration efforts are currently underway and being conducted as a time-critical removal action. In accordance with Section IX.30 of the EPA Administrative Order, a work plan for performing one or more non-time-critical removal actions at the Site was prepared. That work plan (Jacobs 2009), issued by EPA for public comment on October 21, 2009, concluded that significant data uncertainties exist in characterizing the river system, so that more study and time are needed for comprehensive assessment of ecological risk in the river system. It was therefore decided to make two separate non-time-critical removal action decisions, one for the embayment/Dredge Cell area and the other for residual ash in the river. This SAP addresses the sampling and analysis of biotic and abiotic media, which will be used to assess potential human health and ecological risks in the river, and to support decision-making for the restoration of impacted areas.

The purpose of this SAP is to describe the Data Quality Objectives (DQOs), sampling design, and sampling procedures to be used for collecting the additional data. This SAP has been prepared in accordance with EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1993), Appendix B.

1.1 SITE DESCRIPTION

The KIF is located just off Swan Pond Road at the confluence of the Emory and Clinch Rivers on Watts Bar Reservoir in Roane County, near Kingston, Tennessee (Figure 1-1). KIF is one of TVA's larger fossil plants. It generates 10 billion kilowatt-hours of electricity a year, enough to supply the needs of about 670,000 homes in the Tennessee Valley. Plant construction began in 1951 and was completed in 1955. KIF has nine coal-fired generating units. The winter net dependable generating capacity is 1,456 megawatts. The plant consumes some 14,000 tons of coal a day.

Ash, a by-product of a coal-fired power plant, is stored in unlined containment areas, including a former Dredge Cell. Failure of the Dredge Cell dike released about 5.4 million cubic yards (cy) of coal ash. At the time of the slide, the area contained about 16.2 million cy of ash and associated dikes. The dike failure caused about 60 acres of ash in the 127-acre containment area to be displaced. The released ash covered about 300 acres. Fly ash filled the Swan Pond Embayment on the north side of the KIF property adjacent to the failed Dredge Cell (Figure 1-2). A temporary dike (Dike 2) was constructed in the eastern portion of the Swan Pond Embayment to contain the fly ash to the west of the dike until a response action

plan could be developed, approved by the regulators, and implemented. Fly ash also entered the channel and overbank areas of the riverine section of the Emory River. TVA is recovering the material outside of the Swan Pond Embayment by use of mechanical excavators and dredging operations under a time-critical removal action.

The fly ash that was released to the Emory River originates from the coal burned in boilers for power production at KIF. The coal, in its natural state, contains various inorganics that can be retained with the ash after burning. Trace amounts of arsenic, chromium, copper, lead, mercury, nickel, selenium, thallium, vanadium, zinc, and other metals which occur naturally in the coal remain in the ash after coal combustion. Naturally-occurring radionuclides, such as isotopes of potassium, radium, uranium, and thorium, may also remain in the ash after coal combustion. These metals and radionuclides are typically bound to the ash. The ash itself is primarily composed of fine silica particles very similar to sand.

Per the EPA Administrative Order, the “site” is defined as those areas of the KIF where waste material has been deposited, stored, disposed of, or placed or has migrated or otherwise come to be located (Figure 1-3). Most of the 300 acres directly affected by the release was TVA property, although 40 non-TVA owned properties, constituting a total of 8 acres, were affected. TVA has since purchased most of the affected properties and others in the area that may be affected by response actions.

Several different field sampling events and surveys have been performed to characterize the spatial extent of ash deposition. Results indicate that ash may have traveled upstream as far as Emory River Mile (ERM) 6.0, and as far downstream as Tennessee River Mile (TRM) 566. In the upstream direction, the depth of ash appears to diminish quickly beyond about ERM 3.5. In the downstream direction, ash deposition generally diminishes to trace amounts by about ERM 1.0, with pockets of greater depth (about 2 inches to about one foot (ft) in some places) occurring in depositional areas in the Clinch River. Downstream of Clinch River Mile (CRM) 2.0, ash deposits vary from trace amounts to 2 inches. Ash deposition of 0.5 to 1 inch was observed in the Tennessee River at TRM 566 (south of the Clinch River). Only trace amounts of ash have been observed further downstream.

Initial two-dimensional sediment/ash transport modeling conducted by the U.S. Army Engineer Research Development Center indicates that material has likely been transported past TRM 566 during a May 2009 storm event. The primary deposition area for fine particles is predicted to be between TRM 562 and 568.

1.1.1 Climate

Climate in the region surrounding Kingston, Tennessee is warm during summer when average daily temperatures tend to be in the 70's ºF and cold during winter when temperatures tend to be in the 30's ºF. The warmest month of the year is July with an average maximum temperature of 87 ºF, while the coldest month of the year is January with an average minimum temperature of 25 ºF. Temperature variations between night and day tend to be moderate during summer with a difference that can reach 23 ºF, and moderate during winter with an average difference of 22 ºF.

The annual average precipitation at Kingston is 53.23 inches. Rainfall is fairly evenly distributed throughout the year. The wettest months of the year occur between November and April, with highest average monthly precipitation in March of 5.70 inches. The driest months of the year occur in August through October (National Weather Service 2006).

1.1.2 Topography

KIF and the area affected by the ash release lie within the Valley and Ridge physiographic province, a region characterized by narrow, subparallel ridges and valleys trending northeast-southwest.

Physiographic boundaries of the site are Pine Ridge to the west of the site, Swan Pond Creek drainage to the north and the Emory River/Watts Bar Reservoir to the east and south. Topography varies from elevations of 1,000 to 1,100 ft mean sea level (msl) on the tops of the ridges to 737 ft msl at Watts Bar Reservoir. Early maps of the area indicate the ash storage area was formerly a seasonal backwater or floodplain of the Emory River. The backwater was likely subject to periodic flooding; the Emory River floodplain elevations before construction of the KIF varied between approximately 725 and 735 ft msl (based on a 1924 topographic survey). Bottom elevation of the pre-slide embayment area varies between 735 and 737 ft msl. After the slide, ash and intermixed soil filled much of the embayment to depths of more than 20 ft; current top of ash elevations vary between 750 and 760 ft msl, although piles of failed ash up to elevation 790 ft msl are present. Within the former Dredge Cell, top of ash elevations vary between 740 and 820 ft msl.

1.1.3 Surface Water Hydrology

The KIF is on the Emory River, 2.6 river miles above the confluence of the Clinch and Emory Rivers. The Emory River drains a watershed area of approximately 865 square miles with average flow rates between 700 and 1,300 cubic ft per second. The affected reach of Watts Bar Reservoir transitions from the upstream riverine (river-like) reaches of the Emory River to the more lacustrine (lake-like) conditions found in the impounded portions of the backwaters of Watts Bar Reservoir. The reservoir pool extends upstream to above Harriman, Tennessee (ERM 11). Overbank areas in the Swan Pond Embayment are very shallow. In accordance with the Watts Bar Operating Guide, normal summer pool within Watts Bar Reservoir is maintained between 740 and 741 ft msl; normal winter pool is maintained between 735 and 737 ft msl.

The 100-year flood elevations for this reach of the Emory River vary from elevation 747.6 ft msl at ERM 1.5 to elevation 749.4 ft msl at ERM 3.5. At the Swan Pond Embayment, located at ERM 2.2, the 100-year flood elevation would be approximately 748 ft msl. The 100-year flood post-slide elevations were higher than preslide elevations, but will have returned to pre-slide conditions after completion of the time-critical removal action.

The Emory, Clinch, and Tennessee Rivers are waters of the state. “Waters of the State” are defined in T.C.A. §69-3-103(33) and are classified by the Tennessee Water Quality Control Board for suitable uses. The three rivers have been classified for the following uses: domestic water supply, industrial water supply, fish and aquatic life, recreation, irrigation, livestock watering and wildlife, and navigation. The Tennessee River is the source of drinking water for the city of Kingston, Tennessee. The downstream Watts Bar Reservoir is used by several municipalities as a source of drinking water.

1.1.4 Geology

The controlling structural feature of the region is a series of northeast-striking thrust faults, which have forced older rocks from the southeast over younger units. Bedrock units of the Rome Formation, the Lower Conasauga Group, and the Knox Group occur beneath the affected area in northeast-trending bands. These units generally dip to the southeast at angles averaging 45 to 50 degrees (Figure 1-4).

Alluvial and/or residual deposits generally cover bedrock, and form a blanket separating ash deposits from underlying bedrock. Alluvium is generally limited to the natural (pre-reservoir) floodplains of the Emory River and its tributaries. The alluvium consists of a thin (<6 inch) layer of sensitive clayey silt, which overlies a layer of medium to very stiff silt and clay, which in turn transitions to a very loose to medium dense sand and silt. The alluvial deposits are up to 65 ft thick beneath the ash disposal areas at the plant site, but thickness is unknown in areas offsite. Residuum (clayey soil derived from the

weathering of the underlying bedrock) is expected to cover the remaining upland areas within the region, but data regarding its thickness offsite are currently unavailable.

Bedrock beneath most of the ash-affected area is represented by the Lower Conasauga Group and Rome formation. The Lower Conasauga Group primarily consists of shale with interbedded siltstone, limestone, and conglomerate, and is locally of low water-producing capacity. The Rome formation consists of interbedded shale, sandstone, and siltstone, and is a poor water producer. The primary water-bearing units of the region are the limestone and dolomite members of the Knox Group and the Maynardville formation (Upper Conasauga). The Knox Group includes several thick-bedded limestone and dolomite members susceptible to karst development.

1.1.5 Hydrogeology

Groundwater within the region is derived from infiltration of precipitation through the soil overburden. Direct recharge to bedrock aquifers by storm runoff through sinkholes may also occur in areas underlain by karst bedrock. Shallow groundwater movement is generally from upland areas to adjacent stream valleys with groundwater ultimately discharging to streams and springs. Although some deep recharge of deeper bedrock aquifers may occur elsewhere in the region, it is likely that shallow groundwater recharge originating in the site locality discharges directly to the Emory River, its tributaries, or to springs (Figure 1-5). The occurrence of numerous springs along the Emory River and within the Swan Pond Embayment indicates the site lies within a regional groundwater discharge area. Limited stream recharge of shallow groundwater could occur during periods of rapid rise in reservoir elevation causing temporary reversal of groundwater hydraulic gradients.

In a groundwater discharge setting, deeper wells should have higher hydraulic head (higher groundwater elevation) than shallow wells. To assess the likelihood of upward groundwater gradients, the correlation coefficient of well depth versus groundwater elevation was calculated for the wells in the Dredge Cell area. Results showed correlation coefficients of 0.84. Similarly, depth data obtained from eight geotechnical borings installed to the top of rock in the Ash Pond area showed a correlation coefficient of 0.82. These correlations support the expectation of discharge conditions and upward gradients.

Preliminary review of available water supply data indicates that the water-supply wells and springs in the site locality are situated upgradient of ash-affected land bordering streams. Consequently, any ash-related constituents entering shallow groundwater beneath affected areas would be transported a short distance to local streams without encountering wells or springs. There are no known water-supply wells downgradient of the ash, between the ash and the reservoir.

1.1.6 Ecology

Aquatic ecosystems existed in the Swan Pond Embayment prior to the ash release, but were virtually eliminated by the release. Approximately 300 dead fish were found stranded along the banks of the embayment in a debris-line presumably formed during the initial surge of ash. Bottom-dwelling animals (mussels, insects, crayfish, etc.) in areas where large amounts of ash were deposited were likely unable to escape the spill and would have physically been covered by deposits (TVA 2009a).

TVA has systematically monitored the ecological conditions of its reservoirs since 1990 as part of the Vital Signs Monitoring Program. The fish assemblage within the Clinch River in Watts Bar Reservoir has consistently rated good, except for lower scores in 2007, a likely result of widespread drought conditions that continued into 2008. Watts Bar Reservoir rated at or above the valley-wide average in the quality of its sport fishery (TVA 2009a).

The mussel fauna in the Emory River near the KIF has been substantially altered by the impoundment of Watts Bar Reservoir and upstream impacts including mining and urbanization. Six mussel species (giant floater, fragile papershell, pistolgrip, pimpleback, wartyback, and threehorn wartyback) and a common aquatic snail (hornsnail) were found in a pre-spill survey of this area. All of these species, except pistolgrip, are generally tolerant of reservoir conditions.

Wetland areas also existed in the Swan Pond Embayment prior to the ash release. These wetlands were typically associated with shoreline margins, in floodplains of tributary streams, small islands, and at the heads of reservoir coves. Additional small areas with wetland vegetation occurred in ditches along the roadsides or railroad lines. These wetlands included a mix of forested, shrub, and/or herbaceous vegetation depending on the land use. National Wetland Inventory maps show narrow fringe wetlands along the shorelines, three small island wetlands, and a small forested island wetland above the mouth of the Emory River. Between the mouth of Swan Pond Embayment and Swan Pond Circle Road, there were narrow fringe wetlands and two small forested, island wetlands. Above Swan Pond Circle Road, there were narrow fringe wetlands along the shoreline, and wetlands in narrow patches along the margins of the southernmost ash cells. The ash slide eliminated all the wetlands (including three small island wetlands) in the spill area. The ash spill also affected wetlands in the ash pond area; some of these wetlands were heavily used by waterfowl and shorebirds.

Wetland areas along the Emory and Clinch Rivers are generally limited to narrow fringe wetlands. This is partly due to the approximately 5-foot variation in water elevation between winter and summer pool levels. The relatively steep topography long much of the shoreline also limits the areas where soils remain saturated. Exceptions typically are located near shallow inlets fed by springs or small tributaries. The reservoir shorelines are sparsely populated with small beds of emergent vegetation located below the summer pool level. Wetland plants along the summer pool shoreline also are limited in distributions primarily along points and islands. These fringe wetlands appear to be comprised primarily of rushes or cattails. Riparian habitats along the Clinch and Tennessee Rivers are varied in nature and include mature deciduous (or mixed) forests, scrub/shrub, mixed herbaceous vegetation, rock or concrete retaining walls, and manicured lawns.

Terrestrial plant and animal communities in the Ash Pond area have been greatly altered by KIF operations. The dominant plant communities consist of a variety of wetland species in and on the fringe of the lower settling ponds and at the outer base of the dikes. The collapsed dredge cells contained very little vegetation. The dikes were mostly vegetated with a mixture of common, weedy, native and nonnative grasses, and herbs. A band of riparian trees and shrubs, including sycamore, willow, boxelder, and alder occurred along much of the outer edge adjacent to the reservoir. Similar riparian vegetation occurred along other parts of the shoreline of Swan Pond Embayment and on the islands in the embayment. Other affected areas of the reservoir shoreline were landscaped, suburban lawns or oak-hickory forest.

The ash ponds have been heavily used by shorebirds, waterfowl, amphibians, and reptiles, primarily concentrated in the lower settling ponds, which remain relatively intact. The lower settling ponds, Swan Pond Embayment, and the adjacent Emory River have been heavily used by Canada geese, wood ducks, great blue and green herons, great egrets, belted kingfishers, osprey, and double-crested cormorants. A variety of songbirds, semiaquatic mammals, turtles, and water snakes have also been abundant in the riparian vegetation along the shoreline. Ospreys are common in the area, often nesting on natural and man-made structures on and around the KIF properties. Heron colonies also occur near the fossil plant; the closest is approximately 0.3 mile upstream and in direct line of sight of the affected area. A second colony including great blue herons and double-crested cormorants occurs just downstream of the junction of the Emory and Clinch Rivers. The embayment areas filled with spilled ash are being restored as part of the non-time-critical removal action for the Swan Pond Embayment and Dredge Cell (Jacobs 2010).

1.2 SOURCES

1.2.1 Previous Removal Actions

On August 4, 2009, an Action Memorandum was approved for removing ash from the Emory River east of Dike 2 under a time-critical removal action (TVA 2009b). The decision was made to remove ash from the river using hydraulic or mechanical dredging and from dry land areas beyond Dike 2 using land-based equipment and then process, transport, and dispose of the ash recovered. The purpose of removing the ash from the river was to limit the potential for future ash migration and to prevent upstream flooding in the event of a large rainfall. This time-critical removal action is ongoing, and is anticipated to be complete by May 2010.

1.2.2 Residual Sources of Contamination

Upon completion of the time-critical removal action, pockets of ash may remain in the Clinch and Tennessee Rivers. Some additional ash may have migrated into these river systems as a result of high flow events that occurred during the time-critical removal activities. Efforts to remove the ash from the Emory River will have occurred during the time-critical actions, but because over-dredging will not have occurred, there could be small pockets of residual ash in the Emory River. In addition ash may have become intermixed or interbedded with natural river sediments.

Residual ash is present in the Swan Pond Embayment and the former Dredge Cell. This ash is being addressed under a separate non-time-critical removal action. Upon completion of that non-time-critical removal action, ash within the embayment will have been removed and the embayment will have been restored to pre-spill conditions; however, ash will remain within the former Dredge Cell, which could be a source of contamination to the river. Ash deposits also remain in active processing areas, including the Ash Processing Area (“Ball Field”), the Lateral Expansion Area, the Ash Pond, and the Stilling Pond. These facilities are located adjacent to the river and may also be a source of contamination (Figure 1-2).

1.3 TRANSPORT PATHWAYS

The primary transport pathways of contaminants from the source occur through river transport, groundwater transport, and biouptake. Surface erosion and transport in stormwater runoff is not considered a primary transport pathway of concern, since the non-time-critical removal action for the Swan Pond Embayment and Dredge Cell will have removed the ash from the embayment and closed the Dredge Cell.

1.3.1 River Transport

Constituents within the ash may enter the water through suspension or dissolution and be transported in the river system with the river flow. At sufficiently high flow velocities, ash may be suspended in the water column. The small size and granularity of the ash particles mean that they may be easily detached and entrained in flowing water, so this material would continue moving downstream as suspended sediment during periods of high-flow rates. The fly ash deposits may also exhibit cohesive behavior, and may consolidate over time in the river channel. In addition, cenospheres (inert floating ash material) can move downstream on the water surface.

EPA has retained the U.S. Army Corps of Engineers Engineering Research and Development Center at Waterways Experiment Station (ERDCWES) to run a quantitative two-dimensional hydrodynamic and sediment fate and transport model, known as Adaptive Hydraulics (AdH). In general, this model uses system bathymetry, grain size distribution, and river flow data to predict the transport characteristics and

deposition of fly ash in the system. Both cohesive and non-cohesive sediment transport can be simulated with the model, as well as non-alluvial sediments with unique characteristics such as coal fly ash. Additional information on AdH can be found at the following website: http://adh.usace.army.mil/.

Modeling saturated coal fly ash presents a unique problem. Fly ash has a lower particle density than native sediments, and a spherical shape as opposed to the irregular shapes found in quartz based sediments. In addition, the fly ash deposits can exhibit cohesive behavior, and may consolidate over time in the river channel. Because cohesive deposits are more resistant to erosion than non-cohesive deposits, the ERDCWES will be conducting tests in a laboratory flume (SedFlume) to characterize the resistance of fly ash to erosion. The SedFlume will measure the erosion rate of a sample over time as flow is induced over the sample. This erosion rate will then be correlated to the bed shear stress induced by the flow. An empirical equation will be developed from the tests and will be used in the AdH model to specifically predict erosion rates of the fly ash deposits. The natural bed sediment erosion, entrainment, transport, and fate will also be simulated in the model along with the fly ash. Additional information on the SedFlume can be found at the following website: http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=articles!630.

The AdH model domain will extend from one mile upstream of the KIF on the Emory River to the Watts Bar Dam. Both the Clinch and Tennessee Rivers will be included in the domain up to Melton Hill and Fort Loudon Dams, respectively. Because of the size and complexity of the model domain, the problem will be run on the High Performance Computer system at the ERDCWES.

1.3.2 Groundwater Transport

A Conceptual Site Model for groundwater transport at the KIF is shown on Figure 1-5. Infiltration of precipitation through the ash in the closed Dredge Cell may result in leaching of ash-related constituents. Constituents in the leachate may then be transported to the water table and discharged to the Emory River with the groundwater flow. Because the sources are located adjacent to the river and in an area of upward groundwater flow, constituents entering shallow groundwater would be transported only a short distance prior to discharge. Once in the river, the groundwater would become intermixed with the surface water and transported with the river flow. The physical and chemical properties of constituents that influence their transport in groundwater include solubility in water and chemical affinity for solids. Metals tend to adsorb to ash and clay-rich soils, which retards their migration.

1.3.3 Biouptake

Constituents in the ash may enter into the food web through uptake by organisms. Two basic routes of exposure and subsequent uptake by organisms include: (1) direct exposure to dissolved constituents in surface water or porewater with subsequent transport across biological membrane surfaces (e.g., at the gill, gut, or root tip); and (2) ingestion of constituents in prey, surface water, and/or sediment particles with subsequent transport across the biological membrane surfaces. While uptake through direct exposure or ingestion generally describes the exposure for lower-trophic-level species, for upper-trophic-level species, ingestion of constituents in prey is the predominant route of exposure/uptake. Constituents in tissues of organisms in the food chain are likely to be ingested by the species that feed on them (i.e., those occupying higher trophic levels); the result of which may be the expression of toxicological effects in the higher trophic-level species.

The entire mass of a constituent in the environment is not necessarily available for biouptake. Bioaccessibility and bioavailability are the determining factors for biouptake. The portion that the organism can come into contact with is the bioaccessible fraction, which is a function of the behavior and physiology of the exposed organism. The portion that is potentially available for absorption or adsorption by an organism is the bioavailable fraction, which interacts with the exposed organism's biological

membrane surfaces. A wide range of physical, chemical, and biological factors has the potential to influence the bioavailability of constituents in the environment. Bioavailability of constituents in sediment and surface water can vary with changing environmental conditions and is a function of chemical characteristics including chemical type and chemical speciation, as well as the physical and biological environmental conditions.

The processes of bioconcentration and bioaccumulation are important because they provide a basis of predicting potential constituent uptake by flora and fauna. Substances that enter an organism can accumulate, particularly in the lipid (fatty) tissue, which results in a higher concentration of the substance in the organism than in the surrounding environment or in its prey. Subsequent bioaccumulation of constituents can therefore magnify within the food web. Bioconcentration differs from bioaccumulation because it refers only to the uptake of substances into the organism from water alone. Bioaccumlation is the more general term because it includes all means of uptake into the organism.

2. SAMPLING OBJECTIVES (DATA QUALITY OBJECTIVES)

DQOs define the purpose of the data collection effort, clarify what the data should represent to satisfy this purpose, and specify the performance requirements for the quality of information to be obtained from the data. The DQO process is a seven-step iterative planning approach used to prepare plans for environmental data collection activities. The following DQOs for the river system have been prepared in accordance with EPA's *Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4* (EPA 2006), and *Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW* (EPA 2000).

Because the screening-level ecological risk assessment presented in the Engineering Evaluation/Cost Analysis (EE/CA) Work Plan (Jacobs 2009) identified potential unacceptable risk, the DQO process has also followed the process described in EPA's *Ecological Risk Assessment (ERA) Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997). The ERA process is an eight-step iterative approach used to collect and analyze data for assessing potential risks to ecological receptors. Steps 3 and 4 of the ERA process are similar to the 7-step DQO process.

Figure 2-1 summarizes and compares the DQO and ERA processes. A summary of the results of the DQO process development for each environmental medium at the site is presented in Appendix A. As shown in Figure 2-1, results of Step 4 of the ERA process include a SAP (i.e., this document) and a work plan [i.e., the Baseline ERA (BERA) Methodology presented in Appendix B].

2.1 PROBLEM FORMULATION

The scope of the removal action is to fulfill mid-term strategic objectives for the site, as defined in the Administrative Order (EPA 2009a). The scope of the non-time critical removal action decision for the river system includes addressing any residual ash in the Emory, Clinch, and Tennessee Rivers remaining after the time-critical removal action is completed including areas impacted by previous restoration efforts, such as the Swan Pond Embayment. Ultimately, the decision for the river system will center around the following question: In what condition should the river system be left?

The removal action is to remove the ash and restore the river system to pre-spill conditions to the maximum extent practicable. The EE/CA will provide information to make decisions on the nature of the remediation and restoration required. The EE/CA will also provide information to satisfy the requirements for a Jurisdictional Assessment, including maps of the site prior to the spill and following the non-time-critical removal action, areas/species/habitat impacted, revegetation with selected species, habitat created, channel slopes, and similar elements.

The following DQOs were used to define the specific sampling and analysis needed to support the EE/CA decision. The results of the risk assessment will be used to evaluate the need for appropriate long-term monitoring to support CERCLA decision-making. Other studies may be established by TVA researchers to support ongoing natural resources management programs, which are not governed by the following DQOs.

2.1.1 DQO Step 1: State the Problem

Following the completion of the time-critical removal action, pockets of residual ash may remain in the river system, some of which may have become intermixed or interbedded with natural river sediments. Residual ash deposits may serve as a source for further transport downstream or a continuing source of exposure, and may therefore need to be removed or contained. Naturally-occurring metals (e.g., arsenic, chromium, mercury, and selenium) and radionuclides (e.g., radium-226 and thorium-228) are present

within the ash. Sediment may also contain legacy constituents [e.g., polynuclear hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides (chlordane), mercury, cesium-137, or cobalt-60] from other historical sources. Human and ecological receptors may be potentially exposed to these constituents in the residual ash itself, in submerged and seasonally-exposed sediment, in surface water, or in their diet (fish consumption or food chain prey and forage).

A conceptual exposure model (Figure 2-2), depicts the potential receptors, environmental media, and exposure pathways. Seasonally-exposed sediments are present on the banks of the river system, where exposure may occur primarily when the reservoir level is low. Submerged sediments are present on the bottom of the river system where exposure may occur throughout the year. The constituents in sediment may become dissolved or suspended in surface water within the river system, where exposure may occur; conditions occurring after dredging has been completed may be different than those observed during the ongoing time-critical dredging operations.

Bioavailability and bioaccumulation are significant processes for uptake of ash-related constituents within the food chain. Porewater within the sediment may contain chemical constituents that are bioavailable to benthic invertebrates that inhabit these sediments. Benthic invertebrates are primary consumers and detritivores at the base of the food chain; constituents may bioaccumulate in the invertebrates inhabiting the river system, where they may become available to ecological receptors that regularly consume these organisms or their emergent life stages. The constituents may bioaccumulate in fish in the river systems, where they may become available to humans or ecological receptors that regularly consume fish. The constituents may also bioaccumulate in wildlife (aquatic- or riparian-feeding birds and mammals).

Closure of the Dredge Cell under a separate non-time-critical action, will contain any ash remaining onsite beneath a clay cap and cover. Following closure, the constituents within the ash may be mobilized as a result of infiltration of precipitation through the cap, and may be transported downgradient in the groundwater to the Emory River, where exposure may occur in the sediment porewater or surface water.

Potential exposure to humans may occur through recreational use (wading or swimming), or if the river water were to be used as a source of drinking water. The EE/CA Work Plan (Jacobs 2009) presents the methodology, receptors, and exposure parameters for the assessment of potential risks to human receptors from exposure resulting from the release of fly ash at KIF. This information was developed to apply to the media and receptors potentially impacted by the ash release and therefore, applies to potential exposures that may be associated with use of the river system, specifically, recreational exposure to surface water while swimming, recreational exposure to seasonally-exposed sediment, ingestion of fish, and residential use of surface water as an untreated potable water supply.

For ecological receptors, including benthic invertebrates, fish, and wildlife, potential exposure may occur through direct contact, ingestion of sediment or surface water, or bioaccumulation. The ERA methodology, describing appropriate receptors and assessment endpoints, is presented in detail in Appendix B.

2.1.2 DQO Step 2: Identify the Decision

The principal study question is: Do levels of ash-related constituents in sediment, porewater, surface water, or diet (benthic invertebrates, fish, or wildlife) pose unacceptable risk to human or ecological receptors? Several secondary study questions are: If so, what is the geographical location and extent impacted? Are there residual ash deposits present of sufficient thickness or volume for effective removal? If so, how are they distributed; are they deposited uniformly or in isolated pockets? Would ash removal pose greater risk due to increasing exposure to legacy contaminants? Do trends indicate natural attenuation processes (e.g., deposition of fresh sediment, diminishing biouptake) are occurring? For

groundwater, does the flux of ash-related constituents from groundwater to the Emory River result in unacceptable risk?

The ultimate decision to be made is whether the residual ash-related constituents pose a level of risk such that further action is required. Further actions may include general response actions such as monitored natural recovery, removal of residual ash from the river system, capping of residual ash, or combinations of these actions.

2.2 STUDY DESIGN

The next five steps of the DQO process consist of identifying inputs to the decision (data gaps), defining the study boundaries, developing decision rules, specifying the decision errors, and finally optimizing the sampling design. These DQO steps are addressed separately for each environmental medium of concern. Appendix A summarizes the results of the medium-specific DQO process. A summary of the environmental media to be sampled and the corresponding potentially-exposed human and ecological receptors is shown on Figure 2-3. The following describes the planned sampling and study design to fill the identified data gaps.

Existing data will be used to the maximum extent possible. Although existing surface water and sediment data may not be representative of post-dredging conditions, existing data will be compared to post-dredging data to establish trends and determine if conditions have changed. At locations where conditions have not changed, the existing data may be included in the quantitative risk assessments. For example, conditions are not expected to have changed at reference locations; conditions at downstream locations may also not have changed.

The study design describes the data collection needed to support assessment of risks to human and ecological receptors. The results of the EE/CA risk assessment will be used to evaluate the need for appropriate long-term monitoring to support CERCLA decision-making. Other studies may be established by TVA researchers to support ongoing natural resources management programs, which are not governed by the following study design.

The sample types and quantities described in the following sections and listed in Appendix D are the actual number of environmental samples and do not include quality assurance/quality control (QA/QC) samples that will be collected per the requirements of the *TVA KIF Ash Recovery Project Quality Assurance Project Plan (QAPP)*. QA/QC samples planned in support of this plan include field duplicates, equipment rinsate blanks, and matrix spike/matrix spike duplicates. The QA/QC samples are defined in Section 14 of the QAPP and will be collected per the frequencies detailed in Table 14.1 of the QAPP.

Analysis of metals will be in accordance with the QAPP and includes 25 elements: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc.

2.2.1 Ash Deposits

For estimating the volume and distribution of any residual ash deposits, the depth, thickness, areal extent, and degree of mixing or layering needs to be defined. Two methods will be used to distinguish ash from non-ash sediment: (1) visual observations, where the gray ash can be readily differentiated from the natural brown river sediment, and (2) polarized light microscopy (PLM), which provides a quantifiable estimate of the proportion of ash in a sample of sediment. The PLM views mineral specimens under

polarized light, which exhibit colorations when subjected to polarized light filters. When these filters are crossed, characteristics of the mineral specimen can be compared to known characteristics in mineral charts for an accurate identification of the mineral, in this case, ash. Hand-held x-ray fluorescence is also being evaluated as another tool for onsite quantification of ash presence. Ash thicknesses will be measured to within 0.1 ft.

Sampling of ash deposits will be done using vibracore sampling techniques. In general, samples will be taken on a regular grid layout, with samples at any given grid transect taken at mid-channel and both left and right of the channel. Results of ERDCWES AdH sediment transport modeling will be used to help guide sampling, adjusting locations where ash deposits may be likely to occur. Results of total suspended solids (TSS) transport modeling developed by Brigham Young University may be used as a second tool for evaluating where ash deposition is most likely to have occurred. The study boundaries are areas impacted by the ash spill, bank-to-bank, upstream to downstream. A total of 268 sample locations are planned. Planned sample locations and frequency within different sections or reaches of the river system are detailed in Section 3. Sampling frequency will be greater in those reaches where ash deposition from the spill was greatest and will decrease upstream and downstream of those reaches.

Samples will be visually described, particularly visual presence of ash, thickness, and any depositional layering. Visual standards (jars with varying percentages of ash and sediment) will be used to assist field crews in identification of ash. Photographs will be taken of each vibracore. Field PLM estimates of percentage of ash will be made and recorded on the vibracore log. Confirmatory laboratory PLM estimates will be made on 10% of the total samples as quality control.

The physical properties of fly ash are different from those of native sediment materials and may affect bioaccessibility to ash-related constituents in ash deposits. Some sampling teams have observed that objects pushed into the submerged ash meet an initial resistance followed by relatively little resistance to penetration. Ash exposed to air has been observed to form a firm surface as it dries. During handling or bioassay bench testing, containers of saturated ash left undisturbed (or gently vibrated) have been observed to separate into a relatively clear liquid phase underlain by a very dense solid phase. Ash has appeared to be almost dry near the bottom of large containers. Because ash is comprised of spherical glass-like particles of varying sizes, the particles can compact very tightly. A chemically bonded “crust” has not been observed. If ash overlain with water were to form a densely compacted surface or chemically bonded crust, then that crust could prevent bioturbation or recolonization by benthic invertebrates. To assess the occurrence of in-situ crusting of submerged ash deposits, intact samples collected to estimate the volume and distribution of ash will be inspected for evidence of stable structures consistent with a chemically bonded crust. Visual observations will be made of the vibracore samples to identify layers of ash that may constitute a barrier to benthic organisms or to the efflux of water from the sediment.

2.2.2 Seasonally-Exposed Sediment

Seasonally-exposed sediment refers to the sediment that becomes exposed on the river banks during the times that the reservoir levels are low (i.e., winter months December to April). These sediments are submerged during the remainder of the year in shallow water near the river bank. People may be exposed to these sediments during recreational activities (e.g., beachcombing); exposure while swimming or wading is not expected to be significant, since the sediment is washed off by the overlying water. Aquatic plants as well as aquatic- or riparian-feeding birds and mammals may be exposed to these sediments in shallow water along the shoreline. Benthic fish and invertebrates may be exposed to these shallow sediments when the reservoir is at the summer pool level.

A systematic visual survey of the banks of the river system is currently being planned under the time-critical actions. The survey will check for visual evidence of ash when the reservoir is at winter pool level. The spatial extent of any visually distinct ash will be estimated and mapped.

To estimate the potential intake of ash-related constituents in the seasonally-exposed sediment by human or ecological receptors, the concentrations of those constituents needs to be determined. Those concentrations will then be compared to screening criteria (DQO action levels); if the concentration of an analyte exceeds its action level, then the analyte would be retained for inclusion in a detailed risk assessment. For human health screening, EPA regional screening levels (RSLs) for soil will be used for seasonally-exposed sediment. For ecological receptors, EPA Region 4 sediment screening values will be used.

Samples of seasonally-exposed sediment will be collected using hand-auger methods during winter pool months (or by vibracore or Ogeechee™ sampling devices if samples are taken during summer pool months). In general, samples will be taken randomly along each shoreline (right and left bank), regardless of particle make-up (ash/native sediment proportion), because the purpose of this sampling is to estimate total residual risk. Sample locations may be adjusted based on results of the visual survey to bias the sampling towards depositional areas or visible ash and thereby result in conservative estimates of risk for both human and ecological receptors. The study boundaries are areas impacted by the ash spill, upstream to downstream. Exposures would occur in the upper 6 inches of seasonally-exposed or shallow sediment; therefore, the depth of sampling will be the upper 6 inches. A total of 69 samples will be collected. Sample locations planned within different sections or reaches of the river system are detailed in Section 3.

Samples will be visually described, particularly visual presence of ash and thickness or any depositional layering. Photographs will be taken of each sample location. Field PLM estimates of percentage of ash will be made and recorded in the vibracore log. Confirmatory laboratory PLM estimates will be made on 10% of the total samples as quality control. Samples will be analyzed in an offsite analytical laboratory for metals.

Exposures to naturally-occurring radionuclides at activities near background levels of radioactivity may pose risk to humans or ecological receptors as a result of direct exposure to the exposed sediments. Therefore, 25% of the grab samples (18 total) will also be analyzed for naturally-occurring radionuclides (potassium-40, radium-series, thorium-series, uranium-series), plus the U.S. Department of Energy (DOE) legacy radionuclides (cesium-137 and cobalt-60).

In order to estimate potential effects of legacy constituents, 25% of the grab samples (18 total) will also be analyzed for river-specific legacy constituents. Emory River legacy constituents are PAHs, PCBs, and pesticides. Clinch and Tennessee Rivers legacy constituents are mercury, PAHs, PCBs, cesium-137, and cobalt-60. Because mercury, cesium-137, and cobalt-60 are already included in the analysis above, the 25% Clinch River legacy samples will be analyzed only for PAHs and PCBs. Analyses for PAHs will determine concentrations of the 34 parent and alkylated PAHs specified in the EPA procedure for evaluating PAH mixtures in sediment (EPA 2009b). Because of their impact on constituent migration and/or toxicity, 25% of the samples (18 total) will also be analyzed for chemical speciation for arsenic, mercury, selenium, and chromium.

2.2.3 Submerged Sediment

Submerged sediment refers to the sediment that is below water year round. For human health risk evaluation, recreators would use the river system during summer pool months only, so there is no human exposure to continually submerged sediments. For ecological receptors, the BERA will use a weight-of-

evidence process to characterize the magnitude and likelihood of risk. The primary lines of evidence include: (1) constituent concentrations compared to sediment effects values, (2) laboratory bioassays, and (3) biosurveys of benthic and fish communities.

The first line of evidence for evaluating potential ecological risk involves determining the concentrations of ash-related constituents in the submerged sediment so that the potential exposures to ecological receptors can be estimated. Literature-derived sediment effects values for benthic invertebrates and for incidental ingestion by birds and mammals will be used for comparison with constituent concentrations in sediment. If the concentration of an analyte exceeds its effects value, then this may indicate potential risk.

Samples of submerged sediment will be collected concurrently with ash deposit samples. In general, samples will be selected randomly from among the ash deposit samples recovered regardless of particle make-up (ash/native sediment proportion), because the purpose of this sampling is to estimate total residual risk. However, sample locations may be adjusted based on results of the visual survey and field PLM estimates to bias the sampling towards depositional areas or where a higher percentage of ash is present in the sediment and thereby result in conservative estimates of risk for both human and ecological receptors.

The study boundaries are areas impacted by the ash spill, upstream to downstream. Ecological exposures would occur in the upper 6 inches of submerged sediment; therefore, the depth of sampling will be the upper 6 inches. A total of 81 submerged sediment samples will be selected from the ash deposit sampling. Sample locations planned within different sections or reaches of the river system are detailed in Section 3. Grab samples will be analyzed in an offsite analytical laboratory for metals.

Naturally-occurring radionuclides at activities near background levels of radioactivity pose few effects and therefore relatively low risk to ecological receptors as a result of direct exposure to submerged sediments. Therefore, 25% of the samples (20 total) will be analyzed for naturally-occurring radionuclides (K-40, radium-series, thorium-series, uranium-series) plus DOE legacy radionuclides (cesium-137 and cobalt-60) to assess that risk.

In order to estimate potential effects of legacy constituents, 25% of the samples will also be analyzed for river-specific legacy constituents. Emory River legacy constituents are PAHs, PCBs, and pesticides. Clinch and Tennessee Rivers legacy constituents are mercury, PAHs, PCBs, cesium-137, and cobalt-60. Because mercury, cesium-137, and cobalt-60 are already included in the analysis above, the 25% Clinch River legacy samples will be analyzed only for PAHs and PCBs. Analyses for PAHs will determine concentrations of the 34 parent and alkylated PAHs specified in the EPA procedure for evaluating PAH mixtures in sediment (EPA 2009b). Samples analyzed for PAHs, PCBs, or pesticides also will be analyzed for total organic carbon (TOC) so that equilibrium partitioning methods can be used to estimate ecological exposures. To evaluate their impact on constituent migration, bioavailablity, and/or toxicity, 25% of the samples (20 total) will also be analyzed for chemical speciation for arsenic, mercury, selenium, and chromium, and for acid volatile sulfides (AVS) and simultaneously extracted metals (SEM). These will be collected at the same locations as the bioassay samples discussed below.

The second line of evidence for evaluating potential ecological risk involves evaluating the results of laboratory bioassays (toxicity testing) in which benthic invertebrate and larval fish species are exposed to sediment samples in the laboratory and effects on their growth and survivability can be observed. The purpose of this testing is to estimate the bioavailability and risk relative to the presence of ash-related constituents. Reference bioassay tests are used as laboratory controls for comparison with toxic effects due to exposure to ash-related constituents. At the KIF site, reference locations upstream of the impacted area are problematic. The Emory River transitions from primarily riverine in the reference reach to

lacustrine in lower reaches. Above ERM 6.0, natural sediment tends to lack fine particles, so that metal adsorption may be different and benthic communities may be different than downstream areas within the Watts Bar Reservoir. Stream dynamics in the upstream Emory River are higher-velocity flows in response to precipitation, resulting in much coarser sand deposits than finer-grained silt deposits present in the lower-velocity backwaters of the reservoir. However, it is desirable to collect reference samples from the Emory River rather than other side streams, because inflowing surface water from areas further upstream may have legacy contaminants that would influence toxicity. Therefore, an attempt will be made to survey a range of reference locations to see where sufficient quantities of suitable reference sediment may be obtained.

Sediment samples for bioassay testing will be collected from eight representative sites within the Emory River and two reference locations upstream on the Emory River. Samples will also be collected from eight sites and two reference locations on the Clinch River, for a total of 20 samples for sediment bioassay testing. Samples will be collected of the upper 6 inches of sediment using Ponar sampling techniques. A minimum of three to five grab samples will be taken from each site and composited to create a test sample. Consistent with EPA guidance, composite sediment samples for bioassay testing will be characterized for: pH and ammonia of the porewater; organic carbon content (TOC); particle size distribution (percent sand, silt, clay); and percent water content. Overlying water used in test exposures will be monitored for hardness, alkalinity, conductivity, pH, and ammonia at the beginning and end of a test, and temperature and dissolved oxygen will be measured daily. Each composite sediment sample will also be analyzed for metals, naturally-occurring radionuclides, DOE legacy radionuclides, 34 parent and alkylated PAHs, PCBs, pesticides, AVS/SEM, TOC, and grain size, and speciation of arsenic, mercury, selenium, and chromium and for sequentially extracted metals.

Bioassay testing will be done using three indicator species and a combination of short-term chronic and longer duration tests. *Hyalella azteca* is a sensitive species that has been shown to be a good indicator of effects based on testing done to date. *Ceriodaphnia dubia* is a somewhat less sensitive species, but appears to also be less prone to interferences associated with the physical characteristics of the ash, so that effects may be more representative of chemical toxicity. Daphnids have been shown to feed at the sediment surface, thus coming in contact with particulate-bound toxicants, and a standard bioassay protocol is available to test this potential epibenthic exposure pathway. *Chironomus tentans* is a species of midge with larva that burrow in sediments and represent potential dietary and respiratory exposures to sediment and interstitial water. Bioassays will be conducted in accordance with EPA and American Society for Testing and Materials (ASTM) toxicity testing protocols; 10-day and 28-day tests will be conducted for *H. azteca*,10-day and approximately 28-day (emergence) tests for *C. tentans*, and 7-day tests for *C. dubia*.

The sediment testing strategy will use the results of 10-day screening tests along with preliminary analytical results to select representative sediment samples for use in the longer-term definitive tests (which involve sediment dilutions). The results from the screening tests will undergo hypothesis testing to determine significant differences in survival, growth or reproduction relative to the reference controls. The reference control sediment used in these tests will be a 50:50 composite of the two reference samples of each river.

For each river (i.e., the Emory River and the Clinch River) four samples will be used in definitive tests with the 28-day *H. azteca* and *C. tentans* protocols. Of these four samples from each river, at least one will be selected from among those for which significant effects were not observed in the short-term screening tests and up to three will be selected from among those for which there were significant effects observed in the screening tests. A dilution series will be run for each selected site sample using the composite reference sediment in order to estimate effects concentrations (e.g., LC50, IC25) for each sample.

Bioassay testing will also be performed using the same three indicator species on a sample of ash taken from the Swan Pond Embayment. Similar to the sediment samples, 10-day screening tests and longer-term definitive tests using laboratory-prepared dilution series of ash mixed with reference sediment will both be conducted. At the KIF site, simulating field sediment conditions is problematic. Layering of ash and natural sediment would produce a benthic habitat that would be different than a fully mixed sample. However, a relatively intact sample of the size required for bioassay testing cannot reasonably be collected or reconstructed. Therefore, the varying dilutions will be used, and the possible effects due to layering will be recognized as an uncertainty. The ash sample for bioassay testing will be analyzed for the same chemical parameters as the composite sediment samples.

The third line of evidence for evaluating potential ecological risk includes community surveys of benthic invertebrate and fish communities upstream and downstream in the Emory, Clinch, and Tennessee Rivers. These community surveys are discussed under the respective environmental medium.

2.2.4 Sediment Porewater

Sediment porewater refers to the interstitial water present between grains of sediment that is the primary source of exposure to aquatic plants and benthic invertebrates (particularly burrowing organisms) near the base of the food chain. The purpose of evaluating sediment porewater separately from whole sediment is to understand the factors involved in desorption of constituents from the ash/sediment and toxicity of the chemical constituents apart from any physical effects of ash on benthic growth. For evaluating risk to ecological receptors, a weight-of-evidence process will be used to characterize the magnitude and likelihood of risk. Lines of evidence include: (1) constituent concentrations compared to surface water effects values and (2) biosurveys of benthic communities.

The first line of evidence involves determining the concentrations of ash-related constituents in the sediment porewater so that the potential exposures for ecological receptors can be estimated. Literature-derived effects values for aquatic invertebrates will be used for comparison with measured constituent concentrations.

A total of 20 samples will be selected from the submerged sediment sampling locations, including two reference and eight site-related locations in both the Emory and Clinch Rivers. Sample locations planned within different sections or reaches of the river system are detailed in Section 3. Additional volumes of sediment will be collected at those locations so as to provide sufficient volume of porewater for testing. Porewater will be extracted from the sediment on shore prior to shipment to the offsite analytical laboratory. The use of in-situ porewater extraction devises, such as “peepers”, was considered, but considered impractical due to the long time needed for the devises to remain embedded in the sediment in the field and likelihood of damage or loss due to high flow conditions or vandalism. Samples will be filtered and analyzed for dissolved constituents only, including metals. Samples will also be tested for major ions (sulfides, chlorides, and hydroxides), hardness as calcium carbonate ($CaCO_3$), and dissolved organic carbon (DOC). Dissolved oxygen (DO), pH, oxidation-reduction potential (ORP), and specific conductivity (SC) will be measured in the laboratory after extraction of the porewater. Porewater samples will not be tested for PAHs, PCBs, pesticides, radionuclides, or chemical speciation due to practical limitations of collecting sufficient sample volumes and because bulk sediment and/or surface water analyses and organic carbon content can be used to estimate porewater concentrations of these constituents.

The second line of evidence involves benthic invertebrate community surveys upstream and downstream in the Emory, Clinch, and Tennessee Rivers. These community surveys are discussed below under the benthic invertebrates environmental medium.

2.2.5 Surface Water

Surface water refers to the conditions occurring in the river following completion of dredging. People may be exposed to surface water if they use the river system for recreation or as an untreated drinking water source. Aquatic biota are directly exposed to surface water, and birds and mammals that inhabit or forage in the river system may be exposed to surface water in their diet.

To estimate the potential intake of ash-related constituents in surface water by human or ecological receptors, the concentrations of those constituents need to be determined. Those concentrations will then be compared to screening criteria (DQO action levels); if the concentration of an analyte exceeds its action level, then the analyte would be retained for inclusion in a detailed risk assessment. For human health screening, EPA RSLs for residential tap water, Tennessee Drinking Water Standards or Federal Maximum Contaminant Levels, and Tennessee and Federal water quality criteria (WQC) for human consumption of water and organisms are potential DQO action levels to be used for surface water. For ecological receptors, EPA Region 4 screening values and Tennessee and Federal WQC for protection of aquatic life are potential DQO action levels to be used for surface water.

Samples of surface water will be collected at fixed station monitoring locations in the Emory, Clinch, and Tennessee Rivers. TVA has already established 10 fixed station monitoring locations; these locations will be adjusted to correlate with approximate locations of submerged sediment samples and of historical TVA fish health and bioaccumulation studies and to provide representative measurement of water quality evenly distributed across the study area. Sample locations planned within different sections or reaches of the river system are detailed in Section 3.

Surface water samples will be collected at two discrete depth intervals using a peristaltic pump. One sample will be collected at each location at mid-depth for use in evaluating human, pelagic fish, and wildlife exposures and a second sample will be collected approximately one-half meter (1.5 ft) above the bottom for use in evaluating epibenthic water for bottom-dwelling organisms. The 10 fixed station monitoring locations will be sampled once each week for 8 weeks to obtain sufficient quantity of data to demonstrate variability. A total of 160 samples will be taken.

The risk assessment will evaluate seasonal trends based on historical sampling. The uncertainties of seasonal variations will be acknowledged in the risk assessment.

Water-quality parameters (temperature, turbidity, DO, pH, ORP, and SC) will be measured in the field using a multi-analyte programmable data logger. If temperature and DO measurements indicate thermal stratification of the water column, then samples would be collected at mid-depth in the epilimnion, mid-depth in the hypolimnion, and of epibenthic water.

Samples will be analyzed in an offsite analytical laboratory for metals (total and dissolved). In addition, all samples will be analyzed for TSS, total dissolved solids (TDS), DOC, and hardness as $CaCO_3$.

Based on the risk assessments conducted for the Swan Pond Embayment/Dredge Cell EE/CA (Jacobs 2010), external exposure to gamma radiation is not a significant pathway of human exposure for surface water, particularly for the naturally-occurring radionuclides present at the KIF site near background levels of radioactivity. Therefore, 25% of the samples (40 total) will be analyzed for naturally-occurring radionuclides (K-40, radium-series, thorium-series, and uranium-series), and DOE legacy radionuclides cesium-137 and cobalt-60 to assess that risk. These samples may be biased to the area of the ash spill to maximize the likelihood of detection of these ash-related constituents.

The analysis of surface water for other legacy constituents is unlikely to provide useful information, because PAHs, PCBs, and pesticides have low water solubility and partition strongly to sediment particles, making detection in surface water unlikely. Submerged and seasonally-exposed sediments are being analyzed for these legacy constituents. Because of their impact on constituent migration and/or toxicity, 25% of the surface water samples (40 total) will also be analyzed for chemical speciation for arsenic, mercury, selenium, and chromium (dissolved metals analysis only). These will be collected at the same locations as the bioassay samples discussed below.

For ecological receptors, a weight-of-evidence process will be used to characterize the magnitude and likelihood of risk. Lines of evidence include: (1) constituent concentrations compared to surface water effects values, (2) laboratory bioassays, and (3) biosurveys of benthic and fish communities.

The first line of evidence for evaluating potential ecological risk involves determining the concentrations of ash-related constituents in the surface water so that the potential intake by ecological receptors can be estimated. Literature-derived effects values for aquatic plants and animals and for incidental ingestion by aquatic receptors, birds, and mammals will be used as action levels for comparison to constituent concentrations. Sampling previously described (10 fixed station monitoring locations, two discrete depths, weekly for 8 weeks) will be used to characterize surface water for ecological risk evaluation.

Seasonal and high-flow surface water conditions are not planned to be characterized further. Sufficient sampling has been completed for more than 12 months during the time-critical actions during dredging to assess these conditions. Unusual climatic conditions (e.g., drought) are not expected to significantly alter surface water quality and will be recognized as an uncertainty.

The second line of evidence for evaluating potential ecological risk involves evaluating the results of laboratory bioassays (toxicity testing). Surface water samples will be collected from five locations within the Emory River, one of which will be the upstream reference location. Bioassay testing will be done using two indicator species, *C. dubia* and *P. promelas*; testing using *H. azteca* (as planned for sediment bioassays) is not planned for surface water because *H. azteca* live primarily within the sediment, not in the water column. Surface water bioassay tests will be conducted in accordance with EPA toxicity testing protocols; 7-day tests will be conducted for both species, as prior testing has shown these durations to be sufficient to show whether effects occur. Only one round of bioassay testing is planned.

The third line of evidence for evaluating potential ecological risk involves fish community surveys upstream and downstream in the Emory, Clinch, and Tennessee Rivers. These community surveys are discussed in Section 2.2.8.

2.2.6 Groundwater

Groundwater refers to the predicted conditions in the shallow alluvial and residual soils where groundwater discharges to the river sediments. Because current conditions do not reflect long-term constituent flux to the river following closure of the Dredge Cell and Ash Pond, the concentrations of selected ash-related constituents in groundwater will be predicted based on modeled fate and transport simulations. Appendix C presents the planned analysis of groundwater transport of ash-related constituents to the Watts Bar Reservoir. Additional soil and groundwater sampling will be performed to support the proposed modeling; results of this modeling will be used in evaluating risk to human and ecological receptors in the reservoir exposed either to surface water or sediment porewater (Figure 3-12). The groundwater study design includes the following sources of information:

- Existing data will be used to the maximum extent possible. Existing data are available on the site stratigraphy, historical water levels, porosity, hydraulic conductivity, geochemical properties of alluvial and residual soils, and historical aqueous-phase concentrations of metals.

- Existing wells and piezometers will continue to be sampled so as to collect additional data on water levels, hydraulic conductivity, and aqueous-phase concentrations in groundwater. Existing wells include alluvium wells 6AR and 22; residuum wells AD1, AD2, and AD3; and bedrock well 13B. Existing piezometer/well points include 60 ash locations, 82 alluvium locations, and 8 bedrock locations.

- Three new permanent wells will be installed so as to collect data on upgradient stratigraphy, hydraulic conductivity, water levels, and aqueous-phase concentrations in alluvium, residuum, and bedrock groundwater. The permanent wells will include two upgradient bedrock wells and one upgradient residuum well on Pine Ridge. These wells will be drilled using 6-inch nominal diameter hollow-stem auger and air rotary drilling technologies. Well casings will consist of 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) well casings with 10-ft pre-slotted screens and threaded couplings. The annulus around the well screen will be backfilled with filter sand, a bentonite seal, and cement-bentonite grout to the ground surface. A 6-ft long, 6-inch-diameter protective steel casing will be placed around the well casing, extending 3 ft above the ground surface. A steel cap and padlock will be used to secure the well. Four 3-inch-diameter steel bollards will be installed around each well for protection of the wellhead.

- Seven new temporary well points will be installed within the Dredge Cell, Ash Pond, Stilling Pond, and Ash Processing Area (Ball Field) so as to collect additional data on hydraulic conductivity, ash and soil contaminant attenuation capacity, and aqueous-phase concentrations in alluvium, and bedrock groundwater. These temporary well points will be installed using hollow-stem auger drilling methods. Temporary well point casings will be 2-inch-diameter Schedule 40 PVC with prefabricated slotted screens and threaded couplings. Temporary well points will be closed after field testing in accordance TDEC Rule 1200-4-9.16.

- Fifteen new temporary boreholes will also be installed within the Dredge Cell, Ash Pond, Stilling Pond, and Ash Processing Area so as to collect additional data on soil contaminant attenuation capacity, and aqueous-phase concentrations in groundwater in contact with the ash and in the alluvium. These boreholes will be installed using either hollow-stem auger or direct push technology (Geoprobe®) techniques. The boreholes will be closed after field testing in accordance with TDEC Rule 1200-4-9.16.

Stratigraphy. Stratigraphic data will be used to define the three-dimensional overburden lithology, thickness, and top of bedrock elevation within the groundwater model domain. The stratigraphy of the ash deposits, alluvium, residuum, and bedrock will be characterized using existing information from approximately 175 borings in the vicinity. The additional boreholes completed for the new upgradient wells on Pine Ridge or within the Dredge Cell and Ash Processing Area will be also used to characterize stratigraphy from the ground surface at least down to the top of bedrock.

Water-Level Measurements. Water-level measurements will be used to calibrate the groundwater flow model to the current local head field using recent snapshots of water levels in wells, piezometers, and surface water reference points. Water-level measurements will be taken at four onsite surface water locations; 60 coal ash locations; 88 locations within the clay-silt and sand alluvium; four locations within the residuum; and 14 locations within bedrock. Two site-wide temporal snapshots of water levels will be conducted: once during the higher precipitation period (February to April) and once during the lower precipitation period (August to September) to encompass the range of expected water levels. Surface

water elevations and flows within the river at the time of water level sampling will be obtained from TVA River Operations for comparison with site measurements (direct measurements are not required in the river).

Water-level measurements in paired piezometers that are screened separately in bedrock and alluvial aquifers will be used to quantify the natural upward gradient expected from bedrock to alluvium and to determine the direction and magnitude of the vertical gradient. Hydraulic heads will be measured in five pairs of existing piezometers and three pairs of new temporary well points. Pressure transducers with data recorders will be installed in each well to allow continuous measurement of hydraulic heads for at least one month. Frequency of monitoring thereafter will depend on initial monitoring results.

Porosity and Density. Porosity data will be used to develop and calibrate the hydrologic flow model. The porosity of the various hydrostratigraphic units will be measured using relatively undisturbed thin-walled Shelby tube sampling of soil. Samples of residuum will be collected from the two new upgradient well boreholes; samples of alluvium (both clay-silt and sand facies) will be collected from five of the temporary well point and two Geoprobe® boreholes located inside the Dredge Cell/Ash Pond for dry bulk density, total porosity, effective porosity, and moisture content.

Hydraulic Conductivity. Hydraulic conductivity data will be used to develop and calibrate the hydrologic flow model. The horizontal and vertical components of hydraulic conductivity (K_h and K_v) will be characterized for the hydrostratigraphic units represented in the model, with emphasis on K_h measurements since horizontal seepage is expected to be the dominant mode of contaminant transport. Borehole flow metering tests for measurement of K_h will be conducted in three of the temporary well points located inside the Dredge Cell/Ash Pond within the alluvium (both clay-silt and sand facies). Aquifer (slug) tests for measurement of K_h will be performed at existing residuum wells (AD1 and AD2), the new upgradient residuum well (GW-02), existing alluvium wells 6AR and 22, and a new temporary well point in alluvium (TWP-22). In addition, one relatively undisturbed Shelby tube sample will be collected from the new upgradient residuum well borehole (GW-02) for laboratory analysis of K_v. Depending on well yield, either single-well aquifer pumping tests or slug tests will be performed in the two upgradient bedrock wells and three new temporary well points for measurement of bedrock hydraulic conductivity.

Column Leaching Tests. Sequential batch extractions and/or column leaching tests will be performed on ash composite samples to establish relationships between concentration and leaching pore volumes for each modeled ash-related constituent. A total of eight ash composite samples will be collected using plastic-lined split-barrel samplers; six of the ash samples will be collected within the Dredge Cell/Ash Pond area; the remaining two ash samples will be collected from the Ash Processing Area. Samples will be composited vertically from within the same borehole so as to obtain sufficient volume of sample for analysis. Results of the leaching tests will be used to quantify concentration variations in groundwater as a function of leaching (expressed in pore volumes).

Geochemical Analysis. Soil geochemical parameters controlling adsorption, ion exchange, and solubility will be used to simulate natural attenuation of the modeled ash-related constituents during groundwater transport. Both historical and new measurements of soil geochemical parameters will be used to characterize the attenuative capacity of the alluvial and residual soils. Site-specific geochemical data are currently available for three alluvial clay-silt samples, two alluvial sand samples, and two residual soil samples. Nine additional soil samples will be collected from the Dredge Cell/Ash Pond area: four samples of alluvial clay-silt and five samples of alluvial sand. Samples will be analyzed for mineral composition, free iron oxide, cation exchange capacity, exchangeable cations, calcite equivalent, soluble salts, and soil pH.

Constituent Concentrations in Groundwater in Contact with the Ash. Concentrations in the groundwater that is in contact with the ash will be used to define initial conditions within the transport model. The aqueous phase constituent concentrations/radioactivities will be characterized by collecting samples of groundwater from 18 new boreholes or Geoprobe holes completed in coal ash deposits. Three of those boreholes will be subsequently completed as temporary well points in the underlying alluvium. Samples will be collected using low-flow sampling techniques in accordance with TVA's Standard Operating Procedure (SOP) TVA-KIF-SOP-02 *Groundwater Sampling*; samples will be filtered in-line and analyzed for dissolved metals, including mercury, radionuclides, major and minor ions, ammonia-N, TSS and TDS, and field parameters. Major and minor ions include chloride, fluoride, sulfate, and nitrate-nitrite. Field parameters include pH, ORP, DO, SC, and temperature.

Constituent Concentrations in Groundwater. Aqueous phase concentrations/radioactivities in alluvial, residual, and bedrock aquifers through which the groundwater migrates will be used as initial transport model conditions. A minimum of 19 groundwater samples will be collected from the six existing wells, three new wells, seven selected temporary well points, and three Geoprobe® holes. Samples will be filtered in-line and analyzed for dissolved metals, including mercury, radionuclides, major and minor ions, ammonia-N, TSS and TDS, and field parameters.

2.2.7 Benthic Invertebrates

Benthic invertebrates refer to the organisms without backbones that live in the sediment on the bottom of the river. These benthic invertebrates include crustaceans (e.g., crayfish and amphipods), mussels, clams, snails, aquatic worms, and the immature forms of aquatic insects such as mayfly nymphs and non-biting midges. Because they inhabit the sediment and are relatively sedentary, benthic invertebrates are highly exposed to constituents in the sediment and porewater, and are therefore indicators of environmental quality. This is particularly relevant for this site, because the released ash was deposited on the river bottom. Concentrations of ash-related constituents may bioaccumulate in benthic invertebrates over time. In addition, because they are at the base of the food chain, benthic invertebrates and their emergent adult life stages are prey for other ecological receptors. The birds, mammals, or fish that feed on benthic invertebrates or emergent insects are, therefore, the ecological receptor populations of interest for bioaccumulative constituents.

For evaluating the magnitude and likelihood of risk to ecological receptors through food web exposures, constituent concentrations in benthic invertebrates and emergent insects will be determined. Dietary exposure estimates will be modeled based on measured concentrations in prey, and the modeled estimates will be compared with literature-derived effects values for birds and mammals. Constituent concentrations in larval mayflies (*Hexagenia bilineata*) and aquatic snails (*Pleurocera canaliculatum*) will provide supplementary evidence of bioavailability and uptake into the food web. Measured concentrations in larval mayflies and aquatic snails will be used in dietary exposure models for birds and mammals that consume benthic invertebrates. Measured concentrations in emergent mayflies will provide direct concentrations in prey for birds and bats that consume flying insects.

Samples of benthic invertebrates (snails and larval mayflies) for chemical analysis will be collected at seven locations: one reference location upstream in each of the Emory and Clinch Rivers; three locations within the impacted reaches of the Emory River; and two locations within the impacted reaches of the Clinch River. Because emergence of adult *Hexagenia* is unpredictable and sporadic, collections will be made opportunistically at the same approximate locations. Larval mayflies will be collected by taking multiple Ponar/Peterson grabs of sediment and selectively removing the organisms. Adult mayflies will be collected using a combination of methods such as direct removal with forceps from vegetation along the shoreline, sweep nets, and possibly light traps as needed. Snails will be collected by hand from shallow rocky or stable wooden structures near the shoreline. Individual samples will be composited by

species. At least two composite samples each of snails and larval mayflies will be collected at each location , one of which will be depurated (i.e., evacuation of their digestive systems), before analysis. Emergent mayflies do not feed and do not need to be depurated. A total of three composite samples will be collected within each reach, dependent on availability of organisms, to evaluate variability at that location.

Snails and both life stages of mayflies will be analyzed for whole body metals. Results will be reported on a wet weight basis. Benthic invertebrate samples will not be tested for PAHs, PCBs, pesticides, radionuclides, or chemical speciation due to practical limitations of collecting sufficient sample volumes and because bulk sediment and/or surface water analyses can be used to estimate concentrations of these constituents in the food web.

Biosurveys of benthic communities will be conducted to evaluate the magnitude and likelihood of risk to ecological receptors through exposure to sediment and sediment porewater. TVA conducts such surveys on a rotating basis at reservoirs throughout the TVA system, including locations within the Clinch and Tennessee Rivers. In 2009, TVA initiated a supplementary biosurvey program focused on the river system in the vicinity of the fly ash release. This included benthic community sampling at six cross-channel transects in the Emory River (at approximately one-mile intervals), one of which is an upstream reference location. The locations will remain the same for 2010 sampling. The 2009 surveys also included six locations on the Clinch River (including one upstream reference) and two on the Tennessee River (including one upstream reference). Fall 2010 sampling will retain at least five locations in the Clinch River (including one upstream reference). Similarly, three locations in the Tennessee River (including one upstream reference) will be surveyed. For correlation between environmental media, submerged sediment and porewater samples will be collected at locations approximating those for which biota survey transects are collected. Standard habitat characterization data (e.g., water depth and substrate type) will be collected for each site and reference survey location.

Samples for biosurveys of benthic communities will be collected with Ponar/Peterson grab samplers at each of 10 locations across each transect. The sample substrate will be characterized in the field. Each sample will be analyzed in the laboratory for taxonomic identification and enumeration of benthic invertebrates, with results reported for taxa abundance, richness and diversity as indicators of environmental quality.

2.2.8 Fish

Fish communities of interest include both pelagic (open-water or “top-feeding”) and benthic (bottom-dwelling or “bottom-feeding”) communities. Concentrations of ash-related constituents may bioaccumulate in fish over time. In addition, fish are a food source for human recreators who consume fish and for the aquatic- or riparian-feeding piscivorous wildlife; that is, the birds and mammals that feed primarily on fish. To estimate the potential ingestion of ash-related constituents in fish by human or ecological receptors, the concentrations of those constituents need to be determined. For the human health risk assessment, preliminary remediation goals for fish consumption will be used as DQO action levels for comparison to constituent concentrations; if the concentration of an analyte exceeds its action level, then the analyte would be retained for inclusion in a detailed risk assessment. These data will then be used in the human health risk assessment to estimate potential dietary exposures for people who might eat fish from the river system. For the BERA, dietary exposure estimates will be modeled based on measured concentrations in fish, and the modeled estimates will be compared to literature-derived effects values for ingestion by birds and mammals. Concentrations of bioaccumulative constituents in fish also will be used to estimate potential exposures of and effects on fish populations, to the extent feasible. Fish body burden concentrations will be compared with similar literature-derived effects values, which are of limited availability for most constituents and may only provide secondary evidence of risks to fish.

TVA has been conducting bioaccumulation studies of largemouth bass, bluegill, and channel catfish since the fly ash spill occurred; gizzard shad were added in fall 2009. These studies will continue during the spring and fall of 2010. Although historical sampling has been primarily of fish filet (tissue samples), future sampling will determine whole body concentrations through reconstruction of filet and non-filet portions, with gut contents removed. Filet data will be used for evaluation of human health risk, whereas whole body reconstruction data will be used for evaluation of ecological risk.

Samples will be collected from four locations (including one upstream reference location) in the Emory River and from three locations (including one upstream reference location) in the Clinch River. Samples will be collected using a combination of electroshock, gill netting, or other methods as required for obtaining sufficient sample volume for analysis. Samples will be collected of three separate fish species (largemouth bass, bluegill, and channel catfish), which are representative of both pelagic and benthic fish communities. Samples will be collected once. Therefore, a total of up to 21 fish samples will be collected; up to six replicates may be collected of each species at each sample reach location to measure variability within the reach.

Both filet and non-filet portions of each sample (largemouth bass, bluegill, channel catfish) will be analyzed for metals and speciation for arsenic. To the extent that sample volume allows, 25% of the samples will also be analyzed for PCBs, and pesticides as legacy contaminants in the river system. Samples will not be analyzed for PAHs, because PAHs are readily metabolized and excreted. For filet portions only, 25% of the samples will be analyzed for radionuclides. Results will be reported on a wet weight basis; percent moisture and percent lipids also will be determined for each sample.

Samples of gizzard shad and threadfin shad will also be collected, to evaluate food web exposures. Gizzard shad feed on algae, whereas threadfin shad feed on periphyton. Samples will be collected from the same seven locations as the other fish species. Because of their small size, up to 10 individual fish will be composited into a single sample; up to three composite samples will be collected at each location. Samples will be analyzed for a whole fish only (with gut contents removed), no filet data are needed, as shad are not eaten by humans. Shad samples will be analyzed for metals with speciation for arsenic; approximately 25% of the samples will be analyzed for PCBs and pesticides as legacy contaminants in the river system that may bioaccumulate.

Biosurveys of the fish community will be conducted for comparisons with historical surveys. A total of three reaches will be surveyed in the Emory and Clinch Rivers. Comparison to reference conditions will be developed based on comparison to historic biosurveys conducted within the impacted reaches before the ash spill and assessments conducted Valley-wide; therefore, no additional reference biosurveys are needed. The community biosurvey will collect fish from a variety of habitat types based on their proportions in the study area to provide a representation of community structure and function. Standard aquatic and riparian habitat characteristics will be collected for each site and reference survey location. Fish collected will be identified as to species and enumerated, with results reported for species abundance, richness, diversity, age-class structure, and physical condition (anomalies).

2.2.9 Wildlife

Wildlife communities of interest include the aquatic- and riparian-feeding birds and mammals that inhabit or forage along the river system. Concentrations of ash-related constituents may bioaccumulate in wildlife over time and adversely affect wildlife populations. In addition, some wildlife are a food source for higher-level predators. To estimate the potential ingestion of ash-related constituents in wildlife by ecological receptors, the concentrations of those constituents need to be determined. The BERA (Appendix B) will use a weight-of-evidence process to characterize the magnitude and likelihood of risk to carnivorous wildlife. Risks to birds and mammals will be primarily based on modeled dietary exposure

estimates from measured concentrations in their prey and literature-derived effects values for ingestion by birds and mammals, such as no-observed-adverse-effects levels (NOAELs), lowest-observed-adverse-effects levels (LOAELs), and toxicity reference values (TRVs). Concentrations of bioaccumulative constituents in wildlife also will be used to estimate potential exposures of, and effects on, bird and mammal populations, to the extent feasible. These data may provide only secondary evidence of exposure, due to the limited availability of comparable effects values for most constituents. A recognized uncertainty is that because bioaccumulation in upper-level predators occurs over years, the trophic transfer process may take years before maximum exposures are reached at the site.

Samples are being collected of various types of wildlife for chemical analysis to estimate biouptake and/or bioaccumulation of constituents from their diet or other exposure pathways, as well as to model biouptake in their respective predators. TVA has collected blood, organ (liver/kidney), and/or whole body samples of mammals (raccoons), reptiles (turtles), and amphibians (frogs). These collections are expected to continue in the future for purposes other than the BERA. To the extent feasible, concentrations measured in wildlife will be compared with body burden effects values from the scientific literature, which are of limited availability for most constituents and species. Therefore, body burden concentrations may be only secondary evidence of wildlife exposure. Whole body concentrations in amphibians may also be used to estimate a portion of the dietary exposures to predators. However, because these data provide only secondary evidence, historical sampling is sufficient to support the risk assessment; further sampling of mammals, reptiles, and amphibians is not included in this SAP.

Concentrations in bird eggs and nestlings are biomarkers of exposure to constituents. Effects of exposure to some constituents by avian receptors have been described in scientific literature. Egg and/or nestling samples will be collected from aquatic- or riparian-feeding piscivorous birds (herons) and aerial-feeding insectivorous birds (tree swallows). Egg contents (excluding shells) or nestlings will be analyzed for metals. Results will be reported on a wet weight basis. Wildlife surveys also will report clutch size, hatching success, and physical condition (abnormalities) of nestlings.

Osprey are present within the river system near KIF. Osprey are charismatic wildlife of special interest to the general public and may be surveyed or sampled by TVA for purposes other than the BERA. If constituent concentration data for osprey eggs or nestlings are available, they will be used as a secondary line of evidence of exposure and, to the extent feasible, effects. However, they will not be specifically sampled for the BERA due to the limited number of nests and eggs available in the study area.

Heron and tree swallow sampling locations will be consistent with TVA sampling conducted to date. At least one reference location will be sampled upstream of the impacted reaches of either the Emory or Clinch River, where suitable habitat and individual animals can be found and collected. Varying numbers of samples will be collected from the downstream impacted reaches, depending again on presence of habitat and individual animals. Standard habitat characterization will be collected in the vicinity of each site and reference sampling location. No more than ten heron samples are planned to be taken from any given rookery site. A minimum of ten tree swallow samples are planned to be collected from each site. The planned numbers of sites from which samples will be collected are as follows:

- Insectivorous bird (tree swallow) egg/nestling samples: seven sites, including two reference sites.
- Piscivorous bird (heron) egg/nestling samples: three sites, including one reference site.

2.2.10 Aquatic Vegetation

Aquatic vegetation refers to plants that live in direct contact with sediment and/or surface water at least part of the year. These aquatic plants include macrophytes, algae, and periphyton. Macrophytes are vascular aquatic plants that may be emergent (e.g., cattails, rushes, and sedges), submergent (e.g., elodea

and milfoil), or floating (e.g., duckweed). Algae are non-vascular plants that may be single celled, multi-cellular, or filamentous. Periphyton refers to the complex of algae, bacteria, and detritus attached to submerged surfaces. Periphyton and algae account for a significant portion of primary productivity in many freshwater systems and are an important food source for various species of benthic invertebrates, amphibians, fish, birds, and mammals. Emergent and floating macrophytes can comprise a large portion of the diets of waterfowl and herbivorous mammals that feed in aquatic systems. Rooted macrophytes are in direct contact with sediment, porewater, and surface water. Epibenthic algae and periphyton may also be in contact with sediment and porewater, in addition to surface water. As such aquatic plants may be an important pathway for the trophic transfer of constituents in water and sediment to aquatic biota and wildlife feeding in aquatic habitats.

For evaluating the magnitude and likelihood of risk to ecological receptors through food web exposures, constituent concentrations in aquatic plants will be determined. Birds and mammals that feed on macrophytes (e.g., ducks and muskrats) often forage in shallow water and along the shoreline. Therefore, macrophyte sampling will focus on emergent vegetation located near shore. Isolated beds of emergent macrophytes have been observed in some areas targeted for seasonally exposed sediment sampling. Isolated patches of rushes, sedges, and cattails also have been observed at the summer pool waterline in some parts of the river system. Measured constituent concentrations in these plants will be used as direct inputs for dietary exposure models for herbivorous and omnivorous wildlife. When available, concentrations in water and sediment from the vicinity of the emergent plant sample sites also will be used to evaluate potential bioavailability.

For evaluating bioavailability and the potential for trophic transfer of metals, constituent concentrations in periphyton will be determined. Periphyton occur most densely in areas where ample sunlight is able reach the substrate. This is also where the aquatic snails being sampled for this project tend to be located, because periphyton are a primary food item for these and other grazers. Therefore, locations selected for collection of aquatic snails also will be sampled for periphyton once during the growing season.

Samples of emergent vegetation from along the summer pool shoreline will be collected for chemical analysis at three locations in each reach of the Emory, Clinch, and Tennessee Rivers. Samples of emergent vegetation from below the summer pool shoreline also will be collected for chemical analysis at three locations in each reach of the Emory, Clinch, and Tennessee Rivers. These will be co-located with samples of seasonally exposed sediments, to the extent practical. Leaves and stems of emergent plants will be collected from above the ground or water surface. Samples of periphyton grown on artificial substrates will be collected for chemical analysis at each of the benthic invertebrate (snails) sampling locations. Three periphyton samples will be collected at each location and composited into one sample.

Aquatic vegetation samples will be analyzed for metals and percent moisture. Results will be reported on a wet weight basis. Aquatic plants will not be tested for PAHs, PCBs, pesticides, radionuclides, or chemical speciation, because hydrophobic constituents are not expected to accumulate in plant material and due to the large quantity of material required for radionuclides and chemical speciation.

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3. SAMPLE LOCATION AND FREQUENCY

This section presents the sample location and frequency in accordance with the optimized study design. The study design has established planned sample locations and frequency within different sections or reaches of the river system; those reaches are shown on Figure 3-1. The sampling frequency will be greater in those reaches where ash deposition from the spill was greatest and will decrease upstream and downstream of those reaches. The following sections describe the sample location and frequency by environmental medium. Appendix D summarizes the environmental medium, number of samples, analyses or measurements to be taken, analytical protocols, hold times, preservation methods, and containers.

3.1 ASH DEPOSITS

Ash deposit sample locations planned within different sections or reaches of the river system are shown on Figures 3-2 through 3-9. Some ash deposit locations may be adjusted to coincide with historical locations to aid in evaluating trends in sediment transport. Planned locations are summarized below:

- Reference locations upstream of ERM 6.0 (Figure 3-2): Ten locations selected at random, are planned in the Emory River and/or Little Emory River to verify the absence of ash deposits. Efforts will be made to target areas where sediment deposition is likely. Similarly, three locations are planned in the Clinch River upstream of CRM 4.5 and three locations are planned in the Tennessee River upstream of TRM 568.0 in conjunction with submerged sediment sampling.

- Emory Reach C (ERM 3.5 to 6.0) (Figure 3-3): This reach consists of impacted locations upstream of the primary dredging operations. Thirty locations (four per mile, left-center-right of channel) are planned to verify that no deposits exceeding 1 ft in thickness are present. Additional samples targeting the larger coves outside of the main river channel are also planned.

- Emory Reach B (ERM 1.5 to 3.5) (Figure 3-4): This reach consists of sections of the channel that have been dredged in a series of “grids” during the time-critical removal action. Because dredging is being done in a detailed grid layout that results in “terraced” remnants of the river bottom, 16 dredge grid sections will be selected for confirmation sampling and two samples taken from each grid so as to check the terraced remnants. Thirty-two locations (eight per mile, two samples at each dredge grid location) are planned to verify that no deposits remain after dredging has been completed.

  Sections outside of the dredged channel will also be sampled to verify that deposits outside of the regular channel dredging have been sufficiently removed during time-critical dredging activities. Thirty-two locations (approximately eight per mile, left and right of the channel, are planned.

- Intake channel (Figure 3-5): five random locations, similar to non-channel sections above.

- Emory Reach A (ERM 0.0 to 1.5) (Figure 3-6): This reach consists of impacted locations downstream of the primary dredging operations in the Emory River. Thirty-six locations (eight per mile, left-center-right of channel) are planned. Additional samples targeting the larger coves outside of the main channel are also planned.

- Clinch Reach B (CRM 3.0 to 4.5) (Figure 3-7): This reach consists of impacted locations downstream of the primary dredging operations in the Clinch River, yet upstream of the KIF plant discharge. Thirty-six locations (eight per mile, left-center-right of channel) are planned. Additional samples targeting the larger coves outside of the main channel are also planned.

- Clinch Reach A (CRM 0.0 to 3.0) (Figure 3-8): This reach also consists of impacted locations downstream of the dredging operations in the Clinch River, yet downstream of the KIF plant discharge. Thirty-six locations (four per mile, left-center-right of channel) are planned. Additional samples targeting the larger coves outside of the main channel are also planned.

- Tennessee Reach B (TRM 550.0 to 566.0) (Figure 3-9): This reach consists of potentially impacted locations in the Tennessee River, downstream of the confluence with the Clinch River. Twelve locations will be sampled from TRM 566.0 to 568.0 (two per mile, left-center-right of channel).

- Tennessee Reach A (TRM 550.0 to 565.0) (Figure 3-10). This reach consists of downstream Tennessee River locations where deposition of ash from storm event transport is predicted to occur. Three samples will be taken at 5-mile increments (from TRM 550.0 to 565 (center channel, left, and right of channel at approximately TRM 550, 555, 560, and 565) to validate the model results.

- Contingency: Twenty samples are planned targeting larger coves outside of the main river channel or as additional contingency to define anomalies.

3.2 SEASONALLY-EXPOSED SEDIMENT

Sample locations are planned within the same reaches of the river system as described for the ash deposit sampling, but along the banks of the rivers. Locations are shown on Figures 3-2 through 3-8, and summarized below:

- Reference locations upstream of ERM 6.0 (Figure 3-2): A total of five reference locations are planned in the Emory River and/or Little Emory River for use in comparing with downstream levels of constituents. No reference locations are planned in either the Clinch or Tennessee Rivers.

- Emory Reach C (ERM 3.5 to 6.0) (Figure 3-3): Sampling of the upstream impacted reach is planned at 10 locations (four per mile, alternating left-right of channel).

- Emory Reach B (ERM 1.5 to 3.5) (Figure 3-4): Sampling of the non-channel dredged reach is planned at 16 locations (eight per mile, alternating left -right of channel).

- Intake channel (Figure 3-5): two random locations.

- Emory Reach A (ERM 0.0 to 1.5) (Figure 3-6): Sampling of the downstream impacted reach is planned at 12 locations (eight per mile, alternating left-center-right of channel).

- Clinch Reach B (CRM 3.0 to 4.5) (Figure 3-7): Sampling of the downstream reach prior to the plant discharge is planned at 12 locations (eight per mile, alternating left-right of channel).

- Clinch Reach A (CRM 0.0 to 3.0) (Figure 3-8): Sampling of the downstream reach after the plant discharge is planned at 12 locations (four per mile, alternating left-right of channel).

3.3 SUBMERGED SEDIMENT

Sample locations are planned within the same reaches of the river system as described for the ash deposit sampling. Samples collected for analysis of TOC must be co-located with samples collected for analysis of PAHs, PCBs, or pesticides. The ash deposit samples that will be selected for chemical analysis of constituent concentrations in the submerged sediment are shown on Figures 3-2 through 3-9, and summarized below:

- Reference locations (Figure 3-2); A total of nine reference locations are planned for sampling, for use in comparing with downstream levels of constituents. Three locations are planned in the Emory River upstream of ERM 6.0 and/or Little Emory River; similarly three locations are planned in the Clinch River upstream of CRM 4.5 and three locations are planned in the Tennessee River upstream of TRM 568.0.

- Emory Reach C (ERM 3.5 to 6.0) (Figure 3-3): Sampling of the upstream impacted reach is planned at 10 locations (four per mile).

- Emory Reach B (ERM 1.5 to 3.5) (Figure 3-4): Sampling of the primary dredged reach is planned at 16 locations (eight per mile).

- Intake channel (Figure 3-5): A total of two random locations are planned.

- Emory Reach A (ERM 0.0 to 1.5) (Figure 3-6): Sampling of the downstream impacted reach is planned at 12 locations (eight per mile).

- Clinch Reach B (CRM 3.0 to 4.5) (Figure 3-7): Sampling of the downstream reach prior to the plant discharge is planned at 12 locations (eight per mile).

- Clinch Reach A (CRM 0.0 to 3.0) (Figure 3-8): Sampling of the downstream reach after the plant discharge is planned at 12 locations (four per mile).

- Tennessee Reach B (TRM 566.0 to 568.0) (Figure 3-9): Sampling within Tennessee Reach B is planned at four locations from TRM 566.0 to 568.0 (two per mile).

- Tennessee Reach A (TRM TRM 550.0 to 566.0) (Figure 3-10): Sampling within Tennessee Reach A is planned at four locations from TRM 550.0 to 565.0 (one per 5-mile increment at approximately TRM 550, 555, 560, and 565).

Sample locations for collecting sediment for bioassay testing are shown on Figure 3-11. Samples will be collected from two reference locations and eight downstream locations in each of the Emory and Clinch Rivers. Three to five grab samples will be collected at each location and composited to create a test sample. Note that 25% of all sediment samples will be analyzed for chemical speciation and AVS/SEM; it is planned to collect those sample aliquots at the same locations of the bioassay samples.

Samples will also be collected of ash and reference sediment for bioassay testing of gradational mixtures. One of the Emory River reference locations having sufficient deposition of sediment of gradation similar to downstream reaches will be used to collect the needed volume of reference sediment. The needed volume of ash will be collected from ash storage facilities or the Swan Pond Embayment, since ash will have been removed from the river as a result of time-critical removal actions.

3.4 SEDIMENT POREWATER

Sample locations for chemical analysis of constituent concentrations in sediment porewater are intended to be co-located with submerged sediment bioassay test samples. As such, samples will be collected from the same two reference locations and eight downstream locations in each of the Emory and Clinch Rivers. A minimum of three to five grab samples will be collected at each location and composited to create a test sample for extraction of sediment porewater in the laboratory (Figure 3-11).

3.5 SURFACE WATER

Sample locations planned for chemical analysis of constituent concentrations in surface water are shown on Figure 3-12, and summarized below:

- Upstream reference monitoring locations: A total of three reference locations are planned at ERM 8.0, CRM 6.0, and TRM 568.5. The locations of these fixed stations will be adjusted to correlate with approximate locations of reference sediment samples. Historical TVA fish health and bioaccumulation studies have established upstream reference ranges at roughly ERM 8.0 and CRM 6.0; therefore, it is planned to reset the fixed station monitoring to these locations.

- Within the Emory River, a total of four locations are planned at ERM 1.0, 2.0, 3.0, and 4.0. Currently, TVA has established four fixed station-monitoring locations at ERM 0.1, 1.75, 2.1, and 4.0, whereas fish studies are conducted at about ERM 0.9 and 2.0. It is planned to reset the four fixed stations to ERM 1.0, 2.0, 3.0, and 4.0 to provide representative measurement of water quality across the site. Locations will be adjusted to correlate with approximate locations of submerged sediment samples.

- Within the Clinch River, two locations are planned at CRM 2.0 and 3.5. Currently, TVA has established three fixed station monitoring locations at CRM 0.0, 2.0, and 4.0, whereas fish studies are conducted at about CRM 1.5. It is planned to reset the fixed stations to CRM 2.0 and 3.5 to provide a representative measurement of water quality across the Clinch River reaches; these locations will be adjusted to correlate with locations of submerged sediment samples.

- Within the Tennessee River, one location is planned (TRM 566.0). TVA has established a fixed station-monitoring location at TRM 563.5; it is planned to reset this location to TRM 566.0 and to correlate with locations of submerged sediment samples.

Sampling frequency planned for surface water sampling is once each week for eight weeks at each of the 10 monitoring locations. Note that 25% of the water samples will be analyzed for chemical speciation; five of those will be at the same locations of the bioassay testing.

3.6 GROUNDWATER AND AQUIFER TESTING

Locations of existing wells as well as proposed wells, temporary well points, and boreholes, are shown on Figure 3-13. Each monitoring location will be used for different groundwater sampling or aquifer testing purposes. Table 3-1 summarizes the monitoring locations and the specific sampling or testing to be performed at each location. Appendix C further defines the monitoring locations and the specific sampling or testing to be performed at each location.

In general, water levels will be measured in all existing and new monitoring locations where casings are in place. Sampling for groundwater quality will be conducted in the permanent wells, temporary well points and well borehole (Geoprobe®) locations. Other aquifer testing for characteristics such as porosity, hydraulic conductivity, column leaching and other geochemical parameters will be conducted only at selected monitoring locations as shown on Table 3-1.

Table 3-1. Summary of Locations for Groundwater Sampling and Aquifer Testing

Location No.	Type	Target Strata	Water Levels			Porosity and Density	Vertical Hydraulic Conductivity	Horizontal Hydraulic Conductivity			Column Leaching	Geochemical Analysis		Aqueous-phase Constituent Concentrations	
			Feb-Apr	Aug-Oct	Continuous			Alluvium	Residuum	Bedrock	Ash	Clay/Silt	Sand	In Contact with Ash	Groundwater
6AR	Well	Alluvium	X	X				X							X
13B	Well	Bedrock	X	X											X
22	Well	Alluvium	X	X				X							X
AD1	Well	Residuum	X	X					X						X
AD2	Well	Residuum	X	X					X						X
AD3	Well	Residuum	X	X											X
GW-01	Well	Bedrock	X	X		X (residuum)	X (residuum)			X					X
GW-02	Well	Residuum	X	X		X (residuum)	X (residuum)		X						X
GW-03	Well	Bedrock	X	X						X					X
TWP-04	Well Point	Alluvium	X	X	X	X (alluvium)		X			X	X	X	X	X
TWP-05	Well Point	Alluvium	X	X	X	X (alluvium)		X			X	X	X	X	X
TWP-06	Well Point	Alluvium	X	X	X	X (alluvium)		X			X	X	X	X	X
GP-07	Borehole	Ash									X			X	
GP-08	Borehole	Ash									X			X	
GP-09	Borehole	Ash/Alluvium												X	X
GP-10	Borehole	Ash												X	
GP-11	Borehole	Ash												X	
GP-12	Borehole	Ash/Alluvium									X			X	X
GP-13	Borehole	Ash												X	
GP-14	Borehole	Ash												X	
GP-15	Borehole	Ash/Alluvium									X			X	X
GP-16	Borehole	Ash/Alluvium				X (alluvium)					X	X	X	X	
GP-17	Borehole	Ash												X	
GP-18	Borehole	Ash												X	
GP-19	Borehole	Ash												X	
GP-20	Borehole	Ash												X	

Table 3-1. Summary of Locations for Groundwater Sampling and Aquifer Testing
(continued)

Location No.	Type	Target Strata	Water Levels			Porosity and Density	Vertical Hydraulic Conductivity	Horizontal Hydraulic Conductivity			Column Leaching	Geochemical Analysis		Aqueous-phase Constituent Concentrations	
			Feb-Apr	Aug-Oct	Continuous			Alluvium	Residuum	Bedrock	Ash	Clay/Silt	Sand	In Contact with Ash	Groundwater
GP-21	Borehole	Ash												X	
TWP-22	Well Point	Alluvium	X	X				X							X
GP-23	Borehole	Ash				X (alluvium)							X		
TWP-24	Well Point	Bedrock	X	X	X					X					X
TWP-25	Well Point	Bedrock	X	X	X					X					X
TWP-26	Well Point	Bedrock	X	X	X					X					X
	Piezometer		150*	150*	10**										

Notes:

* A total of 150 existing piezometers will be measured
** A total of 5 existing pairs of piezometers will be tested (see Appendix C)

Sampling frequency planned for aquifer testing and water quality sampling is once. Historical sampling in existing wells is sufficient for evaluating water quality trends. The frequency planned for water level measurements is twice, once in the winter when reservoir levels are low and precipitation is high (February to April), and once in the summer when reservoir levels are high and precipitation is normally low (August to October).

3.7 BENTHIC INVERTEBRATES

Sample locations for chemical analysis of constituent concentrations in benthic invertebrates (bioaccumulation) are shown on Figure 3-14, and summarized below:

- Reference locations: Samples will be collected from two reference locations for use in comparing with downstream levels of constituents. One reference location is planned in the Emory River near ERM 6.0, and one in the upstream Clinch River near CRM 6.0.

- Emory River (ERM 0.0 to 6.0): Samples will be collected from three locations within the impacted reaches of the Emory River. One representative sample will be collected from each river reach as follows: Emory Reach A (ERM 1.0), Emory Reach B (ERM 2.5), and Emory Reach C (ERM 4.0).

- Clinch River (CRM 0.0 to 4.5): Samples will be collected from two locations within the impacted reaches of the Clinch River. One representative sample will be collected from each river reach as follows: Clinch Reach A (CRM 1.5), and Clinch Reach B (CRM 3.5).

Transects for biosurveys of benthic invertebrate communities will be taken at roughly one-mile intervals, shown on Figure 3-13. At least one transect will be made within each reach of the river. Transects will therefore be located near ERM 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 (reference location); near CRM 0.5, 1.5, 3.0, 4.0, and 6.0 (reference location); and near TRM 560.8, 566.5, and 574.0 (reference locations).

3.8 FISH

Sample locations for both chemical analysis of constituent concentrations in fish and biosurveys of fish will be from similar river reaches as discussed for benthic invertebrates so that the data are from comparable locations. These locations are general locations, since it is recognized that fish will be collected from broader areas along a given reach where the fish can be found. Locations are shown on Figure 3-15, and summarized below:

<u>Fish Bioaccumulation</u>

- Reference locations: Two reference locations are planned for use in comparing with downstream levels of constituents. One location is planned in the upstream Emory River near ERM 8.0, and one in the upstream Clinch River near CRM 8.0.

- Emory River (ERM 0.0 to 6.0): Samples will be collected from three general locations, one within each of the impacted reaches of the Emory River as follows: Emory Reach A (ERM 1.0), Emory Reach B (ERM 2.5), and Emory Reach C (ERM 4.5).

- Clinch River (CRM 0.0 to 4.5): Samples will be collected from two general locations, one within each of the impacted reaches of the Clinch River as follows: Clinch Reach A (CRM 1.5), and Clinch Reach B (CRM 3.5).

Fish Community Biosurveys

- Reference locations: Comparison to reference conditions will be developed based on comparison to historical surveys conducted within the impacted reaches before the ash spill and assessments conducted Valley-wide. No further fish community biosurveys are planned at these reference locations.

- Emory River (ERM 1.5 to 3.5): Multiple collections will occur within the downstream impacted reach of the Emory (Emory Reach B), to be consistent with historical and ongoing fish community biosurveys.

- Confluence of the Emory and Clinch Rivers (ERM 0.0 to 1.0 and CRM 4.0 to 5.0): Multiple collections will occur at the confluence of Emory River Reach A and Clinch River Reach B, to be consistent with historical and ongoing fish community biosurveys.

- Clinch River (CRM 0.0 to 2.0): Multiple collections will occur within the downstream impacted reach of the Clinch River (Clinch Reach A) prior to its confluence with the Tennessee River, to be consistent with historical and ongoing fish community biosurveys.

3.9 WILDLIFE

Sample locations for chemical analysis of constituent concentrations in wildlife are dependent on the locations of actual colonies/rookeries present along the river. The site locations and/or number of sites will be adjusted depending on the presence of habitat and individual animals at the time of collection. Reference locations will be at sites located outside of impacted reaches of the Emory or Clinch Rivers. The planned locations based on historical presence of rookeries are shown in Figure 3-16. The planned locations and numbers of samples are summarized below:

- Insectivorous bird (tree swallow) egg/nestling samples: Two reference sites have been historically surveyed by TVA, one at Melton Hill Dam, and one at Fort Loudon Dam. Two nesting colonies are located within the impacted the river system, one is located near ERM 3.0, and one near CRM 2.5. Additional tree swallow colonies are being established by TVA researchers as part of ongoing natural resources management programs. These colonies are anticipated near ERM 2.5, CRM 1.0, and TRM 566.0. If additional tree swallow colonies are established by TVA researchers as part of ongoing natural resources management programs, then data collected from those colonies will be used in the risk assessment.

- Piscivorous bird (heron) egg/nestling samples: One reference site has been historically surveyed by TVA on the Tennessee River near TRM 569.5. Two nesting colonies are located within the impacted river system, one near ERM 3.0 and one near CRM 2.5. Additional heron colonies may be established by TVA researchers as part of ongoing natural resources management programs. If established, data collected from those colonies will be used in the risk assessment.

3.10 AQUATIC VEGETATION

Emergent macrophyte sample locations are planned to be co-located with seasonally-exposed sediment samples (Figure 3-17) along the banks of the rivers, to the extent practicable. Both types of emergent macrophytes, those rooted below the summer pool elevation and those rooted along the summer pool shoreline, will be collected at each location if they are present at the time of sampling.

- Reference locations upstream of ERM 6.0: Three locations (two samples, one of both plant types) selected from among those proposed for seasonally-exposed sediment sampling are planned in the Emory River and/or Little Emory River. Similarly, three locations (two samples, one of both plant types) are planned in the Clinch River upstream of CRM 4.5 and the Tennessee River upstream of TRM 568.0. The Clinch River and Tennessee River reference locations are planned to be along the shoreline adjacent to the proposed submerged sediment sampling locations, because seasonally-exposed sediments are not planned for this reach.

- Emory Reach C (ERM 3.5 to 6.0): This reach consists of impacted locations upstream of the primary dredging operations. Three locations (two samples, one of both plant types) selected from among those proposed for seasonally-exposed sediment sampling are planned for this reach.

- Emory Reach B (ERM 1.5 to 3.5): This reach includes sections of the channel that have been dredged during time-critical dredging activities and adjacent areas outside of the dredged channel. Three locations (two samples, one of both plant types) selected from among those proposed for seasonally-exposed sediment sampling are planned for this reach.

- Emory Reach A (ERM 0.0 to 1.5): This reach consists of impacted locations downstream of the primary dredging operations in the Emory River. Three locations (two samples, one of both plant types) selected from among those proposed for seasonally-exposed sediment sampling are planned for this reach.

- Clinch Reach B (CRM 3.0 to 4.5): This reach consists of impacted locations downstream of the primary dredging operations in the Clinch River, yet upstream of the KIF plant discharge. Three locations (two samples, one of both plant types) selected from among those proposed for seasonally-exposed sediment sampling are planned for this reach.

- Clinch Reach A (CRM 0.0 to 3.0): This reach also consists of impacted locations downstream of the dredging operations in the Clinch River, yet downstream of the KIF plant discharge. Three locations (two samples, one of both plant types) selected from among those proposed for seasonally-exposed sediment sampling are planned for this reach.

- Tennessee Reach A (TRM 566.0 to 568.0): This reach consists of potentially impacted locations in the Tennessee River, downstream of the confluence with the Clinch River. Three locations (two samples, one of both plant types) adjacent to submerged sediment sampling locations are planned for this reach.

Periphyton sample locations are planned to be co-located with samples of benthic invertebrates (Figure 3-14) for chemical analysis (bioaccumulation). Artificial substrates will be deployed in the vicinity of where aquatic snails are collected.

- Reference Locations: Samples will be collected from two reference locations for use in comparing with downstream levels of constituents. One reference location is planned in the Emory River near ERM 6.0, and one in the upstream Clinch River near CRM 6.0. Three samples for chemical analysis will be collected and composited into one sample at each location.

- Emory River (ERM 0.0 to 6.0): Samples will be collected from three locations of the Emory River (one location per each). One representative location will be sampled from each river reach as follows: Emory Reach A (ERM 1.0), Emory Reach B (ERM 2.5), and Emory Reach C (ERM 4.0). Three samples for chemical analysis will be collected and composited into one sample at each location.

- Clinch River (CRM 0.0 to 4.5): Samples will be collected from two locations within the impacted reaches of the Clinch River (one location per each) as follows: Clinch Reach A (CRM 1.5) and Clinch Reach B (CRM 3.5). Three samples for chemical analysis will be collected and composited into one sample at each location.

4. SAMPLE DESIGNATION

This section presents the sample management protocols associated with sample designation, custody, and labeling. Data management sample plans, chain-of-custody (CoC) forms, and sample container labels will be produced using EQuIS 5.0 or higher. EQuIS is the sample planning and data management program developed by Earthsoft, Inc., for which TVA has purchased user and license rights. Environmental Standards, Inc. maintains and manages the database and is responsible for the performance and troubleshooting problems with the system. Sample management will follow TVA-KIF-SOP-18 *Management and Implementation of EQuIS-Based Chain of Custody*.

Sample planning steps are required in EQuIS prior to field sampling. First, the Sample Manager will create a data management sample plan in EQuIS for each sampling task and laboratory. The data management sample plan will contain the specific laboratory information and the method analyte groups to be used for each sample matrix that will be collected. The Sample Manager will then create the CoCs, sample identification (ID) numbers for each sample associated with each CoC, and container labels for each sample. Details of each new sampling task will be communicated to the Sample Manager at least one week in advance of sampling so that the necessary data management sample plan(s) can be created in EQuIS.

4.1 SAMPLE CHAIN OF CUSTODY IDENTIFICATION

A unique date-referenced CoC identification number will be assigned to each CoC record generated during the course of the sampling program to facilitate data evaluation and preclude record duplication. The unique CoC identification number is limited to 15 characters or less and is structured as follows:

RSIZZMMDDYYYA, where

RSI = River System Investigation
ZZ = Matrix Code (Table 4-1)
MM = Month
DD = Day
YYY = Year (first Y remains a “Y” followed by last digits of year–Y10)
A = Alpha character designates an order of sequential CoC records for each sampling event

EQuIS-based CoC records will be created in the Sample Planning Module (SPM) of EQuIS Professional. The SPM User’s Manual is included as an attachment to TVA-KIF-SOP-18 for reference. A CoC form will then be generated by EQuIS.

Table 4-1. Sample Identification Codes

Biota Only: AA = Species Code		**Biota Only: B = Body Part Code**		**Biota Only: C = Sample Type Code**		**ZZ = Matrix Code**	
BG	Bluegill	C	Carcass (Non-Filet)	G	Grab (individual animal)	AV	Aquatic Vegetation
BH	Blue heron	E	Egg	C	Composite	BD	Bird
BN	Benthic species	F	Filet			CA	Cell Ash
BS	Bass	G	Whole Body (minus gut content)	**Biota Only: NN = Number Code**		FH	Fish
CC	Channel Catfish	N	Nestling	01	(Sequential Number)	GW	Groundwater
EV	Emergent Vegetation	W	Whole Body			LH	Leachate
FM	Fathead Minnow			02		MS	Mayflies, Snails
GZ	Gizzard shad			03		PORE	Porewater
MFA	Mayfly – Adult			04		RA	Released Ash
MFN	Mayfly - Nymph			05		SED	Sediment
PP	Periphyton					SL	Soil
SL	Snail					SW	Surface Water
TF	Threadfin shad						
TS	Tree swallow						

4.2 SAMPLE IDENTIFICATION

Each individual sample will be assigned a unique date-referenced sample ID, referred to as the "sys_sample_code" in EQuIS. The sample ID is limited to a maximum of 40 characters and is be structured as follows:

KIF-QQQ_(AA.B.C.NN)-ZZ-MMDDYY, where

KIF = Kingston Fossil Plant, or {facility_code} in EQuIS
QQQ = Location Code, or {sys_loc_code} in EQuIS
(AA.B.C.NN) = Biota Code (used for biota only) in EQuIS (Table 4-1)
ZZ = Matrix Code, or {matrix_code} in EQuIS (Table 4-1)
MMDDYY = Date of sample collection, or {Sample_Date} in EQuIS (for example: 122808, 020209)

4.2.1 Location Code Identification

A unique location code, referred to as the "sys_loc_code" in EQuIS, will be assigned for each sample location. The same location can be sampled multiple times by changing the sample date or by appending the sample ID with a sequential number for collection of multiple samples from the same location on the same date. The location code will be created using common site descriptors (such as river mile or other KIF common location names).

4.2.2 Quality Assurance/Quality Control Sample Identification

An additional QA/QC sample code, referred to as the "QA/QC_Code" in EQuIS, will be identified for each QA/QC sample. The QA/QC sample code will be entered into the sample ID between the field matrix code and the sample date per the example below.

KIF-QQQ-ZZ-QC-MMDDYY

EQuIS provides QA/QC code options to be selected when adding QA/QC samples to a CoC record. Project QA/QC codes are summarized below.

- Equipment rinsate blank = EB
- Matrix spike = MS
- Matrix spike duplicate = MSD

When a field duplicate or co-located sample is required, the first letter of the matrix code will be changed to an "A". This allows the potential for all field duplicate samples to be "blind" to the laboratory.

4.3 SAMPLE CONTAINER LABELING PROCEDURES

The Sample Manager will generate sample container labels from EQuIS and provide the CoC forms and container labels to the field sampling crews in accordance with TVA-SOP-ENV-07 *Sampling, Labeling, Packaging, and Shipping*. The sample container labels will be pre-printed with the required labeling information (listed below) with the exception of the time, and sampler's initials. The field sampling crews will affix the labels to the appropriate bottles prior to collecting the samples and complete the time and sampler's initials upon sample collection. The following information at a minimum will be included on the sample container labels:

- Project facility name
- Unique sample identification code
- Field matrix code
- CoC number or task code
- Identification of preservatives used
- Analysis requested
- Date and time of collection
- Sampler's initials
- A bar code containing the sample identification code

Whenever field changes or errors in pre-printed labels have occurred, a Sharpie® or Rite-in-the-Rain® pen will be used to write the correct information on the label, and changes will be initialed and dated.

4.4 CHAIN-OF-CUSTODY PROCEDURES

CoC procedures will be followed in accordance with TVA-KIF-SOP-06 *Field Documentation* and TVA-KIF-SOP-18 *Management and Implementation of EQuIS-based Chain-of-Custody*. Sample custody will be implemented to document sample history from the time of sample collection through shipment, analysis, and disposal. A sample is considered to be in one's custody if one or more of the following conditions apply:

- The sample is in an individual's actual possession,
- The sample is in view after being in an individual's physical possession,
- It was in the physical possession of an investigator and then they secured it to prevent tampering, and/or
- It is placed in a designated secure area.

Each individual field sampler is responsible for the custody of the samples collected until the samples are properly transferred to temporary storage or are shipped to the laboratory. Custody transfer will be

documented by both the relinquishing and accepting parties signing and dating the CoC form. The only exception is the transfer to the laboratory. In this case the samples and CoC forms will be sealed in the coolers with custody seals, and the courier or shipping company will not need to sign the CoC. The laboratory sample custodian will sign the CoC upon opening the coolers and verifying sample receipt. The shipping company or courier will sign a completed courier form or bill of lading since they are not provided access to the inside of the cooler. As per Section 3.4 of TVA-SOP-07 *Sampling, Labeling, Packaging, and Shipping,* if multiple coolers are required, a copy of the original CoC form shall accompany each cooler that contains the samples identified on the CoC. The original CoCs will accompany the first cooler. This document will be used to demonstrate that a sample has been obtained from a specific location and has reached the laboratory without alteration. Accordingly, each EQuIS-based CoC record will document evidence of the collection, shipment, laboratory receipt, and laboratory custody of each sample included in a shipment.

The Sample Manager is responsible for setting up new data management sample plans and generating the CoC forms for new sampling tasks. The EQuIS-generated CoC forms will be pre-populated with the following information:

- Site ID, number, and site address
- Laboratory name and address
- Preservative used (if applicable)
- Sample ID, sample location, and sample type
- Number of sample containers
- Sample matrix
- Sample date
- Analyses (method analyte group) requested
- Sample reason (for this sampling event, only “Investigatory” reason code).
- Any special instructions and/or sample hazards

The field sampling crews are responsible for completing the EQuIS-generated sample CoC form in the field by recording sample custody and documenting sample collection. The field sampling crews will complete the following information on the CoC form:

- Sample collection time
- Sample start depth, sample end depth (if applicable)
- Sample depth units (if applicable)
- Sample type (grab or composite)
- Name of lead sampler, signature of lead sampler, and date and time of lead sampler’s signature
- Sampling company

When new locations are initially sampled, the field sampling crews will complete a sample location form with Global Positioning System (GPS) coordinates for loading into EQuIS. The field sampling crews will document the new location coordinates on the form using a TVA-approved Trimble GPS unit. The completed Sample Location Form will then be forwarded to the data management team for entering the new location information into the EQuIS database.

5. SAMPLING PROCEDURES AND EQUIPMENT

5.1 FIELD SAMPLING PROCEDURES

Field sampling will be conducted in accordance with TVA SOPs for the Kingston Ash Recovery Project, EPA's *Field Branches Quality Management Plan* (EPA 2009d), and with applicable industry-based standards, as referenced below. TVA SOPs are available online at http://public.tva.gov:8161/kingston/sop/.

5.1.1 Ash Deposit Sampling

Samples of ash deposits will be collected using boats equipped with VibeCore-D or similar sampling equipment. Plastic or Lexan tubes will be utilized with the VibeCore-D equipment to collect the samples per TVA-KIF-SOP-05 *Sediment Sampling*.

5.1.2 Seasonally-Exposed Sediment Sampling

Samples of seasonally-exposed sediments will be collected manually using hand augers and trowels during winter pool or using boats equipped with VibeCore-D or Ogeechee™ sampling equipment during summer pool per TVA-KIF-SOP-05 *Sediment Sampling.* Plastic or Lexan tubes will be utilized with the VibeCore-D equipment to collect submerged samples during summer pool.

5.1.3 Submerged Sediment Sampling

Samples of submerged sediments will be a subset of the ash deposit samples. Samples will therefore be collected from boats using either a Ponar grab sampler or VibeCore-D or similar sampling equipment per TVA-KIF-SOP-05 *Sediment Sampling.* Plastic or Lexan tubes will be utilized with the VibeCore-D equipment to collect the samples.

Samples of submerged sediment for AVS/SEM analysis will be collected using Lexan tubes to obtain relatively undisturbed samples, in accordance with TVA-KIF-SOP-09 *Sediment Sampling for AVS/SEM Analysis*.

Bulk ash samples will be collected for use in conducting dilution series bioassay test mixtures. Bulk ash samples will be taken in accordance with TVA-KIF-SOP-04 *Soil Sampling for Inorganic Analysis* and homogenized in accordance with TVA-KIF-SOP-20 *Bulk Ash Homogenization*.

5.1.4 Sediment Porewater Sampling

Sediment porewater samples will be collected by extracting the porewater from composited sediment samples. The sediment samples will be collected as described for submerged sediment sampling using either a Ponar grab sampler, VibeCore-D, or similar sampling equipment, depending on the water depth per TVA-KIF-SOP-05 *Sediment Sampling*. Multiple grab samples may need to be taken so as to collect sufficient volume of sediment for porewater extraction. Samples will be placed into plastic buckets with sealed lids for transport to shore. The objective is to collect sediment interstitial water, not incidentally-collected surface water. Any surface water will be drained off prior to placing the sediment into buckets.

The porewater will be extracted from the sediment on shore, in the field using one of two methods. First, water is known to separate from ash/sediment and rise to the top of the sample container. The free water will be decanted off the top of the bucket and filtered. Second, the remaining sediment sample will be vacuum extracted or centrifuge extracted in accordance with TVA-KIF-SOP-43 *Porewater Collection*

from Sediment and Ash. The extracted porewater will be composited and placed in jars for subsequent offsite testing.

5.1.5 Surface Water Sampling

Discrete samples of surface water will be collected in accordance with TVA-KIF-SOP-01 *Surface Water Sampling* and TDEC document *Quality System Standard Operating Procedure (SOP) for Chemical and Bacteriological Sampling of Surface Water*. Surface water samples will be collected from boats by starting at the farthest downstream location and moving upstream to minimize disturbance of bottom sediments. One sample will be collected at mid-depth in the mid-point of the main current, a second sample will be collected of epibenthic surface water, within one-half meter (1.5 ft) of the bottom of the river.

Surface water samples will be collected using peristaltic pumps and dedicated tubing and inert weights. The peristaltic pump will be lowered to the desired depth and purged for one to two minutes prior to sample collection. The samples for dissolved metals analysis will be filtered through a disposable 0.45 micron filter. Sample bottles will be filled directly from the tubing. The dedicated tubing will be used for up to 32 days and then will be replaced with new tubing.

Water quality measurements (temperature, DO, pH, conductivity, and turbidity) will be collected in situ using a multi-analyte programmable data logger (Hydrolab or equivalent) in accordance with TVA-KIF-SOP-14 *Hydrolab Datasonde® Standardization and Field Parameter Measurement*. The data logger will be lowered to collect the measurements from the same depth and location as the sample for laboratory analysis. The data logger will be allowed to equilibrate for a period of one or two minutes prior to recording the readings in the field logbook.

5.1.6 Groundwater Sampling and Aquifer Testing

This task will include soil sampling, installation of temporary and permanent monitoring wells, groundwater sampling, and aquifer testing.

<u>Soil Sampling</u>

Soil samples will be collected during drilling of wells, temporary well points, and hollow-stem-auger boreholes. Soil samples will be collected continuously from 6 inches below the surface to total depth of the boring, or to bedrock, whichever is encountered sooner. Soil samples will be collected using plastic-lined split-barrel samplers (ASTM D1586) with a sample catch on the lower end, or thin-walled Shelby tube samplers (ASTM D1587), depending on the laboratory analysis. Sample requirements are specified in Appendix D. Soil will be visually classified in the field in accordance with ASTM D2488. Descriptions of the soil cores will be recorded on a boring log, in accordance with TVA-KIF-SOP-39 *Monitoring Well and Piezometer Installation and Completion*. Bedrock cores will not be taken; rock cuttings will be examined for evidence of rock type.

Ends of sample collection tubes (plastic liners or Shelby tubes) will be sealed by coating with paraffin wax, Saran plastic wrap, or plastic end caps secured with tape. Sample temperature will be maintained at approximately 4º C. Sample packaging for shipment to the laboratory will follow ASTM D 4220 to prevent physical damage.

Well Installation

Borings and well installations will be made in accordance with TVA-KIF-SOP-39 *Monitoring Well and Piezometer Installation and Completion*. Borings for monitoring wells will be advanced through the overburden soils using 6-inch diameter hollow-stem auger drilling methods; borings in bedrock will be advanced using air rotary techniques to create a nominal 6-inch diameter borehole. Soil samples will be collected continuously using split-barrel sampler with plastic liner or thin-walled Shelby tube samplers. Descriptions of the soil cores will be recorded on a boring log, in accordance with TVA-KIF-SOP-39. Bedrock cores will not be taken, rock cuttings will be examined for evidence of rock type.

Well materials will consist of 2-inch inside diameter Schedule 40 PVC flush-threaded casing and screen. Well screens will consist of pre-packaged screens having 0.01-inch slot size. The annular space around the screen will be filled with 20/40 filter pack material to a minimum of 2 ft above the top of the screen. A minimum 2-ft layer of bentonite pellets will be placed above the sand pack. The remaining annular space will be grouted to the ground surface with grout consisting of approximately 4 pounds of bentonite per 94-pound bag of Portland cement, with 6 to 7 gallons of potable water. Wells (both permanent wells and temporary well points) will be developed in accordance with TVA-KIF-SOP-39.

Permanent wells will require the installation of a 6-inch diameter steel protective casing extending from a depth of at least 3 ft below ground surface to a minimum of 2.5 ft above ground surface (no more than 0.2 ft above the top of the PVC well casing). The protective casing will be capped with a lockable cap and will be surrounded by a concrete pad 4 ft square and approximately 4 inches thick. The pad will be sloped a minimum of 2 inches from the protective casing to the edge of the pad to provide positive drainage. Four 3-inch-diameter steel bollard posts extending 3 ft above the pad and driven 3 ft into the ground will be set at equal spacing around the protective casing, outside of the perimeter of the concrete pad. An internal drainage hole will be drilled through the steel protective casing just above the mortar collar. A permanent metal tag will be placed in the pad before curing or will be affixed to the steel protective casing; the metal tag will be stamped to indicate TVA-KIF and the well identification. The aboveground protective well casing and bollards will be painted bright yellow so that they can be readily seen. Temporary well points will not require protective casings, pads, or bollards; temporary wells will be abandoned in accordance with TDEC Rule 1200-4-9.16 once all testing and sampling has been completed.

Completed wells, temporary well points, and boreholes will be surveyed by a licensed land surveyor. The well location, ground elevation, top of pad elevation, and top of interior PVC well casing elevation will be surveyed. Survey measurements will be to an accuracy of 0.1 ft horizontal (North American Datum of 1983) and 0.01 ft vertical (North American Vertical Datum of 1988).

Groundwater Sampling

Groundwater sampling will be conducted at both existing and new groundwater wells and temporary well points. Groundwater will be sampled with low-flow sampling techniques using peristaltic pumps or bladder pumps per TVA-KIF-SOP-02 *Groundwater Sampling.* Water level measurements will be made at the time of groundwater sampling using a water level meter per TVA-KIF-SOP-02 *Groundwater Sampling.*

Groundwater samples will also be collected using direct-push technology in hollow-stem auger boreholes or using Geoprobe® sampling techniques. Geoprobe® sampling may be used at borehole locations where no Shelby tube soil samples are to be taken. Samples will be taken by hydraulically pushing the sampling probe to the required depth, and extracting the groundwater using peristaltic pumps for chemical constituent analyses. Samples will be filtered in-line for dissolved analysis only to avoid excessive

turbidity resulting from Geoprobe® sampling in accordance with TVA-SOP-47 *Groundwater and Leachate Sampling Using Direct-Push Systems*.

Aquifer Testing

Aquifer testing will include water level measurements, hydraulic head pressure measurements, borehole flowmeter measurements, and aquifer (slug) tests in accordance with TVA-KIF-SOP-42 *Slug Testing*. Water level measurements will be taken in new and existing wells and piezometers; water levels will be measured at all locations during a single sampling event to obtain a "snapshot" of water levels across the site. Water level measurements will be collected from wells and open piezometers using a water level meter per TVA-KIF-SOP-02 *Groundwater Sampling.* Measurements will be made to the nearest 0.01 ft from the survey mark on the interior PVC casing pipe. Measurements in existing nested vibrating wire piezometers will be taken in accordance with the equipment manufacturer's requirements, with proper calibration and adjustment for ambient atmospheric pressure.

Long-term vertical gradient measurements will be taken using pressure transducers and electronic data loggers positioned in the temporary well points to measure hydraulic head pressures in paired wells. Test data will be downloaded to a laptop computer for subsequent data processing.

Borehole flowmeter tests will be conducted in accordance with procedures specified in the document EPA/600/R-98/058: *Application of the Electromagnetic Borehole Flowmeter*.

Aquifer (slug) tests will be conducted using both slug-in and slug-out tests. During slug-in tests, the slug will be instantaneously inserted into the well to raise the hydraulic head and measure the head decline over time; during the slug-out tests, the slug will be instantaneously removed from the well to lower the hydraulic head and measure the head rise over time. In both cases, the head recovery rate will be recorded, and the data will be evaluated by the appropriate method to determine in-situ horizontal hydraulic conductivity. Pressure transducers and electronic data loggers will be used to record water level changes in the well during the test. Test data will be downloaded to a laptop computer and evaluated in the field to check that the data are usable. Slug tests will be performed in accordance with TVA-KIF-SOP-42 *Slug Testing*.

Single-well aquifer (pump) tests will be conducted on bedrock wells and temporary well points in accordance with ASTM D 4050: *Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems*.

5.1.7 Benthic Invertebrates Sampling

Samples of aquatic snails will be collected by handpicking snails from shallow rocky or wooden structures in accordance with TVA-KIF-SOP-30 *Aquatic Snail Sampling*. Samples of larval mayflies will be collected by taking multiple Ponar/Peterson grabs of sediment and selectively removing the organisms by washing the sediment over a screen to separate the sediment from the nymphs in accordance with TVA-KIF-SOP-29 *Mayfly Nymph Sampling*. Adult mayflies will be collected during the hatch using a combination of methods, such as direct removal with forceps from branches along the shoreline, sweep nets, and possibly light traps as needed. Individual samples will be composited by species into a single sample representative of a particular reach of the river. At least two composite samples each of snails and larval mayflies will be collected at each location; one depurated (i.e., evacuation of their digestive systems) before analysis and the other non-depurated. Emergent mayflies do not feed and do not need to be depurated. The adult mayflies will be taken to the laboratory where species identification will be confirmed and individuals will be separated by life stage (sub-imago and imago) and sex. Replicate

samples will be collected at some locations, dependent on availability of organisms, to evaluate variability at that location.

For the biosurvey of benthic communities, benthic samples will be collected with a Ponar/Peterson grab sampler. Samples will be washed over a mesh screen and the remaining content preserved for laboratory processing and taxonomic analysis in accordance with TVA-KIF-SOP-35 *Benthic Macroinvertebrate Community Sampling*.

5.1.8 Fish Sampling

Fish samples will be collected using a combination of techniques, depending on success in capturing the target species (largemouth bass, bluegill, channel catfish, gizzard shad, or threadfin shad). Fish samples will be collected in accordance with the following procedures:

- TVA-KIF-SOP-31 *Fish Sampling with Gill Nets*
- TVA-KIF-SOP-32 *Fish Sampling with Seines*
- TVA-KIF-SOP-33 *Fish Sampling – Boat Mounted Electrofishing*

For the biosurvey of fish communities, the fish collected will be identified as to species, counted, and examined for anomalies (such as disease, deformations, or hybridization). The fish will be field identified and returned to the river unless either (1) laboratory identification is required for some specimens or (2) the specimens are to be utilized for bioaccumulation studies (constituent concentration analysis).

For bioaccumulation studies, individual fish specimens will be collected and separated into species-specific subsamples. Samples of largemouth bass, bluegill, and channel catfish will be processed in a biological laboratory. Samples will be prepared by initially removing and disposing of the gut contents. Muscle tissue (filets) will then be removed, and placed into labeled containers for shipment to the analytical laboratory. Non-filet portions will be placed into separate labeled containers. For purposes of scientific research by the biological laboratory, the non-filet portions may be further dissected into discrete organs for separate analysis. Whole-body fish data will be obtained by combining results for the filet and non-filet portions of each fish sample. Alternatively, whole-body data may be obtained by collecting and analyzing a separate whole-body fish sample, thereby avoiding the need to calculate whole-body data through reconstruction.

Samples of gizzard shad and threadfin shad (with gut contents removed) will be composited to obtain sufficient volume for analysis. Samples will be analyzed for whole-body concentrations only.

5.1.9 Wildlife Sampling

Egg and nestling samples (tree swallow and heron) will be collected from the nesting colonies using the following procedures:

- TVA-KIF-SOP-15 *Collecting and Processing Heron and Osprey Eggs*
- TVA-KIF-SOP-28 *Nestling Sampling*

Many of the nests are located in trees along shorelines and on electrical transmission towers. Specialized equipment such as vertical rope gear, tree spikes, ladders, and/or a bucket truck will be used to access the nests. Once the sampler has gained access to the nest, the sampler will note the absence/presence and number of eggs or young in each nest (clutch size). One egg will be randomly collected from each nest. Up to ten individual nests will be sampled within each colony. Each egg collected will be placed in a re-sealable bag clearly labeled with the sample identification and then placed in a sealable plastic container

lined with bubble wrap. The sealable plastic container will be placed in a bag and lowered by rope to personnel on the ground or boat. The eggs will be weighed and then frozen whole and shipped to the lab. Contents of the eggs will be removed from the shell prior to analysis at the lab.

Nestlings will be sampled in a similar manner. A single nestling (more than 14 days old) will be removed from each nest box. The number and condition of the nestlings will be noted. Nestlings will be euthanized using carbon dioxide or cervical dislocation, then frozen whole. Samples will be analyzed for whole-body concentrations only.

5.1.10 Aquatic Vegetation Sampling

Samples of emergent vegetation will be collected in accordance with TVA-KIF-SOP-38 *Vegetation Sampling*. Samples of emergent vegetation from below the summer pool shoreline for chemical analysis also will be collected at three locations in each reach of the Emory, Clinch, and Tennessee Rivers.

Samples of periphyton will be collected using artificial substrates following the methods described in *Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish Second Edition* (EPA 2010) and in accordance with TVA-KIF-SOP-59 *Periphyton Sampling*. Within each reach, three individual samples will be composited into a single sample representative of the river reach. A minimum of one composite sample will be collected at each location. Duplicate samples will be collected at one location, dependent on availability of organisms, to evaluate variability at that location.

5.2 DECONTAMINATION PROCEDURES

Equipment used for collecting samples or field measurements, including excavating and drilling equipment, that comes into contact with potentially contaminated media will be decontaminated prior to use unless the equipment is received sealed and certified clean from the manufacturer. Reusable sampling equipment will be decontaminated between sampling locations. This project will use disposable equipment to the extent feasible that does not require an initial decontamination and will be properly disposed after use at a single location. Dedicated sampling equipment that is not certified clean by the manufacturer, will be decontaminated prior to the initial use and will not require decontamination prior to subsequent use at the same location/well. Specific step-wise equipment decontamination procedures for sampling and heavy equipment will be in accordance with TVA-KIF-SOP-08 *Decontamination of Equipment.*

5.3 PACKAGING/SHIPPING PROCEDURES

Sample packing and shipping procedures will follow the general guidance in TVA-KIF-SOP-07 *Sample Labeling, Packing, and Shipping* and the following step-wise procedure. Upon completion of sampling activities, field sampling crews will return to the field sampling house and relinquish samples to the Sample Custodian or designee. The Sample Custodian or designee is responsible for reviewing the field documentation and packaging samples from the field crews for shipment to the appropriate analytical laboratories.

The initial step, to packaging/shipping includes a quality assurance check of the field sampling crew documentation. The Sample Custodian or designee will review each CoC and bottle label to verify that there are no errors and that documentation has been accurately completed. The Sample Custodian or designee will check that sample containers are accounted for and match the quantities on the CoC records, and that the dates and times are correct and accurate on the CoCs and labels. Any inconsistencies or errors will be corrected using indelible ink by striking through the erroneous entry with a single line and

initialing and dating the corrected entry. Once the sample documentation has been verified, the samples will be packaged in sturdy ice chests for shipment as follows:

1. If the cooler has a drain, completely duct tape the inside and outside of the drain.
2. Place a new large sturdy garbage bag in the cooler.
3. Place wet ice (double bagged in sturdy plastic bags) inside the garbage bag.
4. Check that each sample container has an initialed/signed custody seal and is intact.
5. Package all sample containers in sturdy plastic bags (i.e., Ziploc bags).
6. Place the bagged sample containers inside the wet ice packed garbage bag.
7. Place the temperature samples in the center of the samples in the garbage bag, if applicable.
8. Seal the garbage bag containing the samples and double bagged ice.
9. Place the original executed CoCs in a sturdy plastic bag and tape to the inside lid of the cooler. If multiple coolers, include copies of original CoC in all coolers.
10. Seal the cooler with duct/strapping tape and place custody seals on two opposite corners of the cooler.
11. Place “Fragile” and “This Side Up” stickers on at least two sides of the cooler (preferably all four sides), if sample containers are glass bottles.
12. Add the appropriate U.S. Department of Transportation (DOT) placarding to the cooler (if required).
13. Complete the appropriate bill of lading or courier documentation form for the shipment.

The Sample Custodian or designee is responsible for making copies of the CoCs and shipping paperwork and distributing them for filing in the central data management filing system.

5.4 FIELD NOTEBOOK PROCEDURES

Field logbooks will be prepared in accordance with the general guidance in TVA-KIF-SOP-06 *Field Documentation* and as described below. Each field sampling crew and the Field Team Leader will maintain field sampling logbooks to document the activities conducted by the field crew for each day fieldwork is conducted.

Each field logbook will be assigned a unique number and maintained in a locked fire-proof cabinet/safe. Field logbooks will be bound with sequentially numbered pages. Logbook entries will be made with black indelible ink (preferably with a Rite-in-the-Rain® pen). Each entry will be recorded chronologically with a time notation. Unused sections or blank pages will be lined out and initialed and dated. Each bottom page with entries will be signed and dated by the recorder. Errors in the logbook will be lined out (with a single line strike through) with the corrected entry initialed and dated. Copies of the field logbooks will be made at least weekly to minimize loss of data that could result from the loss or destruction of a logbook during field activities. The logbook copies will be reviewed by the Sample Manager (or designee) to verify that entries are legible.

At a minimum the following elements will be recorded in the field logbooks:

- Name and location of the site
- Date(s) of sample collection or event
- Name and affiliation of the Field Team Leader
- Names of field team members and responsibilities
- Daily time of arrival to the site

- Daily weather conditions
- Pertinent field observations
- Daily summary of equipment preparation procedures and identification/serial numbers of equipment, if appropriate
- Time of sample collection
- Numbers and types of samples collected and sample identification numbers and analysis, preservatives, etc.
- A description of sampling methodology by reference to the project control documents (such as the SAP, Quality Assurance Project Plan, or SOPs)
- Specific sampling characteristics (such as depth, temperature, turbidity, etc.) as outlined in specific sampling SOPs
- Physical description and sketch of the sample collection location(s)
- Provide a reference to GPS data collected, if applicable
- Record of daily phone calls and/or contact with individuals at the site
- Management or disposal of investigation-derived wastes

5.5 INVESTIGATION-DERIVED WASTE MANAGEMENT PROCEDURES

As part of field investigation activities, various types of investigation-derived wastes (IDW) will be generated including standard municipal refuse (i.e., cardboard, plastic, paper), solid (i.e., ash, soil and sediments), and liquid (i.e., decontamination fluids and purge water from groundwater sampling) wastes. This section identifies the various waste streams expected to be generated and the procedural steps for the disposition of these waste streams. If additional waste streams are identified during field investigation activities that are not already addressed in this section, appropriate actions will be taken to ensure that proper waste disposition requirements are followed.

IDW will be handled in accordance with TVA-KIF-SOP-12 *Management of Investigation-Derived Waste.* Table 5.1 lists the anticipated waste streams that will be generated in association with the sampling and investigative activities and the disposition pathway for each waste stream. Drums or waste containers stored onsite will be inspected weekly and the results of the inspection recorded in a field logbook.

Different IDW streams (e.g., soil and water) will not normally be containerized together; therefore, separate containers will be used for each IDW stream. However, IDW with similar levels of contamination (based on field screening or previous analytical results) may be containerized together.

To determine if contamination of IDW material is suspected, the following evaluation procedure will be used. Note that no field screening with a photoionization detector is required, since no volatile organic compounds are present at the site.

- Evaluate previous analytical results, if available;
- Inspect the material for visual or olfactory evidence of contamination;
- Utilize additional field tests (e.g., pH, color, and other chemical or physical characterizations) to the extent possible; and
- Utilize generator knowledge to help characterize the IDW to the extent possible.

Drums and containers used to store IDW will be appropriately labeled with the following information:

- Site name and address
- Type of material (see Table 5.1)
- Accumulation date(s)

- Additional Comments
- Site contact name and phone number

In addition, a "Hazardous Waste" label will be used with the notation of "pending analysis," if a waste is known or suspected to be characteristically hazardous per the Resource Conservation and Recovery Act. The outside of the drums may need to be cleaned prior to labeling. If the waste is to be transported across or onto public roadways, DOT-applicable labeling and shipping papers will be used.

Table 5-1. Investigation-Derived Waste Streams and Disposition Pathways

IDW Stream	Disposition Pathway
General refuse (paper, plastic bags, cardboard, etc.)	Place in municipal trash or recycling receptacle as appropriate.
Personal protective equipment (nitrile gloves, Tyvek, etc.)	Return to KIF site and place in municipal trash receptacle.
Ash (obtained from river characterization activities)	Containerize in plastic bucket, tub, etc., and return to KIF site for disposition in ash management system (i.e., Ash Processing Area).
Ash (obtained during on-land characterization activities)	Leave in place if in exclusion zone. If sampling occurs outside of exclusion zone, then containerize in 5-gallon bucket or drum and return to KIF site (Ash Processing Area) for disposition.
Soil (generated during drilling or Geoprobe activities)	Spread soil and/or rock cuttings at the ground surface, and grade to allow drainage.
Sediment (obtained during river characterization activities)	Return small volumes (<1 gallon) to the river where the sampling occurred. Containerize larger volumes and return to KIF for storage in a waste accumulation area pending analysis.
Surface water (river water)	Return to location if unpreserved bottle. If preserved bottle ware with surface water, send to TVA Neutralization Lab.
Solid (generated sludges from equipment decontamination)	Decontaminate equipment at one of the two truck wash locations, if drilling occurs in the exclusion zone. If drilling occurs outside of the exclusion zone or on private property, then collect and containerize decontamination sludges, and return to KIF site (Ash Processing Area) for disposition.
Groundwater (purge water, development water)	Containerize groundwater in 55-gallon drums and return to KIF site (Ash Processing Area Rim Ditch) for disposition.
Decontamination fluid	Collect and containerize decontamination fluids and return to KIF site (Ash Processing Area Rim Ditch) for disposition.

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6. REFERENCES

40 CFR Part 300. *National Oil and Hazardous Substances Pollution Contingency Plan (NCP)*.

42 U.S.C. § 7401 et seq. *Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1980*.

American Society of Agronomy (ASA) and Soil Science Society of America (SSSA) 1996. M*ethods of Soil Analysis, Part 3. Chemical Methods, Methods 14, 15, 16 and 40.* Madison, WI.

American Society of Testing and Materials (ASTM) 2009 (July 1). *ASTM D 4793: Standard Test Method for Sequential Batch Extraction of Waste with Water*.

ASTM 1996 (October 10). ASTM D4050-96 (2008): *Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems*.

ASTM E 1706-05. Standard Test Method for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates. Annex A2. Guidance for conducting sediment toxicity tests with *Daphnia magna* (*D. magna*) and *Ceriodaphnia dubia* (*C. dubia*).

Chao, T.T. and L. Zhou, 1983 (May 11). *Extraction techniques for selective dissolution of amorphous iron oxides from soils and sediments,* Soil Science Society of America Journal, vol. 47.

U.S. Environmental Protection Agency (EPA) 2010. *Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish Second Edition EPA 841-B-99-002*. http://www.epa.gov/OWOW/monitoring/techmon.html.

EPA 2009a (May 11). *Administrative Order and Agreement on Consent, Docket No. CERCLA-04-2009-3766*, Region 4.

EPA 2009b (October). *Evaluating Ecological Risk to Invertebrate Receptors from PAHs in Sediments at Hazardous Waste Sites*, EPA/600/R-06/162F, ERASC-011F, Narragansett, RI.

EPA 2009c (January). *EPA SW-846, Draft Method 1314: Leaching Test (Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio) of Constituents in Solid Materials using an Up-Flow Percolation Column*.

EPA 2009d (May 8). *Field Branches Quality Management Plan*, U.S. EPA Region 4, Science and Ecosystem Support Division, Atlanta, Georgia.

EPA 2006 (February). *Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4*, EPA/240/B-06/001, Washington, D.C.

EPA 2002 (December). *Guidance for Quality Assurance Project Plans, EPA QA/G-5*.

EPA 2000 (January). Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW, EPA/600/R-00/007, Washington, D.C.

EPA 1998 (August). *Application of the Electromagnetic Borehole Flowmeter*, EPA/600/R-98/058, Washington, D.C.

EPA 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments.*

EPA 1994. *Assessment and Remediation of Contaminated Sediments (ARCS), Remediation Guidance Document*, EPA 905-B94-003, Great Lakes National Program Office, Chicago, IL. Available online at: http://epa.gov/glnpo/arcs/EPA-905-B94-003/EPA-905-B94-003.html.

EPA 1993 (August). *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA*, Publication 9360.0-32, Washington, D.C.

Environmental Standards, Inc. (ESI) 2009 (December 18). *Quality Assurance Project Plan for the Tennessee Valley Authority Kingston Ash Recovery Project. TVA-KIF-QAPP*. Prepared for the Tennessee Valley Authority, Office of Environment and Research, Environmental Resources.

Jacobs 2010 (January). *Kingston Ash Recovery Project, Non-Time-Critical Removal Action, Embayment/Dredge Cell Engineering/Cost Analysis (EE/CA).*

Jacobs 2009 (August). *Kingston Ash Recovery Project, Non-Time-Critical Removal Action Scope and Engineering Evaluation/Cost Analysis (EE/CA) Work Plan*.

National Weather Service 2006 (March 7). Oak Ridge Climate Normals and Records (1971-2000), National Weather Service Forecast Office, Morristown, Tennessee.

Querol, X., Juan, R., Lopez-Soler, A., Fernandez-Turiel, J. L., and Ruiz, C. R., 1996. "Mobility of Trace Elements from Coal and Combustion Wastes." Fuel, vol. 75(7), p. 821-838.

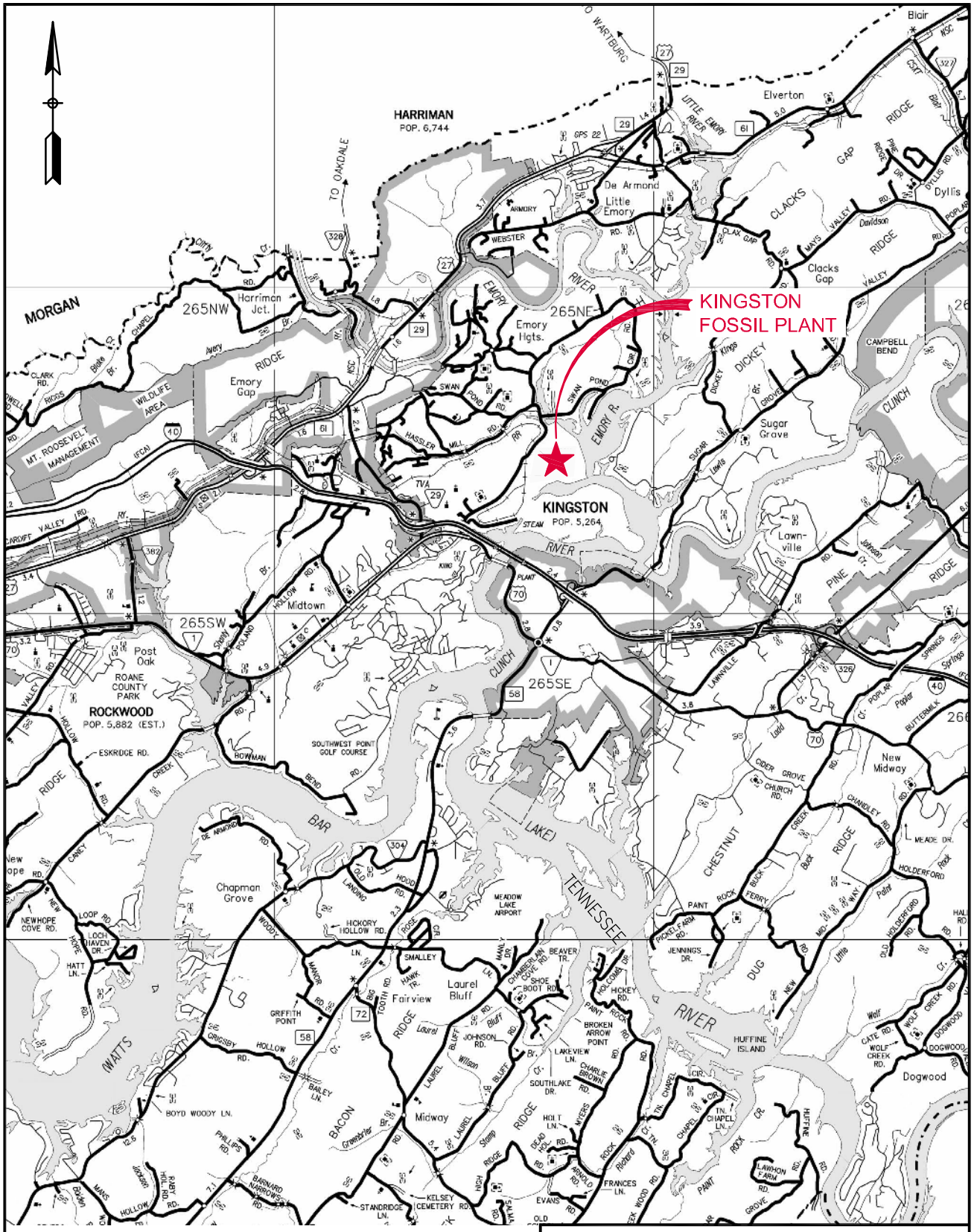
Tennessee Department of Environment and Conservation (TDEC) 2009 (January 12). *Commissioner's Order, Case No. OGC09-0001*, Division of Water Pollution Control.

TDEC 2008. *Quality System Standard Operating Procedure (SOP) for Chemical and Bacteriological Sampling of Surface Water, Division of Water Pollution Control*.

Tennessee Valley Authority (TVA) 2009a (February). *Environmental Assessment, Initial Emergency Response Actions for The Kingston Fossil Plant Ash Dike Failure, Roane County, Tennessee*.

TVA 2009b (August 4). *Action Memorandum: Request for Removal Action at the TVA Kingston Fossil Fuel Plant Release Site, Roane County, Tennessee*.

FIGURES



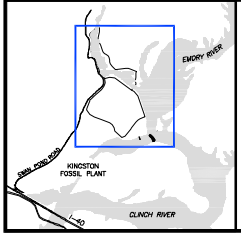
SOURCE:
GENERAL HIGHWAY MAP, ROANE COUNTY, TENNESSEE
TENNESSEE DEPARTMENT OF TRANSPORTATION, 2006

0 1 2 4
SCALE IN MILES

FIGURE 1-1
LOCATION OF THE
KINGSTON FOSSIL PLANT
KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\050_Fig 1-1 SAP Location Map.dwg Apr 29,2010 -bperaro



0 500 1000 2000
SCALE IN FEET

DATE OF PHOTO: AUG. 2009

FIGURE 1-2
KEY FEATURES OF THE KINGSTON FOSSIL PLANT AREA

KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\051_Fig 1-2 SAP Site Features.dwg Apr 29,2010 -bperatro

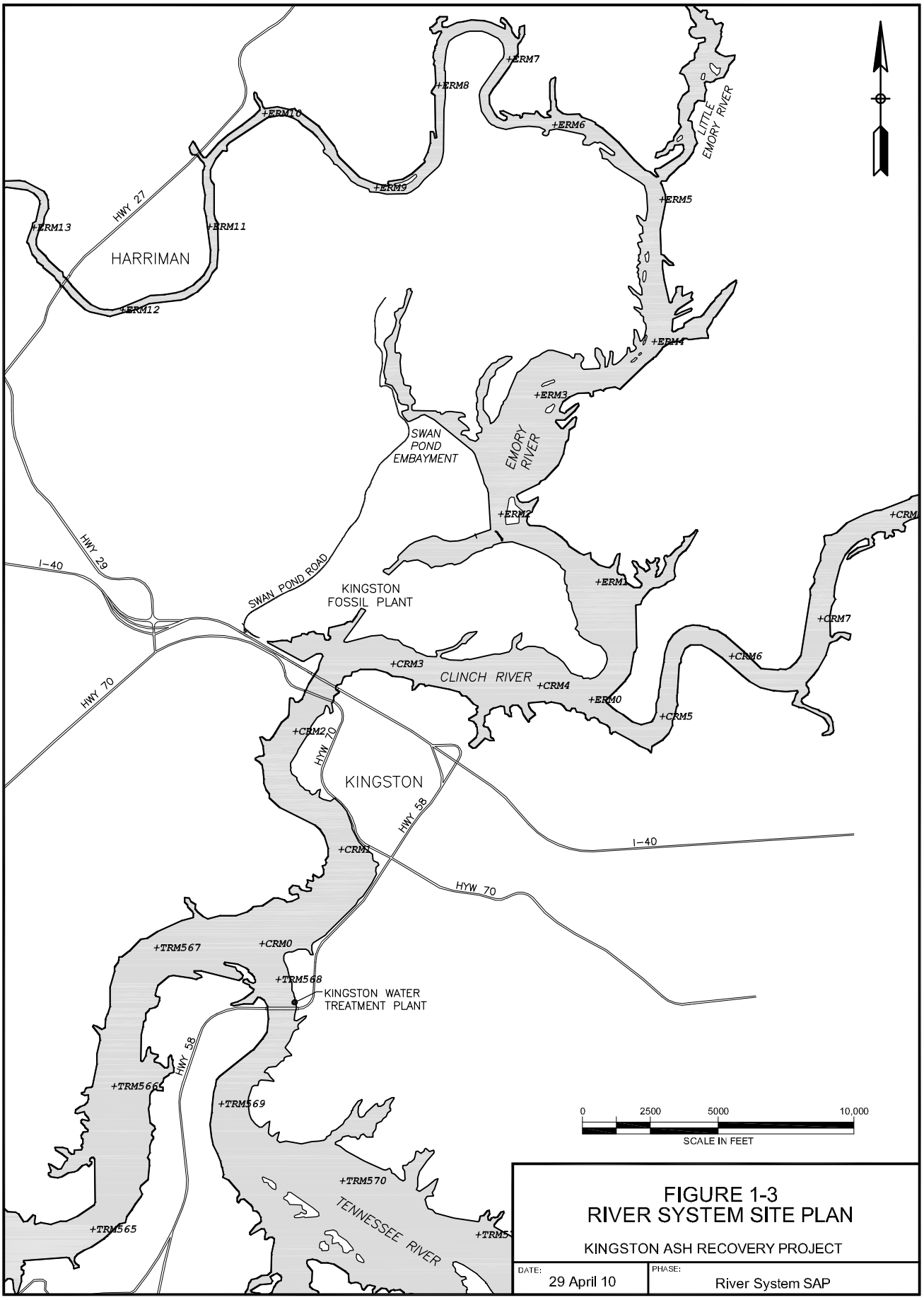
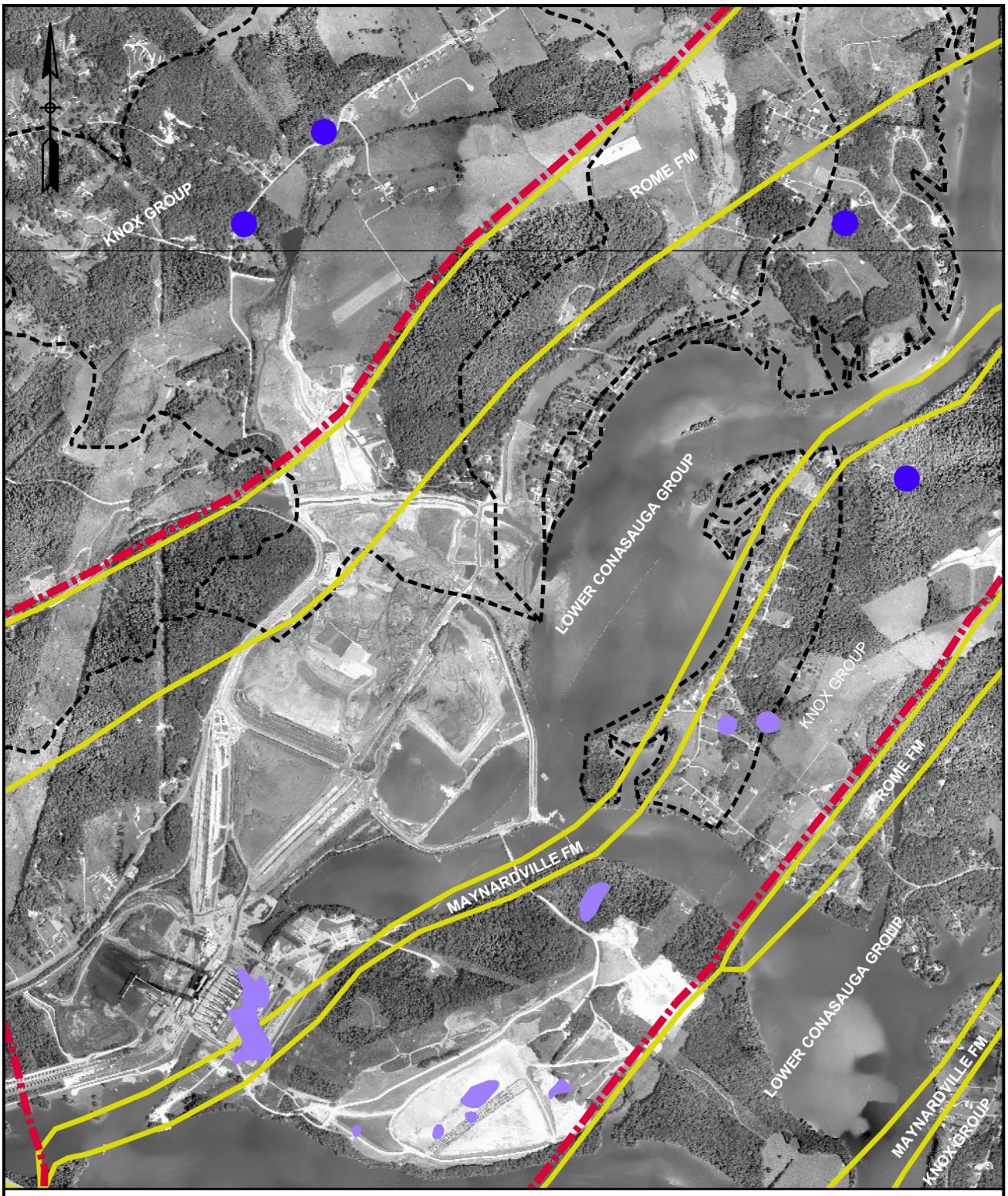


FIGURE 1-3
RIVER SYSTEM SITE PLAN

KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\052_Fig 1-3 SAP River System Site Plan.dwg May 04,2010 -bperatro



DATE OF PHOTO: AUG. 2009

LEGEND

- SPRING
- GEOLOGIC CONTACT
- GEOLOGIC FAULT
- SINKHOLE
- WATERSHED BOUNDARY

0 1000 2000 4000
SCALE IN FEET

FIGURE 1-4
HYDROGEOLOGIC FEATURES OF THE KINGSTON FOSSIL PLANT AREA
KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\053_Fig 1-4 SAP Hydro Features.dwg Apr 29,2010 -bperairo

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\054_Fig 1-5 SAP Groundwater CSM.dwg Apr 29,2010 -bperatro

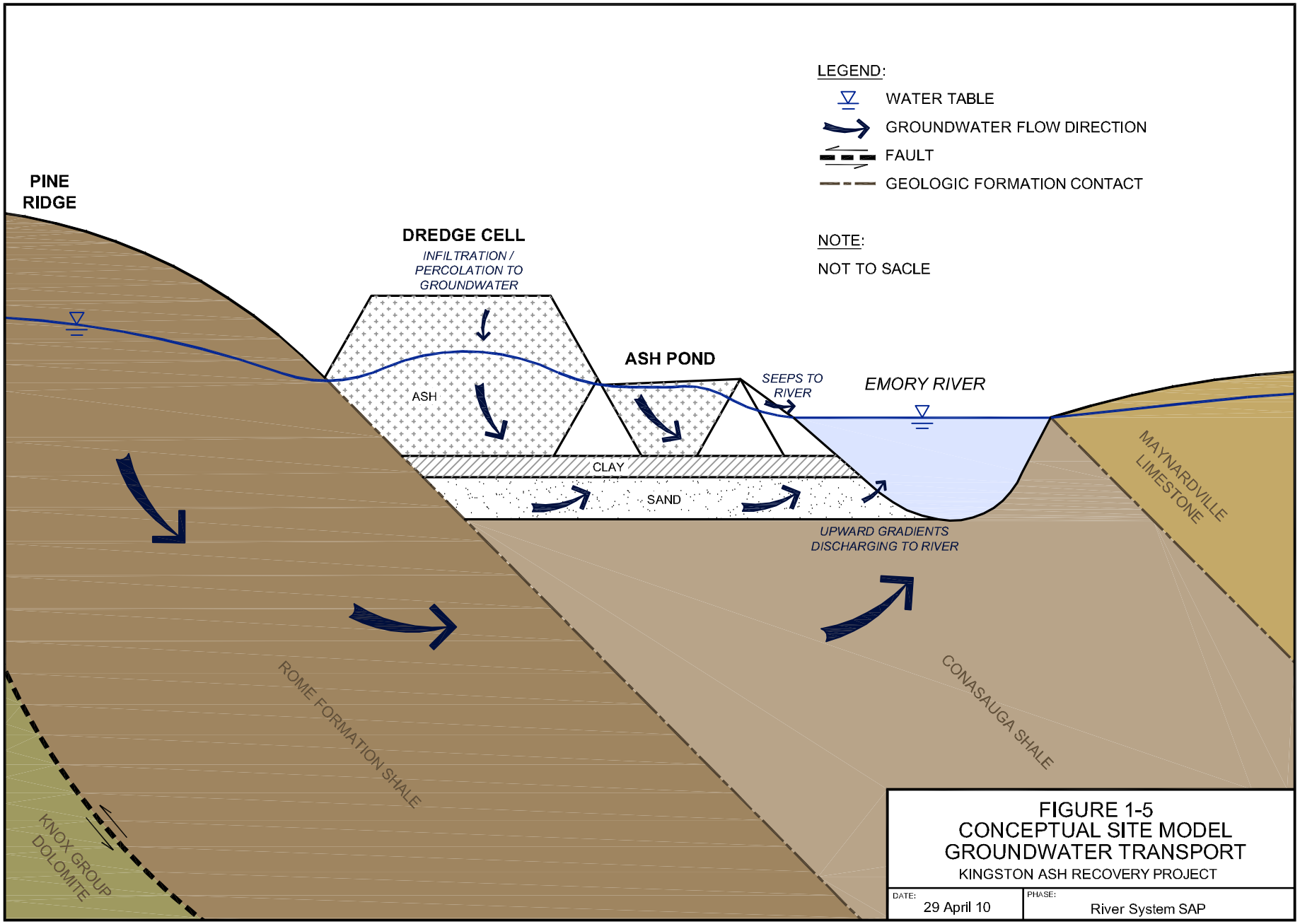


FIGURE 1-5
CONCEPTUAL SITE MODEL
GROUNDWATER TRANSPORT
KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

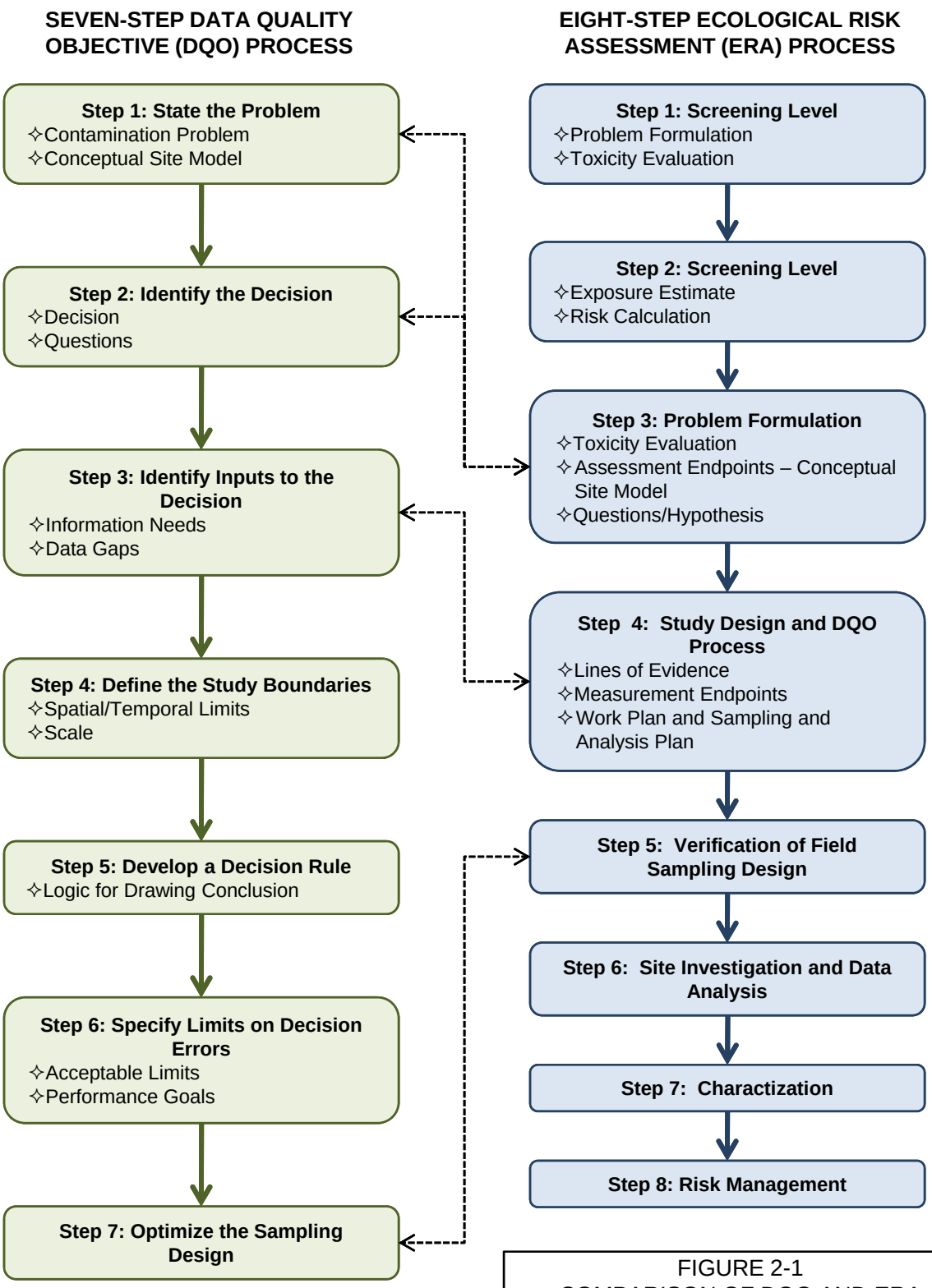


FIGURE 2-1
COMPARISON OF DQO AND ERA PROCESSES
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10	PHASE: River System SAP

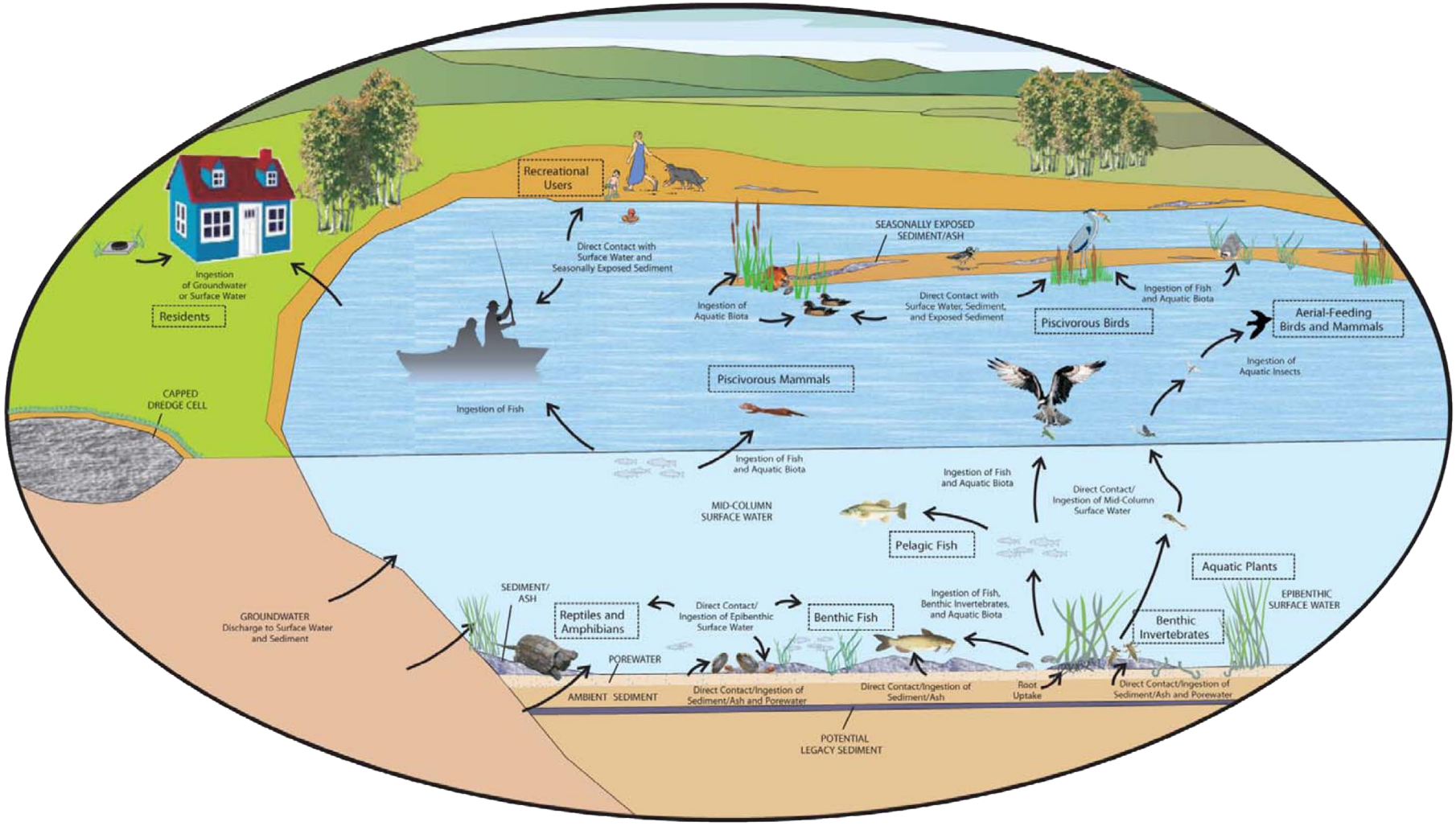


FIGURE 2-2
CONCEPTUAL EXPOSURE MODEL

KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

ENVIRONMENTAL SAMPLE MEDIUM [1]			ECOLOGICAL RECEPTOR								HUMAN RECEPTOR	
			AQUATIC PLANTS	BENTHIC INVERTEBRATES	BENTHIC FISH	PELAGIC FISH	AQUATIC / RIPARIAN-FEEDING MAMMALS	REPTILES / AMPHIBIANS	AQUATIC / RIPARIAN-FEEDING BIRDS	AERIAL-FEEDING BIRDS & MAMMALS	RESIDENTS	RECREATORS
ASH DEPOSITS			●	●	●	●	●	●	●	N	●	●
SEASONALLY-EXPOSED SEDIMENTS			●	●	●	N	●	●	●	N	●	●
SUBMERGED SEDIMENTS			●	●	●	N	N	N	N	N	N	N
SEDIMENT POREWATER			●	●	N	N	N	N	N	N	N	N
SURFACE WATER		EPIBENTHIC	●	●	●	N	N	●	N	N	N	N
		MID-DEPTH	●	N	N	●	●	●	●	●	●	●
GROUNDWATER[2]			N	N	N	N	N	N	N	N	●	N
PREY / FORAGE	BENTHIC INVERTEBRATES	SNAILS	N	E	N	N	●	N	●	N	N	N
		LARVAL MAYFLIES	N	E	N	N	N	N	●	N	N	N
		ADULT MAYFLIES	N	E	N	N	N	N	N	●	N	N
	FISH	PELAGIC (LARGEMOUTH BASS)	N	N	N	E	●	N	●	N	●	●
		PELAGIC (BLUEGILL)	N	N	N	E	●	N	●	N	●	●
		BENTHIC (CATFISH)	N	N	E	N	●	N	●	N	●	●
		BENTHIC (GIZZARD SHAD)	N	N	E	N	●	N	●	N	N	N
	MAMMALS	MAMMALS (RACOONS)	N	N	N	N	E	N	N	N	N	N
	AMPHIBIANS / REPTILES	AMPHIBIANS / REPTILES	N	N	N	N	○	E	○	N	N	N
	BIRD EGGS / NESTLINGS	PISCIVOROUS (HERON)	N	N	N	N	●	N	E	N	N	N
		INSECTIVOROUS (SWALLOW)	N	N	N	N	●	N	N	E	N	N

LEGEND:

E DATA FOR THIS SAMPLE MEDIUM TO BE USED AS BIOMARKER FOR EXPOSURE

N DATA FOR THIS SAMPLE MEDIUM ARE NOT TO BE USED TO EVALUATE THIS RECEPTOR

● DATA FOR THIS SAMPLE MEDIUM ARE TO BE USED TO EVALUATE RECEPTOR

○ EXISTING SAMPLING RESULTS TO BE USED TO EVALUATE RECEPTOR

NOTES:

1. DATA QUALITY OBJECTIVES WERE DEVELOPED FOR ENVIRONMENTAL MEDIA WITH POTENTIALLY COMPLETE RECEPTOR EXPOSURE PATHWAYS.

2. GROUNDWATER FLUX TO SEDIMENT POREWATER AND SURFACE WATER EVALUATED UNDER THOSE MEDIA.

FIGURE 2-3
ENVIRONMENTAL MEDIA AND POTENTIALLY-EXPOSED RECEPTORS
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10 | PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\057_Fig 2-3 SAP Environmental Media.dwg Apr 29,2010 -bperaro

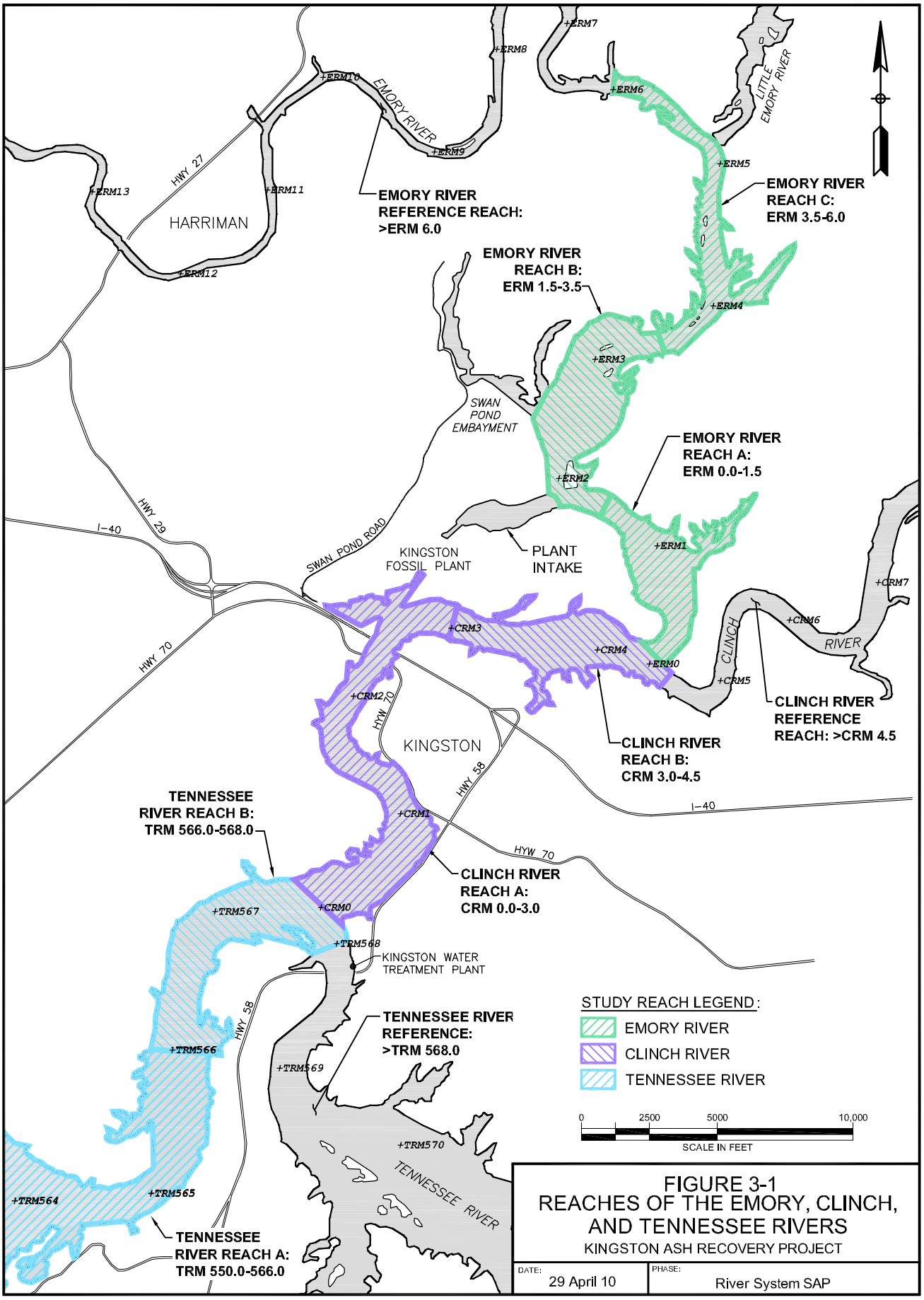
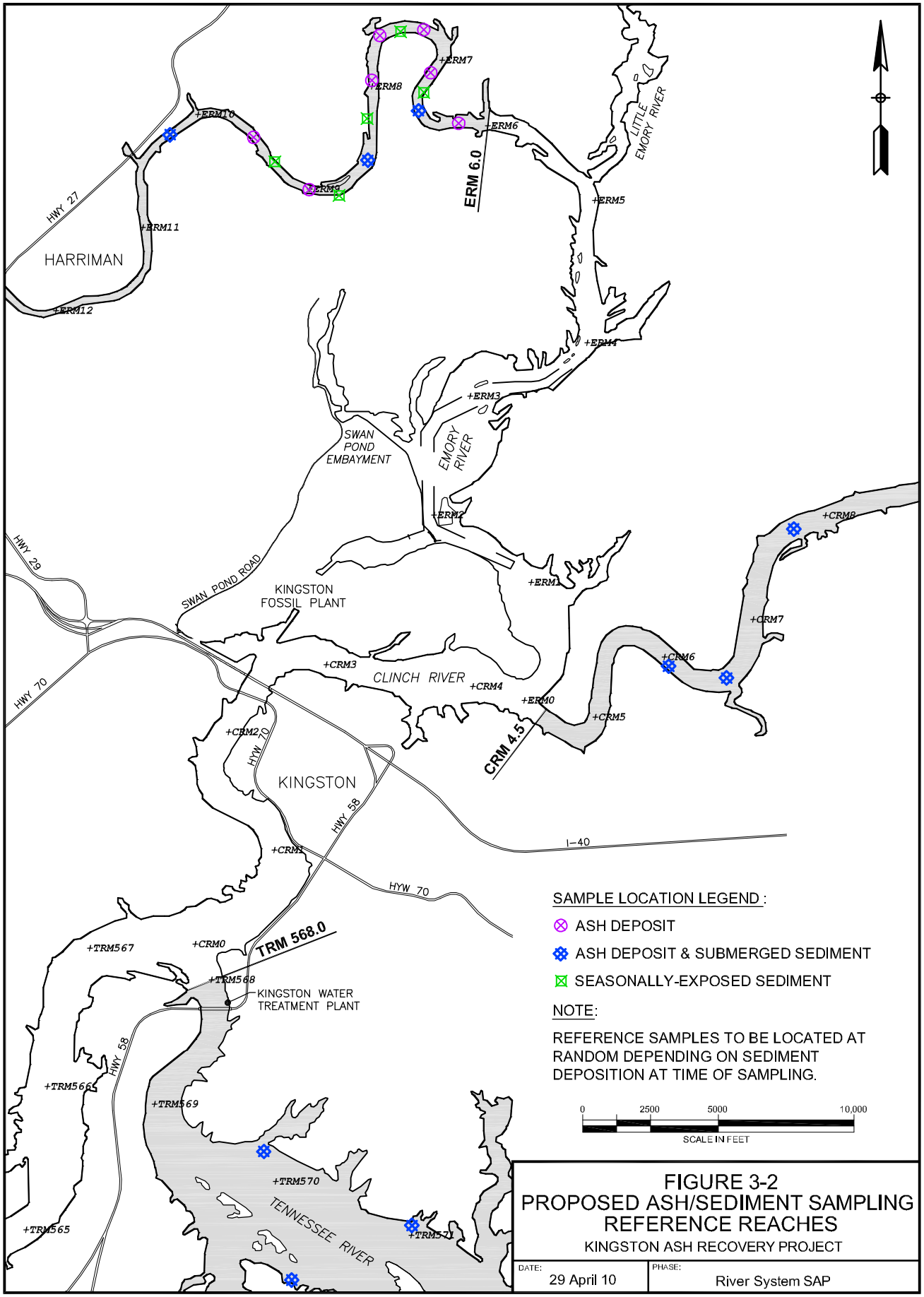


FIGURE 3-1
REACHES OF THE EMORY, CLINCH, AND TENNESSEE RIVERS
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10
PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\058_Fig 3-1 SAP River Reaches.dwg May 05,2010 -bperaro


+ERM7
+ERM8
+ERM10
+ERM6
ERM 6.0
LITTLE EMORY RIVER
+ERM9
+ERM5
HWY 27
+ERM11
HARRIMAN
+ERM12
+ERM4
+ERM3
SWAN POND EMBAYMENT
EMORY RIVER
+ERM2
+CRM8
HWY 29
SWAN POND ROAD
KINGSTON FOSSIL PLANT
+ERM1
+CRM7
+CRM6
+CRM3
CLINCH RIVER
+CRM4
+ERM0
+CRM5
HWY 70
+CRM2
HYW 70
CRM 4.5
KINGSTON
HWY 58
I-40
+CRM1
HYW 70
+TRM567
+CRM0
TRM 568.0
+TRM568
KINGSTON WATER TREATMENT PLANT
HWY 58
+TRM566
+TRM569
+TRM570
TENNESSEE RIVER
+TRM571
+TRM565
SAMPLE LOCATION LEGEND :
ASH DEPOSIT
ASH DEPOSIT & SUBMERGED SEDIMENT
SEASONALLY-EXPOSED SEDIMENT
NOTE:
REFERENCE SAMPLES TO BE LOCATED AT RANDOM DEPENDING ON SEDIMENT DEPOSITION AT TIME OF SAMPLING.
0
2500
5000
10,000
SCALE IN FEET
FIGURE 3-2
PROPOSED ASH/SEDIMENT SAMPLING REFERENCE REACHES
KINGSTON ASH RECOVERY PROJECT
DATE:
29 April 10
PHASE:
River System SAP
T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\059_Fig 3-2 SAP Ref Reaches.dwg Apr 29,2010-bperairo

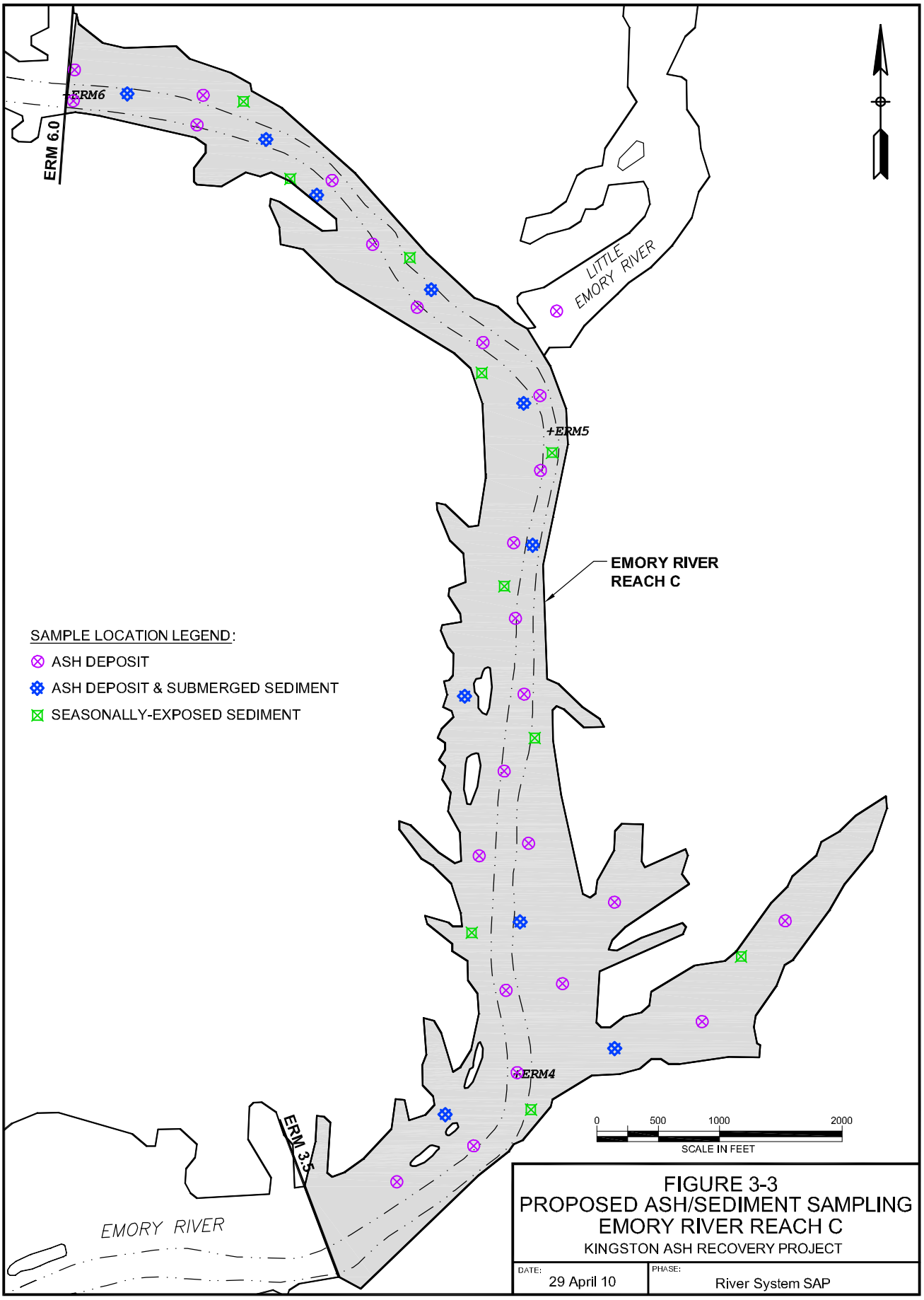


FIGURE 3-3
PROPOSED ASH/SEDIMENT SAMPLING
EMORY RIVER REACH C
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\060_Fig 3-3 SAP Emory C.dwg May 04,2010-bperatro

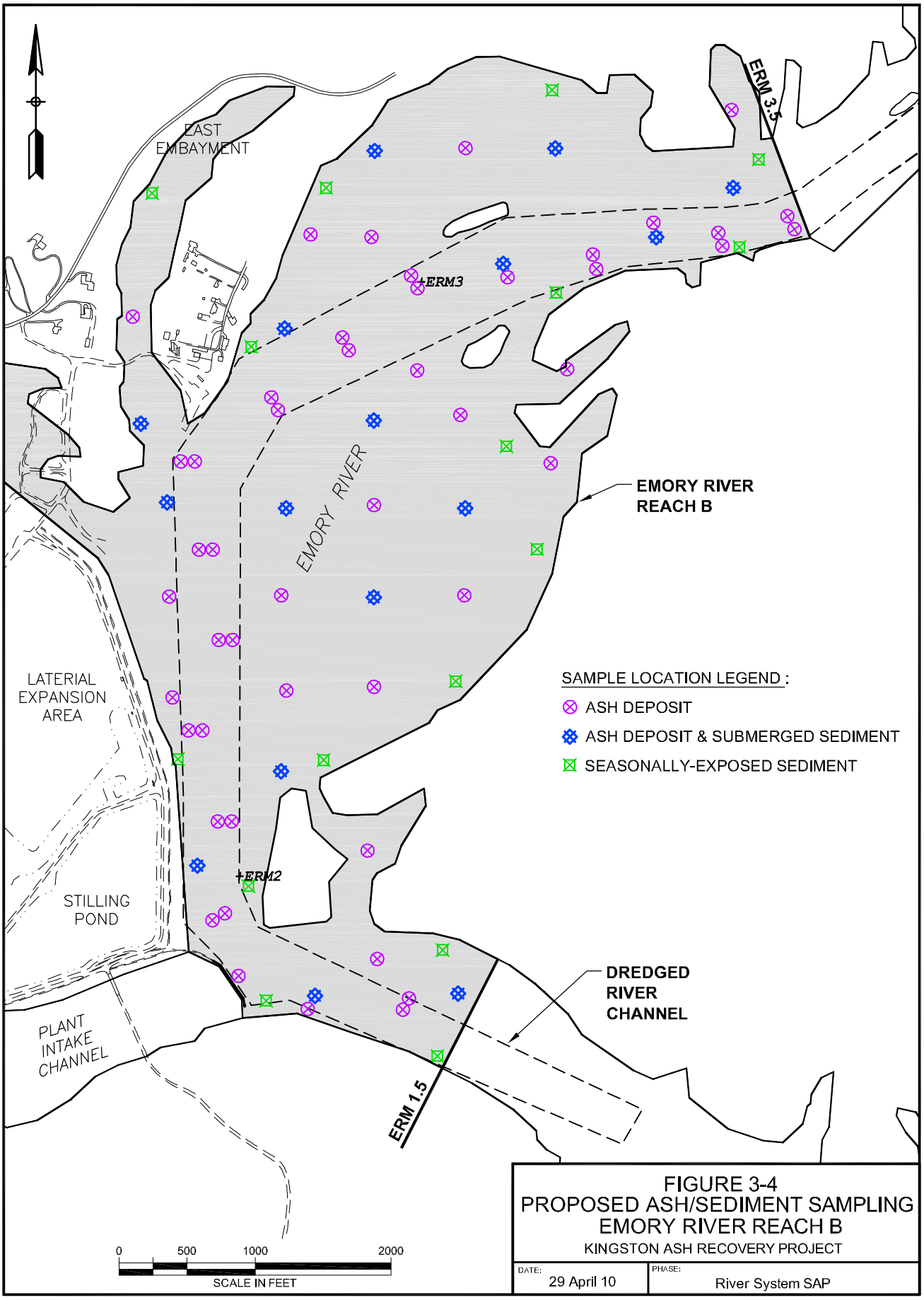


FIGURE 3-4
PROPOSED ASH/SEDIMENT SAMPLING
EMORY RIVER REACH B
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\061_Fig 3-4 SAP Emory B.dwg May 04,2010 -bperaro

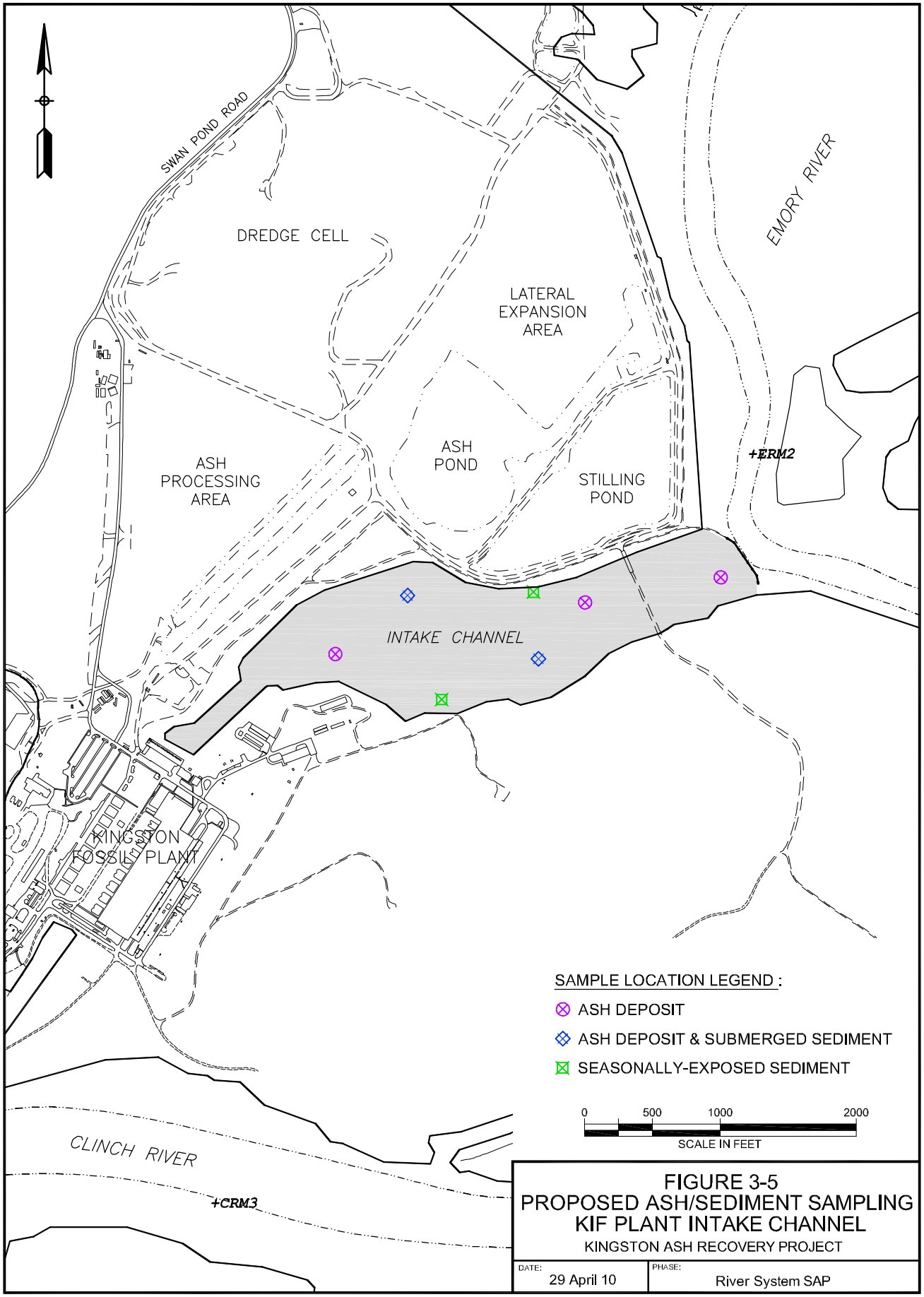
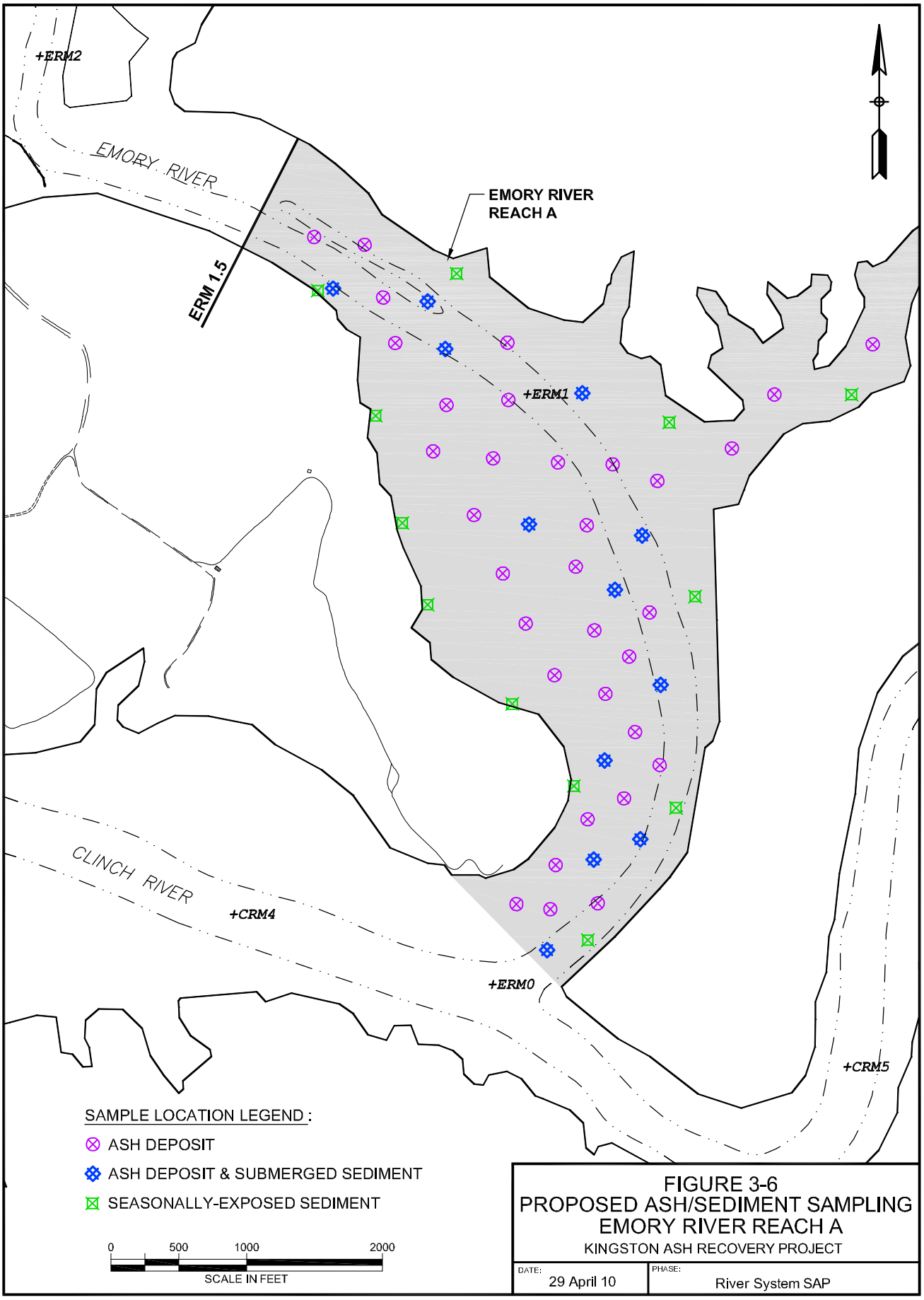


FIGURE 3-5
PROPOSED ASH/SEDIMENT SAMPLING
KIF PLANT INTAKE CHANNEL
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\062_Fig 3-5 SAP Plant Intake.dwg Apr 29,2010 -bperatro


+ERM2
EMORY RIVER
EMORY RIVER
REACH A
ERM 1.5
+ERM1
CLINCH RIVER
+CRM4
+ERM0
+CRM5
SAMPLE LOCATION LEGEND :
ASH DEPOSIT
ASH DEPOSIT & SUBMERGED SEDIMENT
SEASONALLY-EXPOSED SEDIMENT
0
500
1000
2000
SCALE IN FEET
FIGURE 3-6
PROPOSED ASH/SEDIMENT SAMPLING
EMORY RIVER REACH A
KINGSTON ASH RECOVERY PROJECT
DATE:
29 April 10
PHASE:
River System SAP
T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\063_Fig 3-6 SAP Emory A.dwg May 04,2010 -tpperaro

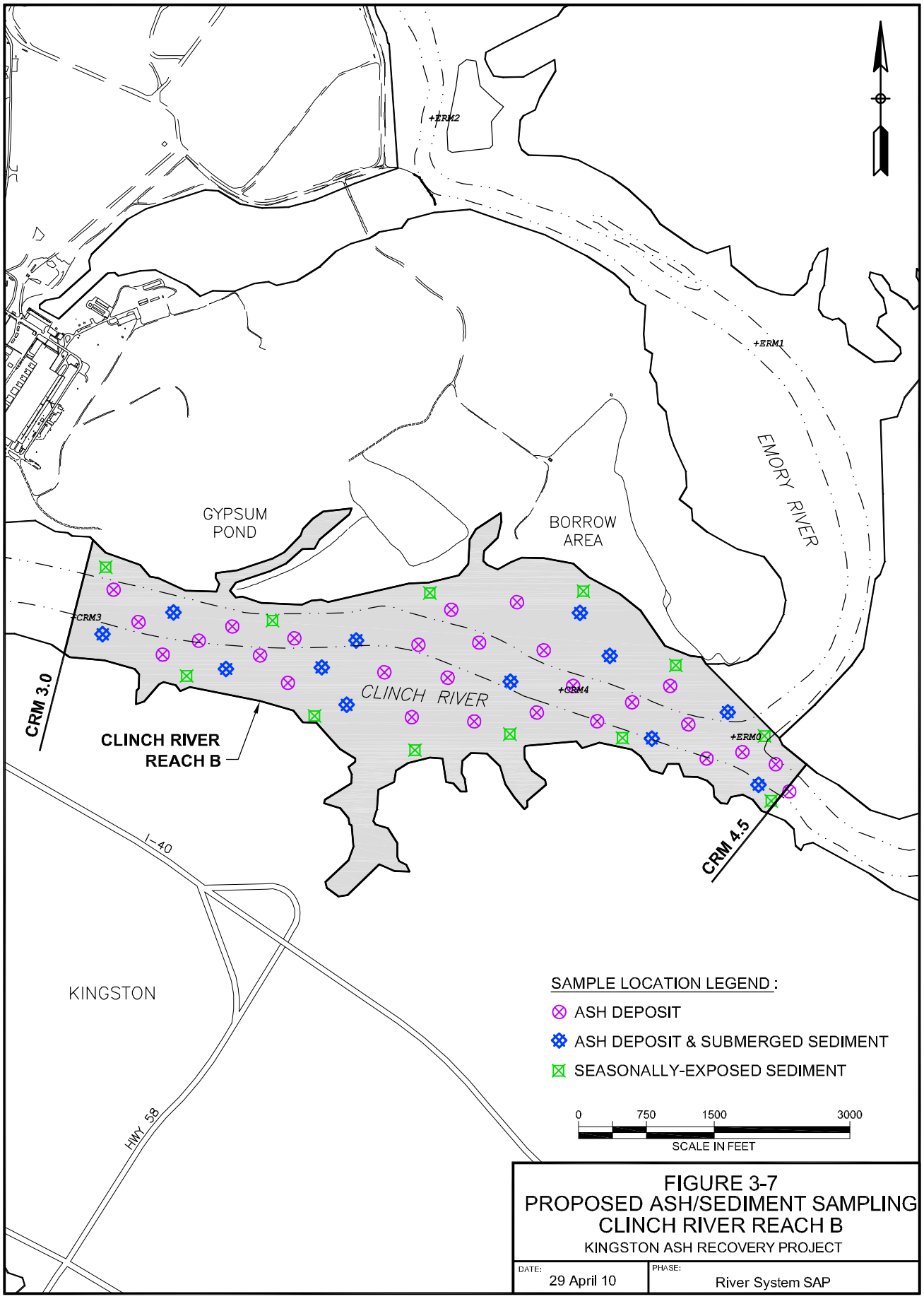


FIGURE 3-7
PROPOSED ASH/SEDIMENT SAMPLING
CLINCH RIVER REACH B
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\064_Fig 3-7 SAP Clinch B.dwg May 04,2010 -bperairo

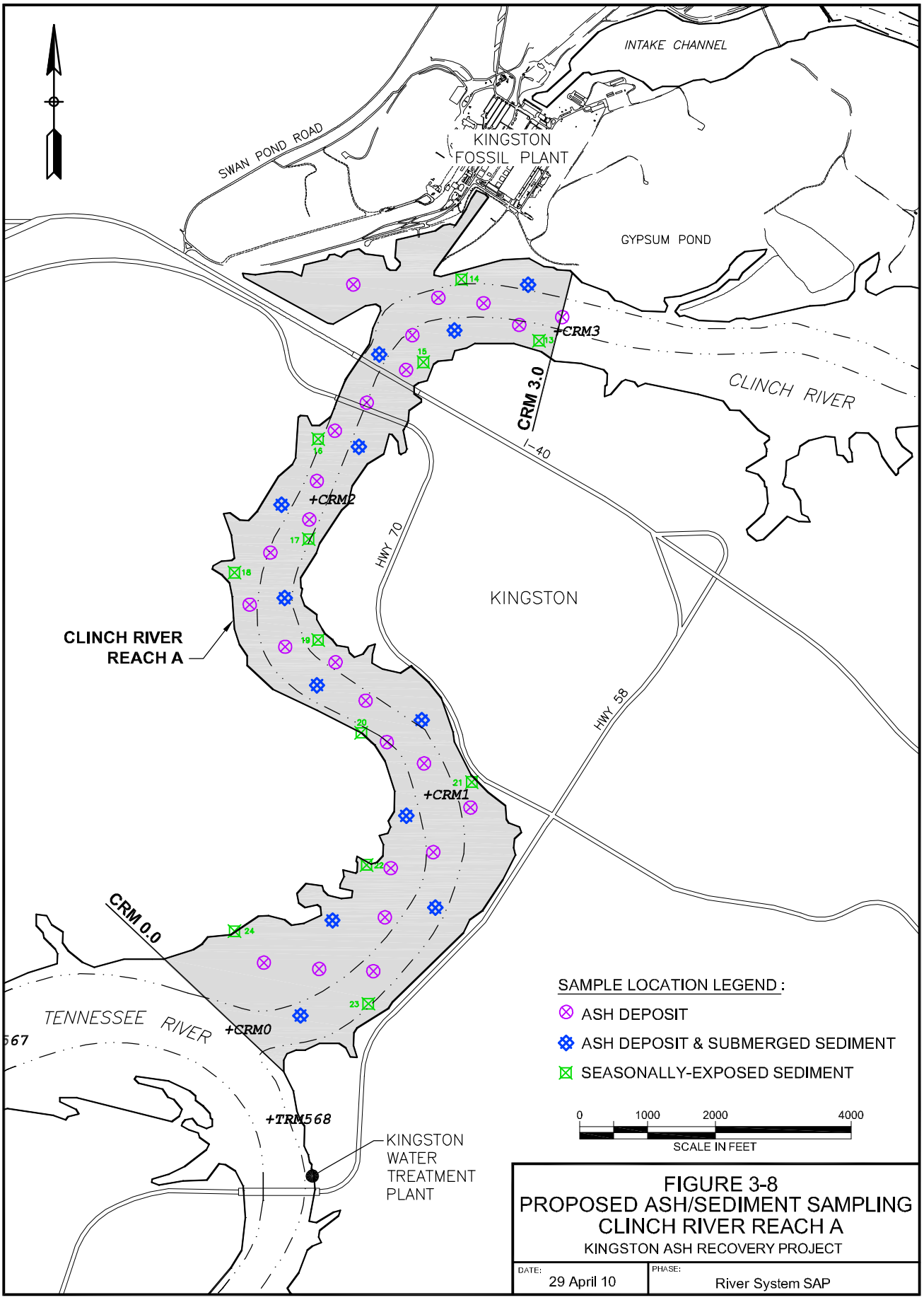


FIGURE 3-8
PROPOSED ASH/SEDIMENT SAMPLING
CLINCH RIVER REACH A
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\065_Fig 3-8 SAP Clinch A.dwg May 05,2010 -bperairo

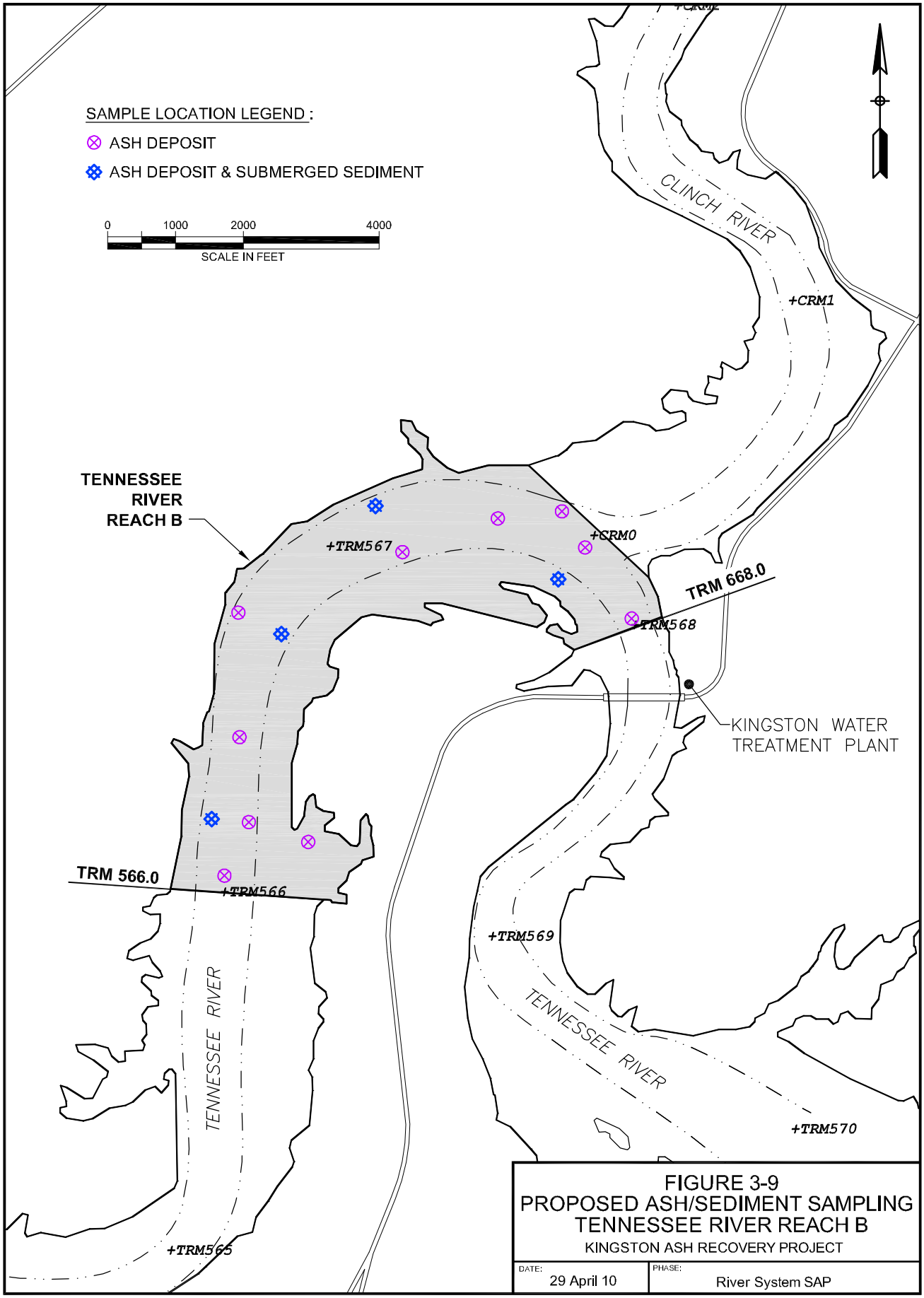


FIGURE 3-9
PROPOSED ASH/SEDIMENT SAMPLING
TENNESSEE RIVER REACH B
KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\066_Fig 3-9 SAP Emory A.dwg May 04,2010 -bperaro

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\067_Fig 3-10 SAP Tennessee A.dwg May 04,2010 -bperatro

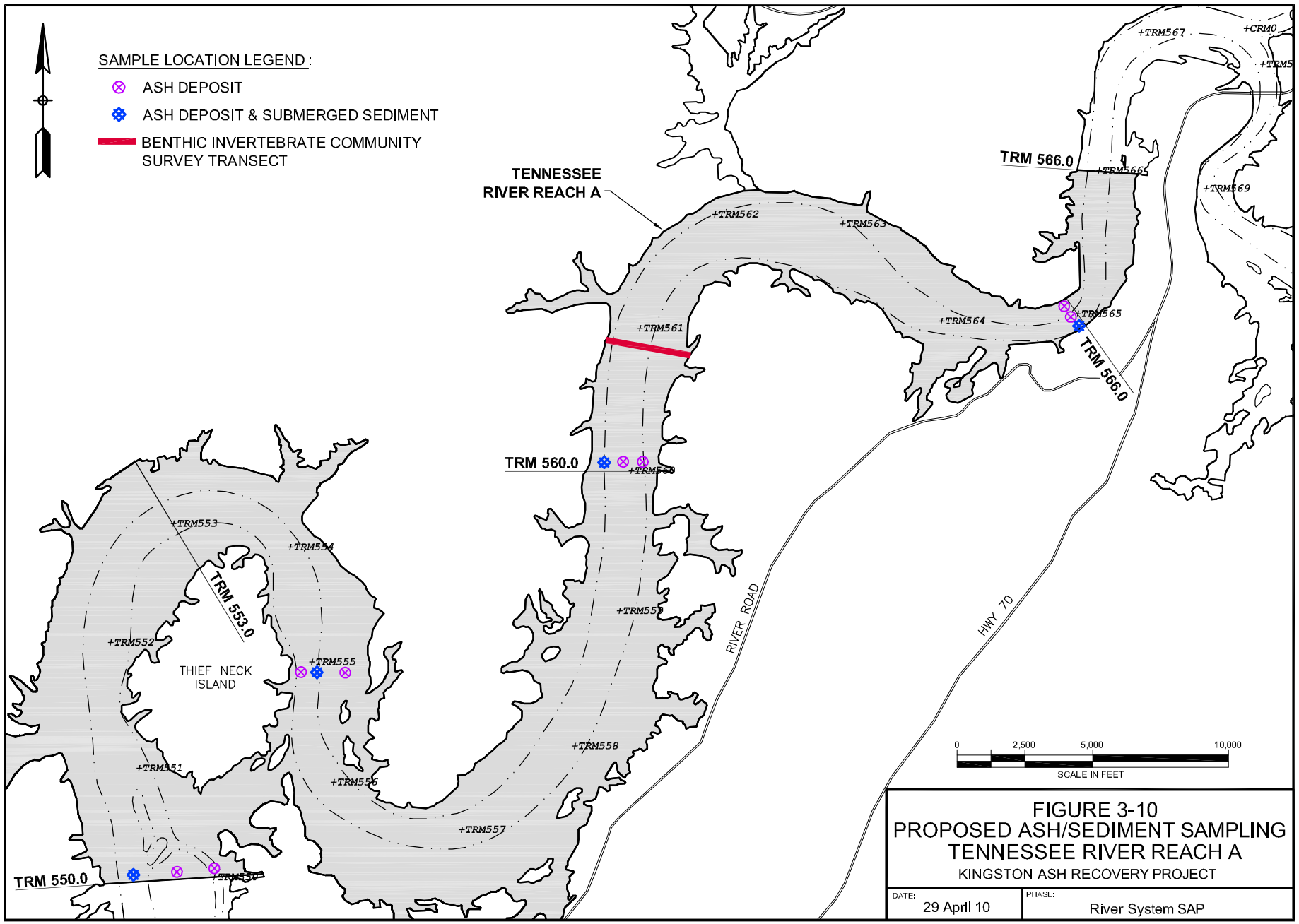


FIGURE 3-10
PROPOSED ASH/SEDIMENT SAMPLING
TENNESSEE RIVER REACH A
KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

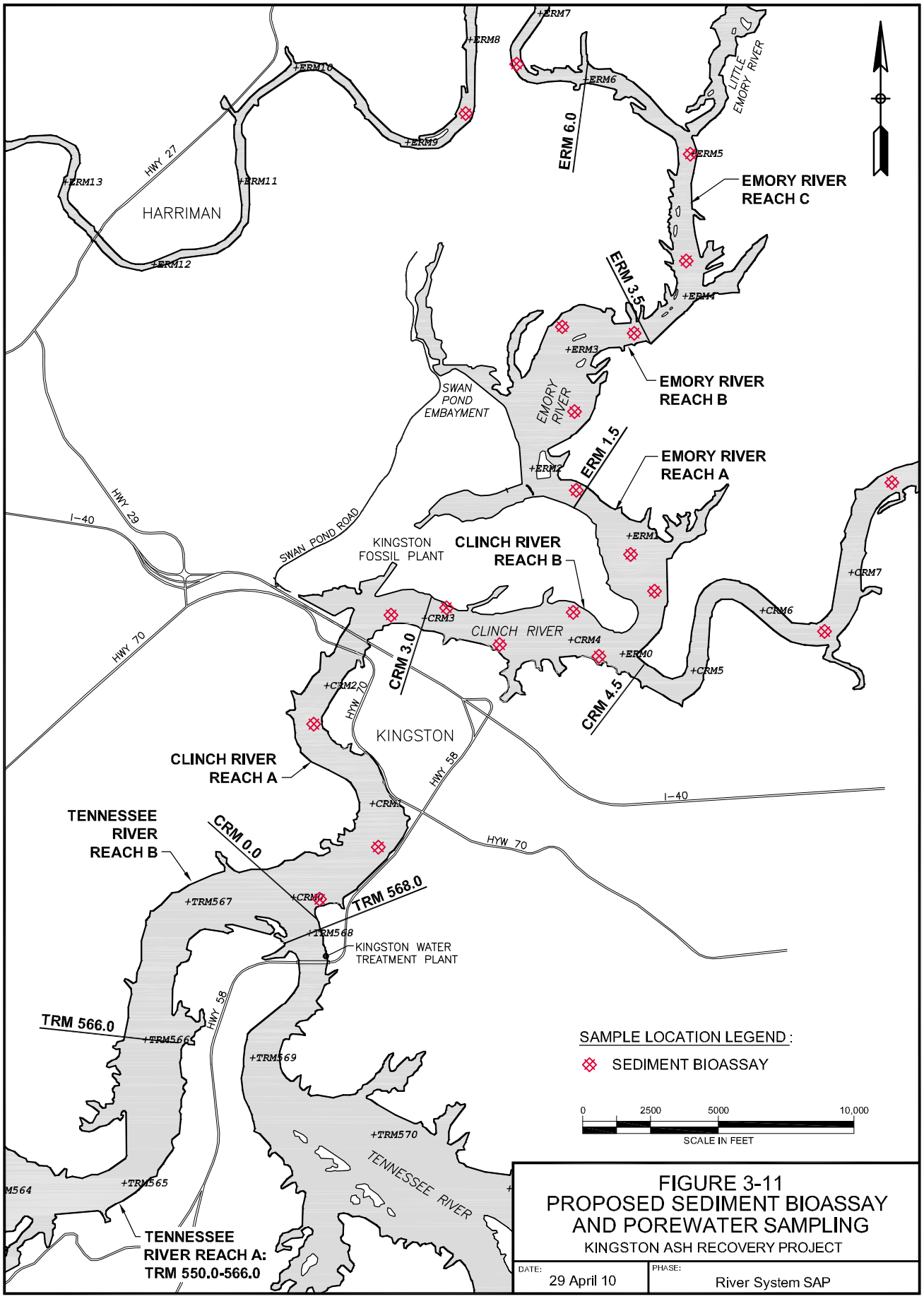


FIGURE 3-11
PROPOSED SEDIMENT BIOASSAY AND POREWATER SAMPLING
KINGSTON ASH RECOVERY PROJECT

DATE:	PHASE:
29 April 10	River System SAP

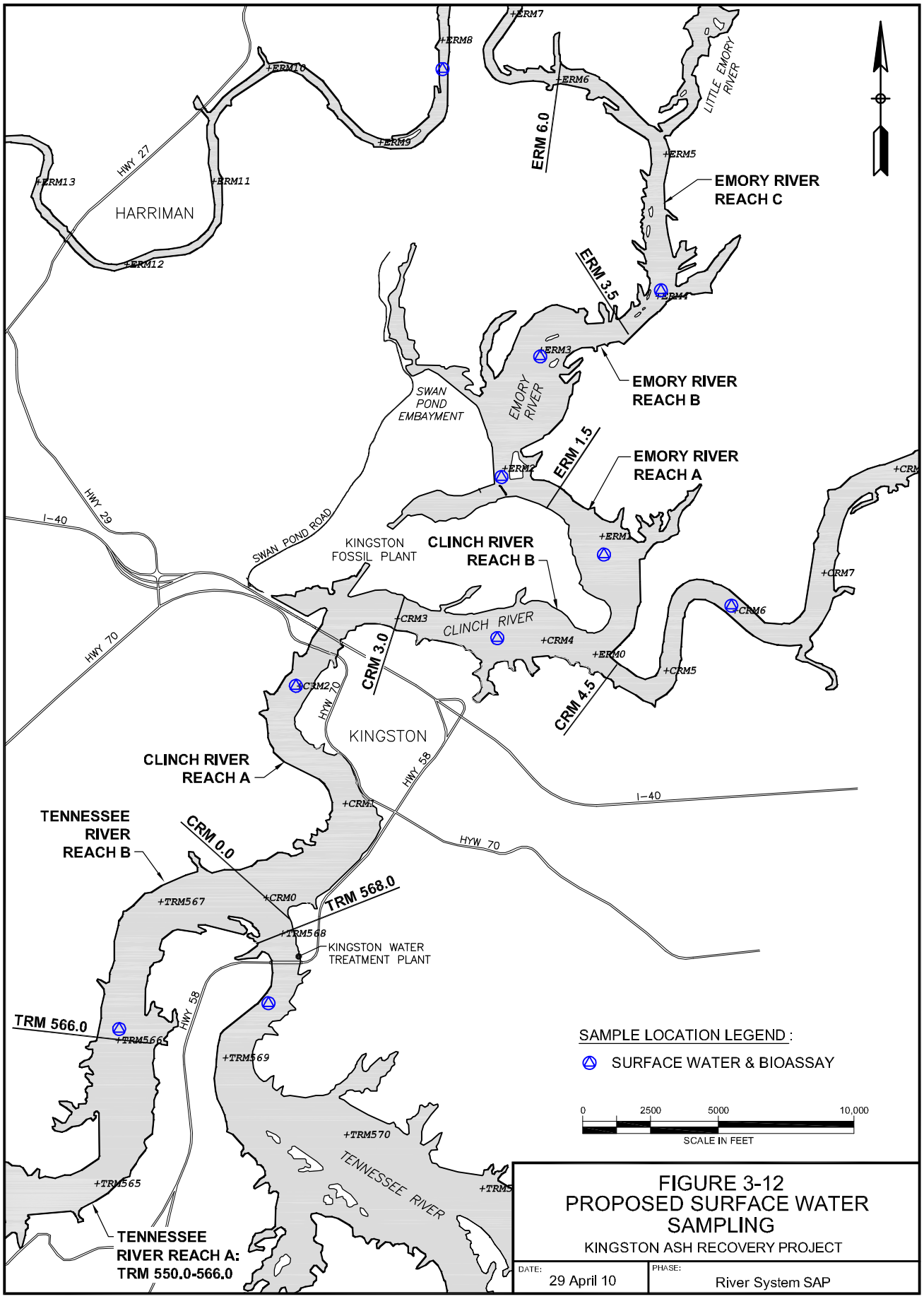


FIGURE 3-12
PROPOSED SURFACE WATER SAMPLING
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\069_Fig 3-12 SAP Surface Water.dwg May 05,2010-bperatro

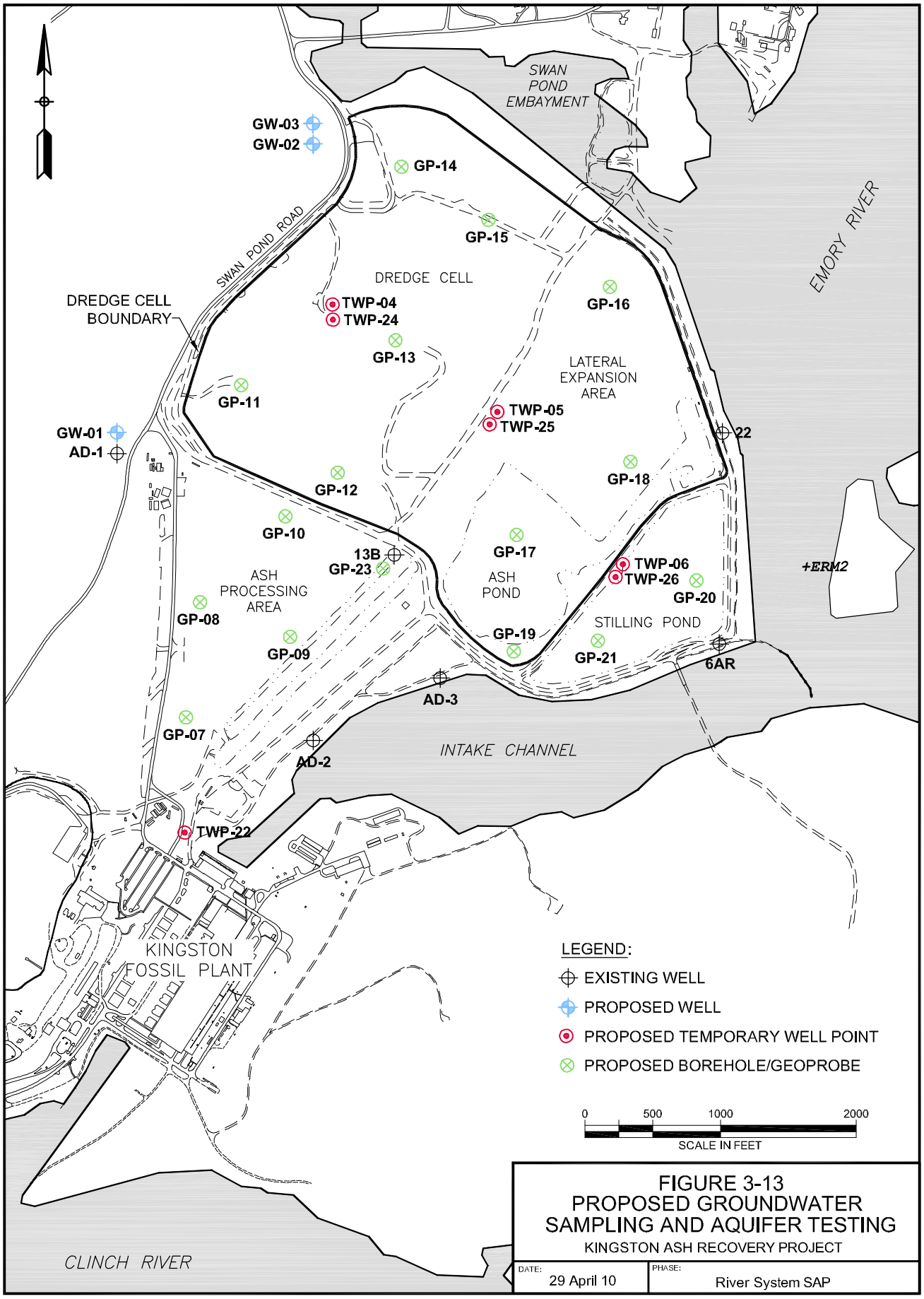


FIGURE 3-13
PROPOSED GROUNDWATER SAMPLING AND AQUIFER TESTING
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10
PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\070_Fig 3-13 SAP Groundwater.dwg May 04,2010 +peraro

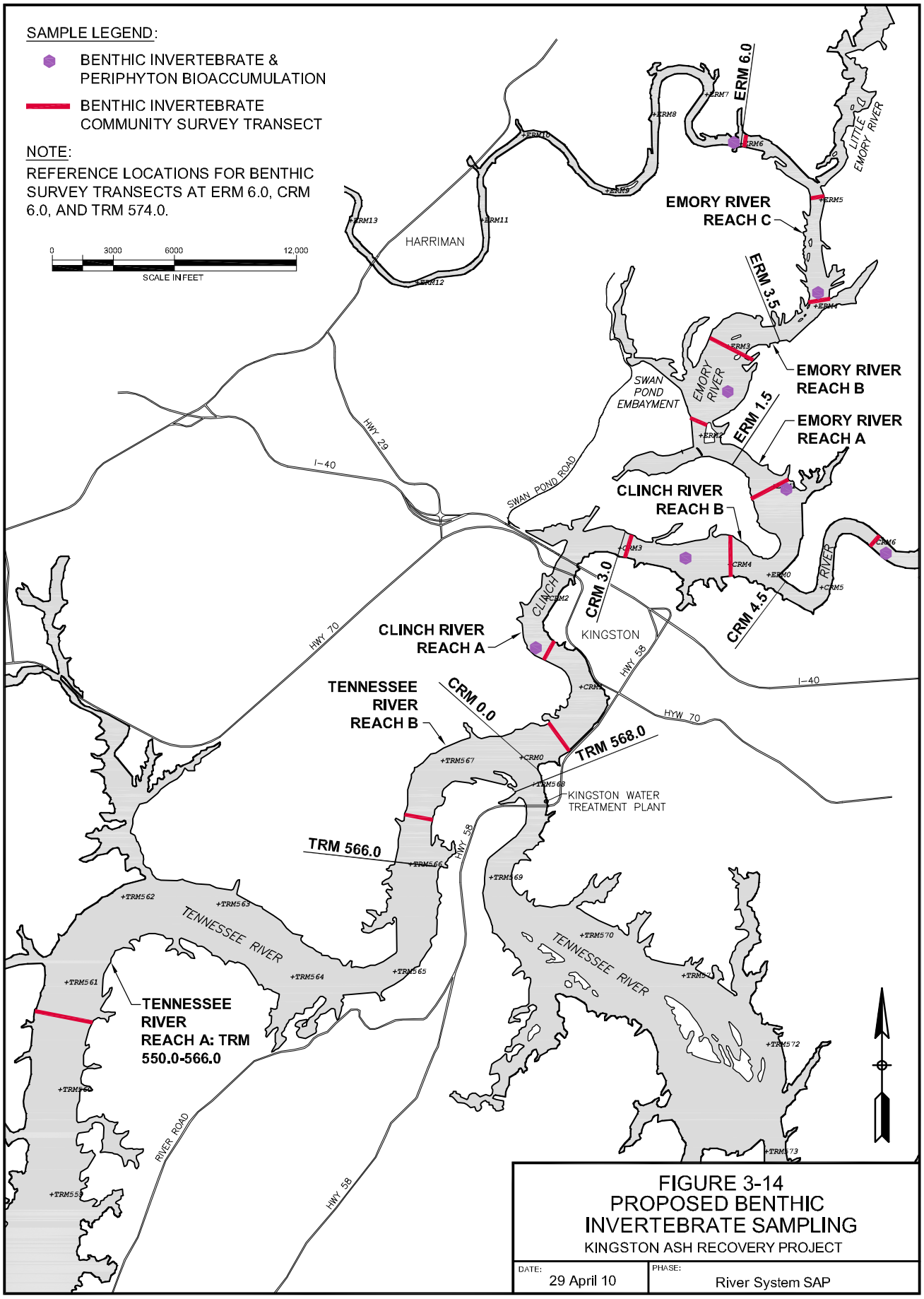


FIGURE 3-14
PROPOSED BENTHIC INVERTEBRATE SAMPLING
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\071_Fig 3-14 SAP Benthic Invertebrates.dwg May 05,2010 -bperatro

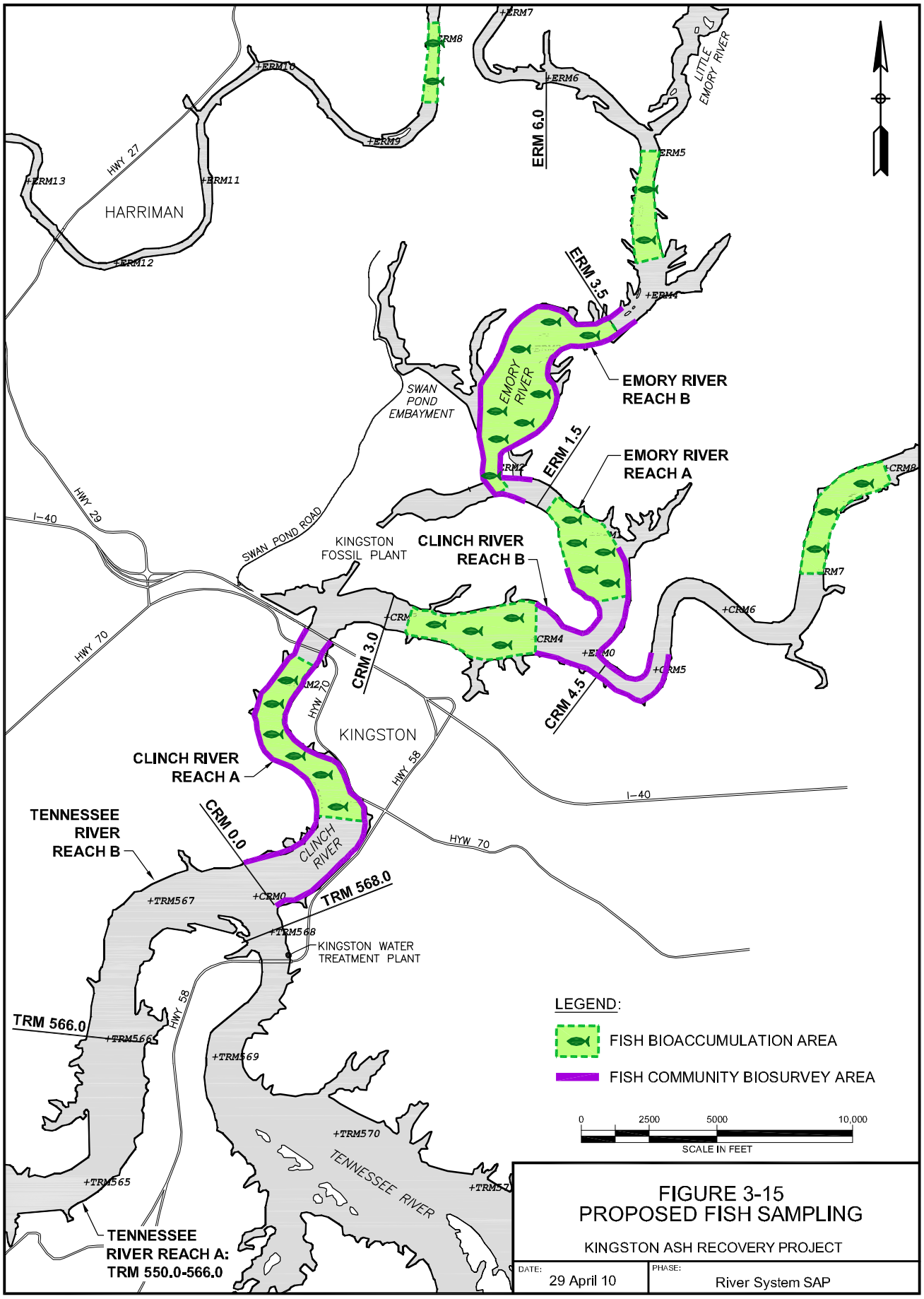


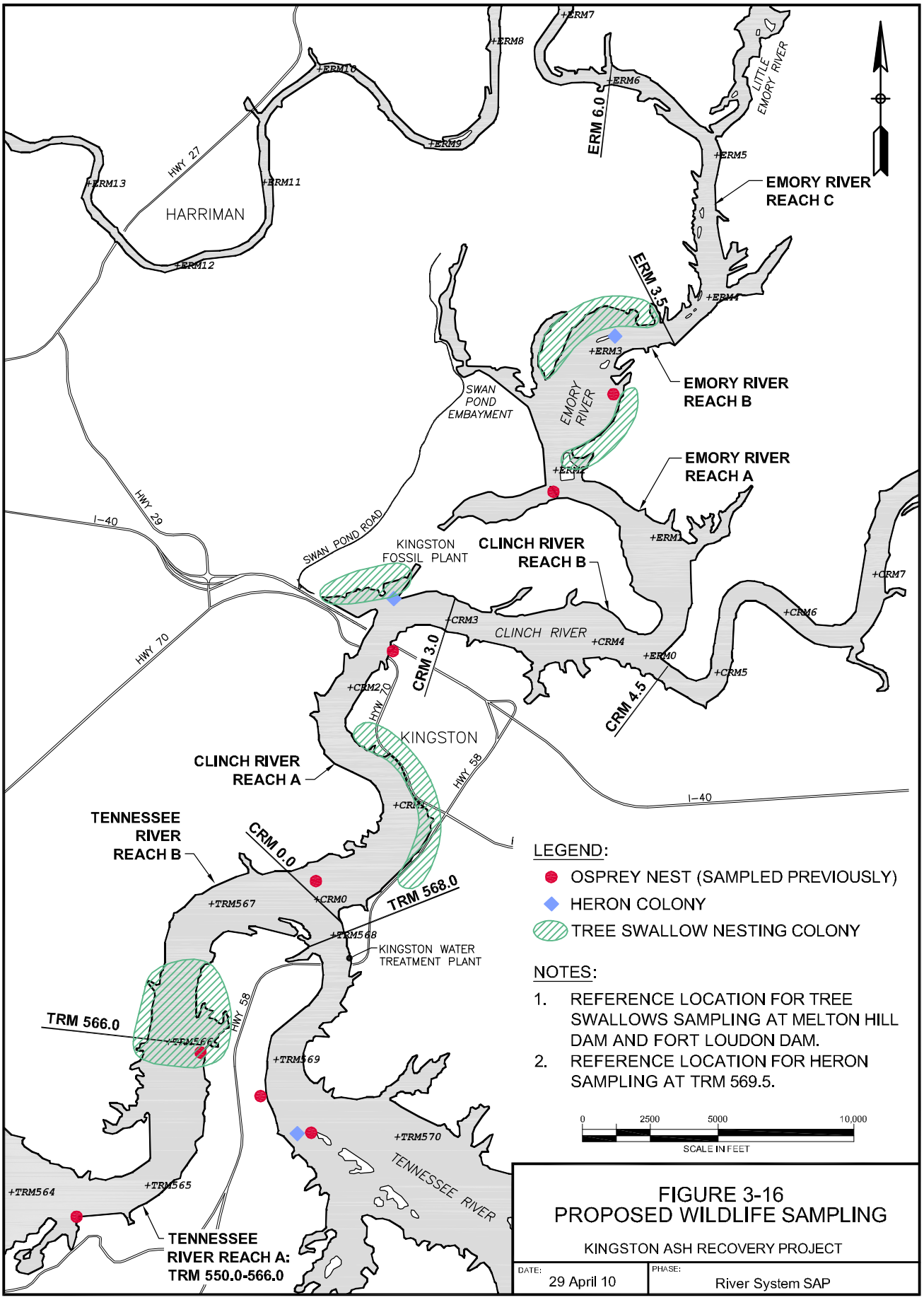
FIGURE 3-15
PROPOSED FISH SAMPLING

KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\072_Fig 3-15 SAP Fish Sampling.dwg May 05,2010 -bperatro


HARRIMAN
HWY 27
+ERM13
+ERM11
+ERM12
+ERM10
+ERM9
+ERM8
+ERM7
+ERM6
ERM 6.0
LITTLE EMORY RIVER
+ERM5
EMORY RIVER REACH C
ERM 3.5
+ERM4
+ERM3
EMORY RIVER REACH B
SWAN POND EMBAYMENT
EMORY RIVER
+ERM2
EMORY RIVER REACH A
+ERM1
HWY 29
I-40
SWAN POND ROAD
KINGSTON FOSSIL PLANT
CLINCH RIVER REACH B
+CRM7
+CRM6
+CRM3
CLINCH RIVER
+CRM4
+ERM0
+CRM5
CRM 3.0
CRM 4.5
HWY 70
+CRM2
HYW 70
KINGSTON
HWY 58
CLINCH RIVER REACH A
+CRM1
I-40
TENNESSEE RIVER REACH B
CRM 0.0
+CRM0
TRM 568.0
+TRM567
+TRM568
KINGSTON WATER TREATMENT PLANT
TRM 566.0
+TRM566
HWY 58
+TRM569
+TRM570
TENNESSEE RIVER
+TRM564
+TRM565
TENNESSEE RIVER REACH A: TRM 550.0-566.0
LEGEND:
OSPREY NEST (SAMPLED PREVIOUSLY)
HERON COLONY
TREE SWALLOW NESTING COLONY
NOTES:
1. REFERENCE LOCATION FOR TREE SWALLOWS SAMPLING AT MELTON HILL DAM AND FORT LOUDON DAM.
2. REFERENCE LOCATION FOR HERON SAMPLING AT TRM 569.5.
0
2500
5000
10,000
SCALE IN FEET
FIGURE 3-16
PROPOSED WILDLIFE SAMPLING
KINGSTON ASH RECOVERY PROJECT
DATE:
29 April 10
PHASE:
River System SAP
T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\073_Fig 3-16 SAP Wildlife Sampling.dwg May 05,2010-bperaro

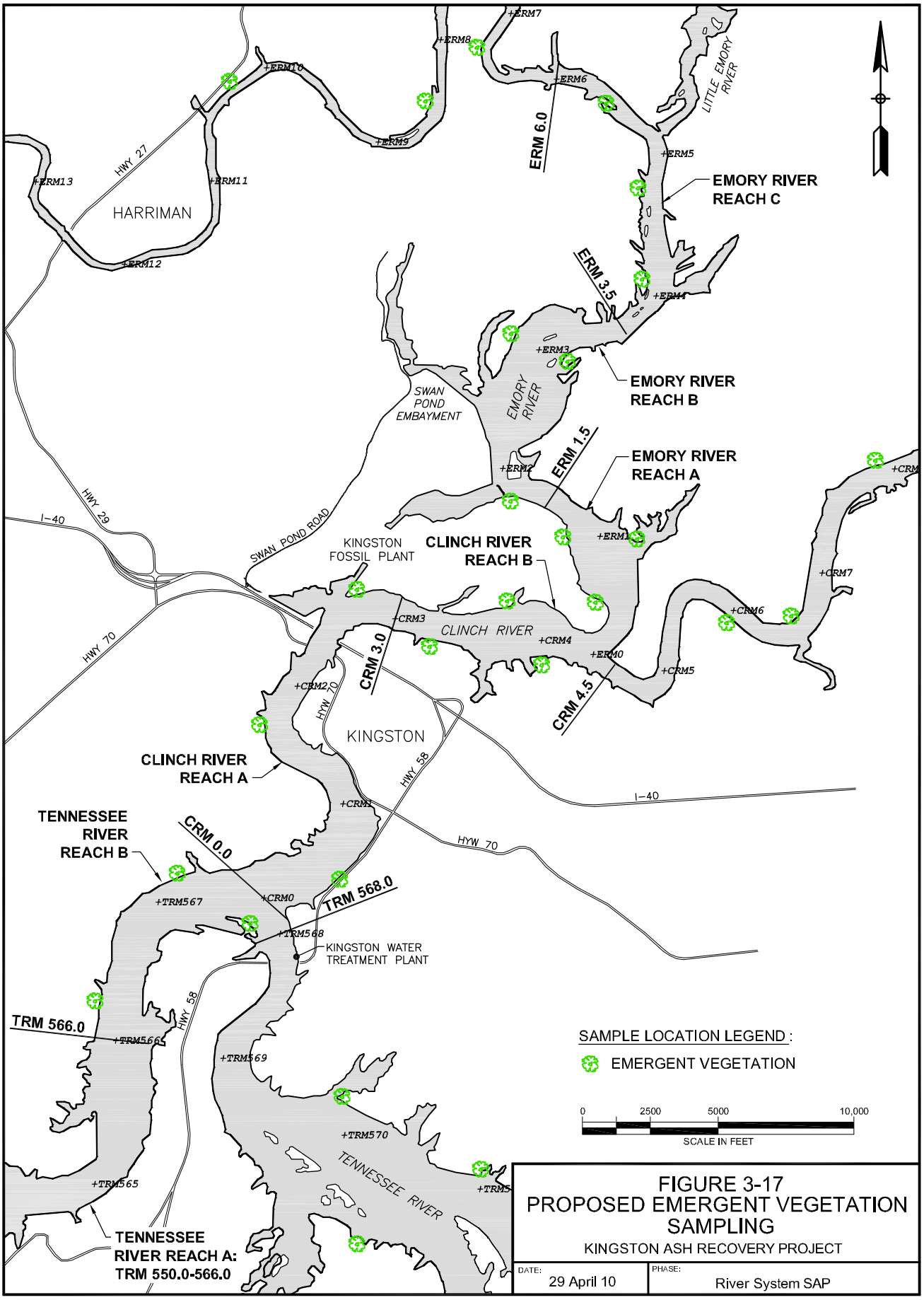


FIGURE 3-17
PROPOSED EMERGENT VEGETATION SAMPLING
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10

PHASE: River System SAP

T:\0002 ENGINEERING\01 DRAWINGS AND SPECS\Report Graphics\River System SAP\074_Fig 3-17 SAP Vegetation Sampling.dwg May 05 2010 -bperaro

Appendix A
Data Quality Objectives for Environmental Media

Appendix A
Data Quality Objectives for Environmental Media

DQO Step	ASH DEPOSITS
State the Problem	Residual ash deposits may be present in the river system following completion of the time-critical removal action, which may serve as a source for further transport downstream, and may therefore need to be removed or contained.
Identify the Decision	The principal study question is: Are there residual ash deposits present of sufficient thickness and volume for effective removal? How far are they distributed, and are they uniformly deposited or in isolated pockets?
Identify Inputs to the Decision	• Depth, thickness, and areal extent of deposits • Degree of mixing or layering (percentage of ash)
Define the Study Boundaries	River study boundaries are areas impacted by the ash spill, shore to shore, upstream to downstream. The following sections are differentiated for data needs: • Background ("reference") locations upstream of ERM 6.0 • Upstream impacted sections, ERM 3.5 to 6.0 • Dredged channel segments (dredge grids), ERM 1.5 to 3.5 • Non-channel sections and coves, ERM 1.5 to 3.5 • Swan Pond Embayment • Intake channel • Downstream impacted sections, ERM 0.0 to 1.5; CRM 0.0 to 3.0; ERM 3.0 to 4.5; and TRM 550.0 to 568.0
Develop a Decision Rule	Ash deposits should be distinguishable from non-ash sediment. If ash deposits cannot be distinguished, then they cannot be removed. Thicknesses of 0.1 ft should be identified to estimate total volume; thickness of 1 ft or more should be identified to estimate volumes available for effective removal. If ash deposits exceed 1 ft in thickness, then removal/containment may be considered viable.
Specify Limits on Decision Errors	The total volume estimate to be determined within 1% (50,000 cy of the 5.4 M cy of ash released). Vertical extent (thickness of deposit) to be determined within 0.1 ft accuracy at any given location. Depth profiles are not critical to volume estimates; depth to be determined to within nearest 2 ft elevation. Horizontal extent to be determined to within 1% of river miles ($^1/_8$-mile of the 13.5 miles impacted); lateral extent to be determined mid-channel and to either side of channel. To guide sampling design, Visual Sampling Plan estimated a minimum of 96 samples needed in impacted Emory River sections using a 660-ft-square ($^1/_8$ mile) size of potential deposits.
Optimize the Design	Two methods for distinguishing ash: 1. Visual observations; visual standards (jars with varying percentages of ash and sediment) to be used to assist field crews and photos of each vibracore to document observations. 2. PLM; field measurements to be used to quantify percentage of ash with confirmatory laboratory PLM measurements on 10% of the total samples as QC check.
	Locations based on regular grid layout in each stream section; locations to be modified based on results of ERDCWES AdH sediment transport modeling to predict areas where deposition occurs.

Appendix A
Data Quality Objectives for Environmental Media

DQO Step	ASH DEPOSITS
Optimize the Design	1. Reference locations upstream of ERM 6.0: 10 locations in Emory River, three in Clinch River, three in Tennessee River to verify absence of ash deposits; coordinate with sediment sampling; locations at random where deposition occurs. 2. Upstream impacted locations ERM 3.5 to 6.0: 30 locations (10 1/8-mile sections, left/center/right of channel); plus additional for larger coves. 3. Dredged channel stream section ERM 1.5 to 3.5: 32 locations; (16 1/8-mile sections, two samples in former dredged grid panels) to check for ash remnants in terraced-shaped dredge grid panels. 4. Non-channel stream section ERM 1.5 to 3.5: 32 locations (16 1/8-mile sections, left/right bank outside of channel); plus additional for larger coves. 5. Swan Pond Embayment: Not available for sampling until after non-time-critical removal action. 6. Intake Channel: five locations selected at random. 7. Downstream Emory River ERM 0.0 to 1.5: 36 locations (12 1/8-mile sections, left/center/right); plus additional for larger coves. 8. Downstream Clinch River CRM 3.0 to 4.5: 36 locations (12 1/8-mile sections, left/center/right). CRM 0.0 to 3.0: 36 locations (12 ¼-mile sections, left/center/right); plus additional for larger coves. 9. Downstream Tennessee River TRM 550.0 to 568.0: 18 locations (9 ½-mile sections, left/center/right); plus additional for larger coves.
	Applicable SOP: • TVA-KIF-SOP-05 *Sediment Sampling*

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Data Quality Objectives for Environmental Media

DQO Step	SEASONALLY-EXPOSED SEDIMENT
State the Problem	Ash mixed with natural sediment contains naturally-occurring metals (e.g., As, Se) and radionuclides (e.g., Ra-226, Th-228). Sediment may also contain legacy constituents (e.g., PAHs, PCBs, pesticides, mercury, Cs-137, Cr) from other sources. These sediments are present on the banks of the river system where seasonal exposure by humans or ecological receptors may occur when the reservoir level is low.
Identify the Decision	The principal study question is: Do levels of hazardous constituents in the seasonally-exposed sediment pose unacceptable risk to human or ecological receptors? If so, what is the geographical location and extent of the impacted sediment?
Identify Inputs to the Decision	• Concentrations of ash-related constituents in seasonally-exposed sediment: metals, radionuclides, and legacy constituents • Exposure parameters to evaluate potential intake of constituents by human receptors • Literature-derived effects values for ecological receptors
Define the Study Boundaries	The human receptor populations of interest are recreational users of the river system. Swimmers would use the river system during summer pool only; exposure will be evaluated for those sediments that are seasonally-exposed during winter months. The ecological receptor populations of interest are benthic invertebrates, aquatic receptors (fish), and riparian-feeding birds, and mammals. The spatial boundaries of the river study are areas impacted by the ash spill, upstream to downstream. Exposures would occur in the upper 6 inches of seasonally-exposed zone when reservoir level is low (winter months). The following sections are differentiated for data needs: • Background (“reference”) locations upstream of ERM 6.0 • Emory River sections, ERM 0.0 to 1.5; ERM 1.5 to 3.5; ERM 3.5 to 6.0 • Clinch River sections, CRM 0.0 to 3.0; CRM 3.0 to 4.5
Develop a Decision Rule	In seasonally-exposed sediment, EPA RSLs for soils are screening criteria (action levels) for human health. If the concentration of an analyte exceeds its RSL then there may be risk for the corresponding receptor, and the analyte will be retained for inclusion in the risk assessment. For ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. Comparisons of sediment concentrations with literature-derived effects values are used as lines of evidence for characterizing risks. If the concentration of an analyte exceeds its literature-derived effects value for benthos, fish, or for incidental ingestion by birds and mammals, then risks to benthic invertebrates, fish, or wildlife may be indicated. If significant risks to benthos, fish, or wildlife are indicated, then one or more remedial goals may be derived for purposes of remedial action evaluation. These remedial goals may be based on constituent concentrations or presence of ash (e.g., thickness, percentage). For chemical concentrations, the null hypothesis for seasonally-exposed sediment is that the average concentration of an ash-related constituent is greater than or equal to its respective action level or effects value. The alternative hypothesis is that the average concentration is less than its respective action level.
Specify Limits on Decision Errors	Concentrations in seasonally-exposed sediment to be determined with detection limits below the RSL or literature-derived sediment effects value. Prior ash sampling has shown that the material is relatively homogenous with normally-distributed constituent concentrations near background levels; seasonally-exposed sediments are expected to demonstrate similar variability.

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Data Quality Objectives for Environmental Media

DQO Step	SEASONALLY-EXPOSED SEDIMENT
Specify Limits on Decision Errors	For chemical concentrations, the probability limit for a false rejection decision is 5%. The probability limit for a false acceptance decision is 20%. This means there is <5% chance that the risks may be calculated to be acceptable when they are actually unacceptable, and <20% chance that the risks may be calculated to be unacceptable when they are actually acceptable. To guide sampling design, Visual Sampling Plan estimated a minimum of 15 samples needed based on the action limits, probability limits, and standard deviations of the ash-related constituents.
Optimize the Design	Samples to be taken using hand auger (or vibracore if during summer pool). Samples to be visually described, particularly the presence of ash; photographs to be taken of each sample location.
	1. Background (reference) locations: five locations to verify levels of constituents in areas not impacted by the ash spill; locations at random up Emory and Little Emory Rivers. For use in comparing with downstream levels of constituents. Also use existing TVA/EPA/TDEC and DOE literature-based levels in typical regional soils for comparison only in uncertainty assessment. 2. Emory/Clinch River sections: Survey for visual evidence of ash will be performed in these sections when the reservoir is at winter pool level. Spatial extent of any visually distinct ash will be estimated. Samples to be selected regardless of particle make-up (ash/native sediment proportion) because purpose is to estimate total residual risk. Locations may be adjusted based on visual survey to target depositional areas or visible ash. a. Upstream Emory River ERM 3.5 to 6.0: 10 locations (4/miles, alternating left/right of channel). b. Dredged channel stream section ERM 1.5 to 3.5: deep water, no samples to be taken. c. Non-channel ERM 1.5 to 3.5: 16 locations (eight/mile, alternating left/right of channel). d. Swan Pond Embayment: Not available for sampling until after non-time-critical removal action. e. Intake Channel: two locations. f. Downstream Emory River ERM 0.0 to 1.5: 12 locations (eight/mile, alternating left/right of channel). g. Downstream Clinch River CRM 3.0 to 4.5: 12 locations (eight/mile, alternating left/right of channel). h. Downstream Clinch River CRM 0.0 to 3.0: 12 locations (four/mile, alternating left/right of channel). 3. Tennessee River sections: no samples to be taken.
	PLM; field measurements to be used to quantify percentage of ash with confirmatory laboratory PLM measurements on 10% of total samples as QC check. Samples to be analyzed for metals. Twenty-five percent of the samples will be analyzed for radionuclides (K-40, Ra-series, Th-series, U-series, Cs-137, Co-60). Although legacy constituents are not site-related, they may contribute to overall risk; therefore, 25% of the samples to be analyzed for Emory River legacy constituents (PAHs, PCBs, pesticides). To evaluate impact on constituent migration and/or toxicity, 25% of the samples to be analyzed for chemical speciation (As, Hg, Se, Cr).
	Applicable SOPs: • TVA-KIF-SOP-05 *Sediment Sampling* (On-Shore Method) • TVA-KIF-SOP-04 *Soil Sampling for Inorganic Analysis*

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DQO Step	SUBMERGED SEDIMENT
State the Problem	Ash mixed with natural sediment contains naturally-occurring metals (e.g., As, Se) and radionuclides (e.g., Ra-226, Th-228). Sediment may also contain legacy constituents (e.g., PAHs, PCBs, pesticides, mercury, Cs-137, Cr) from other sources. These sediments are present within the river system where exposure by ecological receptors (fish, benthos) may occur.
Identify the Decision	The principal study question is: Do levels of ash-related constituents in the sediment pose unacceptable risks ecological receptors? If so, what is the geographical location and extent of the impacted sediment?
Identify Inputs to the Decision	• Concentrations of constituents in sediment: metals, radionuclides, and legacy constituents. • Bioavailability of these constituents (e.g., bioassays, biosurveys of benthos & fish). • Chemical speciation of selected constituents (As, Hg, Se, Cr) and co-factors that affect bioavailability (AVS, organic carbon). • Literature-derived sediment effects values for ecological receptors. • Spatial distribution of constituent concentrations.
Define the Study Boundaries	The human receptor populations of interest are recreational users of the river system. Swimmers would use the river system during summer pool only; exposure will be evaluated for those sediments that are seasonally-exposed during winter months. Therefore, there would be no exposure to continually-submerged sediments for human receptors. The ecological receptor populations of interest are benthic invertebrate communities, particularly burrowing benthos (benthic in fauna), and bottom fish. The spatial boundaries of the river study are areas impacted by the ash spill, upstream to downstream. Ecological exposures are more likely to occur in the upper 0.5 ft of sediment. The following sections are differentiated for data needs: • Background (“reference”) locations upstream of ERM 6.0, CRM 4.5, and TRM 568.0. • Emory River sections, ERM 0.0 to 6.0. • Clinch/Tennessee River sections; CRM 0.0 to 4.5; TRM 550.0 to 568.0.
Develop a Decision Rule	For ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. The following lines of evidence will be considered for characterizing risks: • Comparison of sediment concentrations with literature-derived effects values. If the concentration of an analyte exceeds its literature-derived effects value for benthos or for incidental ingestion by fish, birds and mammals, then this may indicate potential risk. • Comparison of laboratory bioassays (toxicity testing) conducted on site-related sediments with those conducted on reference sediments. If effects on growth or survivability of benthic or epi-benthic invertebrates are observed in site-related sediments, then this may indicate bioavailability and potential risk. • Comparison of biosurveys of benthic invertebrate and fish communities in site-related locations with those in reference locations. If differences in species abundance, richness, or diversity are observed in site-related locations, then this may indicate environmental stress and potential risk.
Develop a Decision Rule	If significant risks to benthic invertebrates or bottom fish are indicated, then one or more remedial goals may be derived for purposes of remedial action evaluation. These remedial goals may be based on constituent concentrations or quantity of ash (e.g., thickness, percentage). The null hypothesis for sediment is that the average concentration of an ash-related constituent is greater than or equal to its respective action level. The alternative hypothesis is that the average concentration of an ash-related constituent is less than its respective action level.

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Data Quality Objectives for Environmental Media

DQO Step	SUBMERGED SEDIMENT
Specify Limits on Decision Errors	Concentrations in sediment to be determined with detection limits below the ecological sediment effects values. Prior ash sampling has shown that the material is relatively homogenous with normally-distributed variations in constituent concentrations near background levels; sediment is expected to demonstrate similar variability. For chemical concentrations, the probability limit for a false rejection decision is 5%. The probability limit for a false acceptance decision is 20%. This means there would be <5% chance that the risks calculated to be acceptable are actually unacceptable; and <20% chance that the risks calculated to be unacceptable are actually acceptable. To guide sampling design, Visual Sampling Plan estimated a minimum of 15 samples needed based on the action limits, probability limits, and standard deviations of the ash-related constituents.
Optimize the Design	Sediment samples for chemical analysis to be taken using vibracore techniques, during the collection of ash deposit samples. Samples to be selected at random to represent a range of particle make-up (ash/native sediment proportion) because purpose is to estimate risk relative to presence of ash. Locations may be adjusted based on visual survey to target depositional areas or higher percentages of ash.
	1. Background (reference) locations: nine locations for use in comparing with downstream levels of constituents to verify levels of constituents in areas not impacted by the ash spill; three upstream in Emory and Little Emory Rivers, three upstream in Clinch River, and three upstream in Tennessee River. 2. Emory River sections: a. Upstream ERM 3.5 to 6.0: 10 locations (four/mile). b. Dredged grids and non-channel ERM 1.5 to 3.5: 16 locations (eight/mile). c. Swan Pond Embayment: not available for sampling until after non-time-critical removal action. d. Intake Channel: two locations. e. Downstream ERM 0.0 to 1.5: 12 locations (eight/mile). 3. Clinch River sections: a. CRM 3.0 to 4.5: 12 locations (eight/mile). b. CRM 0.0 to 3.0: 12 locations (four/mile). 4. Tennessee River sections: TRM 550.0 to 568.0: 36 locations (two/mile).
	Samples to be analyzed for metals. Although direct exposure to radionuclides under water is limited, they may contribute to risk; therefore, 25% of the samples to be analyzed for radionuclides (K-40, Ra-series, Th-series, U-series, Cs-137, Co-60), legacy constituents (PAHs, PCBs, pesticides). In Clinch and Tennessee Rivers only, 25% of the samples to be analyzed also for legacy constituents. Because of impact on bioavailability, 25% of the samples to be tested for TOC. Because of impact on constituent migration and/or toxicity, 25% of the samples to be analyzed for chemical speciation (As, Hg, Se, Cr), alkylated PAHs, and AVS/SEM.
	Whole sediment samples for laboratory bioassays to be collected from eight site and two reference locations in both Emory and Clinch Rivers. Locations to be selected to represent a range of particle make-up (ash/native sediment proportion) because purpose is to estimate bioavailability and risk relative to presence of ash. Samples collected from upper 6 inches using Ponar sampling techniques. Minimum three to five grab samples from each location, to be composited to create one test sample.
	Dilution series laboratory bioassays to be done of ash mixed with reference sediment at following five proportions: 100%, 75%, 50%, 25%, and 0% ash. Each dilution to be homogenized to represent a range of site conditions.

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DQO Step	SUBMERGED SEDIMENT
Optimize the Design	Whole sediment and dilution series bioassay tests to be done using three indicator species: • *H. azteca*; 10- and 28-day tests • *C. dubia*; 7-day tests • *C. tentans*; 10- and 28-day tests Samples of sediment and renewal water to be analyzed for EPA toxicity testing list of parameters, including metals, naturally-occurring radionuclides, legacy constituents (PAHs, PCBs, pesticides), AVS/SEM, TOC, and grain size.
	Benthic invertebrate and fish community surveys to be done at upstream and downstream locations in the Emory River, Clinch River, and Tennessee River. (Discussed under respective benthic invertebrate and fish environmental medium).
	Applicable SOPs: • TVA-KIF-SOP-05 *Sediment Sampling* (Off-shore Method) • TVA-KIF-SOP-04 *Soil Sampling for Inorganic Analysis* • TVA-KIF-SOP-04 *Bulk Ash Homogenization*

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DQO Step	SEDIMENT POREWATER
State the Problem	Submerged sediment mixed with ash contains naturally-occurring metals (e.g., As, Se) and radionuclides (e.g., Ra-226, Th-228). Sediment may also contain legacy constituents (e.g., PAHs, PCBs, pesticides, mercury, Cs-137, Cr) from other sources. Chemical speciation and concentration in sediment interstitial water (porewater) are considered strong indicators of constituent bioavailability to benthic invertebrates that inhabit these sediments.
Identify the Decision	The principal study question is: Do levels of ash-related constituents in the sediment porewater pose unacceptable risks to ecological receptors? If so, what is the geographical location and extent of impacted sediment?
Identify Inputs to the Decision	• Concentrations of constituents in sediment porewater: metals/metalloids, radionuclides, and legacy constituents. • Bioavailability of these constituents (e.g., bioassays, biosurveys). • Chemical speciation of selected constituents (Se, As, Hg, Cr) and co-factors of the sediment and porewater that affect bioavailability (redox, sulfides, chlorides, hydroxides, carbon content). • Spatial and distribution of constituent concentrations.
Define the Study Boundaries	The ecological receptors of interest are benthic invertebrate communities, particularly burrowing benthos (benthic in fauna). The spatial boundaries are areas impacted by the ash spill, upstream and downstream. Exposures for benthos are more likely to occur in the upper 0.5 ft of sediment. The following river sections are differentiated for data needs: • Background (“reference”) locations upstream of ERM 6.0. • Emory River sections, ERM 0.0 to 6.0. • Clinch/Tennessee River sections; CRM 0.0 to 4.5; TRM 550.0 to 568.0.
Develop a Decision Rule	For ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. The following lines of evidence are to be considered for characterizing risks to benthic invertebrates: • Comparison of porewater concentrations with literature derived effects values. If the concentration of an analyte exceeds its literature-derived effects value for benthic invertebrates, then this may indicate potential risk. • Comparison of biosurveys of benthic invertebrate in site-related locations with those in reference locations. If differences in species abundance, richness, or diversity are observed in site-related locations, then this may indicate environmental stress and potential risk. If significant risks to benthic invertebrates are indicated, then one or more remedial goals may be derived for purposes of remedial action evaluation. The null hypothesis for sediment porewater is that the average concentration of an ash-related constituent is greater than or equal to its respective action level. The alternative hypothesis is that the average concentration of an ash-related constituent is less than its respective action level.

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Data Quality Objectives for Environmental Media

DQO Step	SEDIMENT POREWATER
Specify Limits on Decision Errors	Concentrations in sediment porewater to be determined with detection limits below the ecological effects values. Prior ash sampling has shown that the ash is relatively homogenous with normally-distributed variations in constituent concentrations near background levels; sediment porewater is expected to demonstrate similar variability. For chemical concentrations, the probability limit for a false rejection decision is 5%. The probability limit for a false acceptance decision is 20%. This means there would be <5% chance that the risks calculated to be acceptable are actually unacceptable; and <20% chance that the risks calculated to be unacceptable are actually acceptable. Because porewater samples have not been collected at the site, a minimum number of samples cannot be quantitatively estimated using Visual Sampling Plan, but is expected to be similar to sediment and/or surface water (15 to 46 samples).
Optimize the Design	Porewater samples to be collected together with submerged sediment samples for bioassay (toxicity testing); additional sediment quantities are to be collected so as to provide sufficient volume of porewater for testing. Porewater to be extracted from the sediment in the laboratory, and filtered prior to analysis.
	• Background (reference) locations: two locations in both the Emory and Clinch Rivers, co-located with reference sediment locations. • Emory/Clinch River sections: 8 downstream locations in both the Emory and Clinch Rivers, co-located with submerged sediment locations for bioassay (toxicity testing).
	Water quality parameters (temperature, turbidity, DO, pH, ORP, SC) to be measured in lab using multi-analyte programmable data logger. Samples to be analyzed for dissolved (filtered) metals. Samples also to be analyzed for major ions (sulfides, chlorides, hydroxides), hardness as $CaCO_3$, and DOC. Chemical speciation to be measured in sediment and does not need to be repeated for porewater.
	Benthic invertebrate surveys to be done at upstream and downstream locations in the Emory River. (Discussed under benthic invertebrate environmental medium).
	Applicable SOPs: • TVA-KIF-SOP-05 *Sediment Sampling* (Off-Shore Method) • TVA-KIF-SOP-43 *Porewater Collection from Sediment and Ash*

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Data Quality Objectives for Environmental Media

DQO Step	SURFACE WATER
State the Problem	Ash/sediment contains naturally-occurring metals (e.g., As, Se) and radionuclides (e.g., Ra-226, Th-228). Sediment may also contain legacy constituents (e.g., PAHs, PCBs, pesticides, mercury, Cs-137, Cr) from other sources. These constituents may dissolve or become suspended in surface water within the river system where exposure by humans or ecological receptors (benthos, fish, birds, mammals, reptiles, and amphibians) may occur. Conditions occurring after the dredging has been completed may be different than those observed during the ongoing dredging operations.
Identify the Decision	The principal study question is: Do levels of ash-related constituents in surface water pose unacceptable risks to human or ecological receptors? If so, what is the spatial extent of the unacceptable exposures?
Identify Inputs to the Decision	• Total and dissolved concentrations of ash-related constituents in surface water, both pelagic (open water) and epibenthic (river bottom near the sediment-water interface): metals, radionuclides, and legacy constituents. • Exposure parameters to evaluate potential intake of constituents by human receptors. • Bioavailability of these constituents (e.g., bioassays, biosurveys). • Water quality characteristics that may affect bioavailability of constituents (hardness, alkalinity, pH, DO, TSS).
Define the Study Boundaries	The human receptor populations of interest are recreational users of the river system and residential receptors using surface water as a potable water source. The ecological receptor populations of interest are aquatic plant and animal (fish) communities; wildlife populations that feed or drink from the river system. The spatial boundaries are those areas impacted by the ash spill, upstream to downstream. Human exposures are more likely to occur in shallower water (<20 ft deep). Bottom fish may experience different exposures than pelagic fish and wildlife, because constituents diffusing from sediment and ash may be more concentrated near the sediment-water interface. The following sections are differentiated for data needs: • Background ("reference") locations upstream of ERM 6.0. Also upstream of CRM 4.5 and upstream of TRM 568.0 • Emory River sections, ERM 0.0 to 6.0 • Clinch/Tennessee River sections; CRM 0.0 to 4.5; TRM 566.0 to 568.0 There is no temporal boundary of the study. Sampling during time-critical actions during dredging have shown no seasonal variations and therefore data are not required to be collected over more than one sampling season. Temporary high-flow events do not represent prolonged exposure and therefore data are not required to be collected during high-flow events.
Develop a Decision Rule	Available screening levels (action levels) for protection of human receptors include: risk-based screening levels for residential tap water, Tennessee DWS, and Tennessee and Federal WQC for human consumption of water and organisms. If the total (unfiltered) concentration of an analyte exceeds its action level, then there may be risk for the corresponding receptor, and the analyte will be retained for inclusion in the risk assessment.

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DQO Step	SURFACE WATER
Develop a Decision Rule	For ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. The following lines of evidence will be considered for characterizing risks to ecological: • Comparisons of dissolved and total surface water concentrations with literature-derived effects values. If the concentration of an analyte exceeds its literature-derived effects value for benthos, fish, or for incidental ingestion by wildlife (birds and mammals), then this may indicate potential risk. • Comparison of laboratory bioassays (toxicity testing) conducted using site-related surface water with those conducted using reference surface water. If effects on growth or survivability of test species are observed in site-related surface water, then this may indicate bioavailability and potential risk. • Comparison of biosurveys of fish communities in site-related locations with those in reference locations. If differences in species abundance, richness, diversity, age-class structure, or physical condition (abnormalities) are observed in site-related locations, then this may indicate environmental stress and potential risk. If significant risks to benthos, fish, or wildlife are indicated, then one or more remedial goals may be derived for purposes of remedial action evaluation. The null hypothesis for surface water is that the average concentration of an ash-related constituent is greater than or equal to its respective action level. The alternative hypothesis is that the average concentration is less than its respective action level.
Specify Limits on Decision Errors	Concentrations in surface water to be determined with detection limits below the respective DWS or WQC or ecological surface water effects values. For chemical concentrations, the probability limit for a false rejection decision is 5%. The probability limit for a false acceptance decision is 20%. This means there would be <5% chance that the risks calculated to be acceptable are actually unacceptable; and <20% chance that the risks calculated to be unacceptable are actually acceptable. To guide sampling design, Visual Sampling Plan estimated a minimum of 46 samples needed based on the action limits, probability limits, and standard deviations of the ash-related constituents.
Optimize the Design	Surface water samples to be collected at set locations ("fixed stations"), with multiple sampling events at each location to evaluate variability. These fixed station sampling locations to be sampled once each week for 8 weeks to obtain sufficient quantity of data and to demonstrate variability over time. Samples to be collected using Kammerer depth sampler or peristaltic pump. Two samples, both a mid-depth sample and a near-bottom sample, are to be collected at each location.
	TVA has already established fixed station sampling locations, which are to be modified as described below: • Background (reference) locations; one location upstream in the Emory, Clinch, and Tennessee Rivers. Current fixed station sampling locations are established on the Emory River (ERM 12.2), Clinch River (CRM 5.5), and Tennessee River (ERM 568.5). Historical TVA fish health and bioaccumulation studies have upstream reference ranges established at roughly ERM 8.0 and CRM 6.0; therefore, reference locations will be reset to coincide with these locations and with reference sediment locations: ERM 8.0, CRM 6.0, and TRM 568.5.

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DQO Step	SURFACE WATER
Optimize the Design	• Emory River sections: 4 downstream locations total. Current fixed station sampling locations are established at ERM 0.1, 1.75, 2.1, and 4.0; TVA fish studies are conducted at ERM 0.9 and 2.0. Therefore, Emory River locations will be reset to coincide with these locations and to provide representative data across the impacted river reaches following time-critical actions: ERM 1.0, 2.0, 3.0, and 4.0. • Clinch River sections: two downstream locations total. Current fixed station sampling locations are established at CRM 0.0, 2.0, and 4.0; TVA fish studies are conducted at about CRM 1.5. Therefore, Clinch River locations will be reset to provide representative data across the river reaches, outside of immediate effects of Emory River or Tennessee River waters: CRM 2.0 and 3.5. • Tennessee River section: one downstream location. Current contingent fixed station sampling location is established at TRM 563.5, which is to be reset to coincide with sediment sampling locations in the Tennessee River: TRM 566.0.
	Samples of surface water to be analyzed for metals. Because of impact on bioavailability, samples to be tested also for TSS, TDS, DOC, and hardness as $CaCO_3$. Samples to be tested in the field for DO, SC, and Temperature. Twenty-five percent of the samples to be analyzed for radionuclides (K-40, Ra-series, Th-series, U-series). In Clinch Tennessee and Rivers only, 25% of the samples to be analyzed also for legacy constituents Cs-137 and Co-60. Because of impact on constituent migration and/or toxicity, 25% of the samples to be analyzed for chemical speciation (As, Hg, Se, Cr) – dissolved (filtered) analysis only.
	Surface water samples for laboratory bioassays to be collected from four sites and one reference location in the Emory River. Locations to be collocated with fixed station sampling locations: ERM 1.0, 2.0, 3.0, 4.0, and 8.0. Surface water bioassay tests to be done using two indicator species: • *C. dubia*; 7-day tests • *P. promelas* (larval fathead minnow); 7-day tests
	Fish community surveys to be done at upstream and downstream locations in the Emory River, Clinch River, and Tennessee River. (Discussed under fish environmental medium).
	Applicable SOPs: • TVA-KIF-SOP-01 *Surface Water Sampling* • TDEC document *Quality System Standard Operating Procedure (SOP) for Chemical and Bacteriological Sampling of Surface Water*

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DQO Step	GROUNDWATER
State the Problem	Naturally-occurring metals (e.g., As, Cr, Hg, Se) and radionuclides (e.g., Ra-226, Th-228) within the ash may be mobilized as a result of infiltration of precipitation, and may be transported downgradient in the groundwater to the Emory River, where exposure by humans or ecological receptors (fish, benthos) may occur.
Identify the Decision	The principal study question is: Does the flux of ash related constituents from groundwater to the Emory River result in unacceptable risk to human or ecological receptors?
Identify Inputs to the Decision	• Stratigraphy of ash deposits, alluvium, residuum and bedrock within groundwater model domain. • Water level measurements for monitoring wells, piezometers and surface-water reference points within study area to support flow model development and calibration. • Flow rate: Percolation through the clay cap and landfilled ash to groundwater would control leachate generation rate. Hydraulic conductivity, effective porosity, total porosity, formation thickness, and hydraulic gradients in the sand layer beneath the ash would control the lateral flow rate. Piezometric data are available across the site in ash and sand; bedrock flow is not well characterized, but upward gradients are known to exist. • Geochemical attenuation properties of alluvium and residuum affecting fate and transport, including leachability of ash and soil attenuation capacity. • Concentrations of ash-related constituents in groundwater, both in contact with ash and in each formation: As, Se, Cr, Hg, Ra-226, and Th-228 represent constituents in ash with preliminary screening risks to either human health or ecological receptors. Concentrations in the ash are well known. Concentrations in the groundwater in contact with the ash are largely unknown; concentrations in the underlying alluvial sand layer and bedrock are limited to a few well locations. • Concentrations within the mixing zone within the river; river flow rate and mixing zone would define the resulting concentrations. River flow is known (low-flow and storm frequency flow). Mixing zone may be modeled.
Define the Study Boundaries	The spatial boundaries of the study are Pine Ridge upgradient of the Dredge Cell, the Dredge Cell north to Swan Pond Embayment, and the Ash Processing Area east to the Emory River; including the Ball Field and Stilling Pond (Dike C). Subsurface boundary extends to bedrock upgradient of the Dredge Cell and along Dike C, where groundwater discharges to the river. Boundaries of the groundwater model domain encompass the study area and extend beyond study boundaries to conform to natural hydrologic boundaries, such as, the Pine Ridge topographic divide and the Emory River. The temporal boundaries of the study are seasonal hydrologic changes that would affect flux; these include (1) wet season and winter-pool reservoir stage (February thru April) and, (2) dry season and summer-pool reservoir stage (July thru September). Baseline conditions (no clay cap) are not to be defined, since the Dredge Cell and Ash Pond are being capped under a separate non-time-critical removal action; conditions are to be defined for steady-state leaching through a clay-capped cell. The receptor populations of interest are human populations using the Emory River for recreational use or as a potable water supply, and benthic and aquatic biota in the Emory River.

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DQO Step	GROUNDWATER
Develop a Decision Rule	Screening levels (action levels) for protection of human receptors include: risk-based screening levels for residential tap water, Tennessee DWS or Federal Maximum Contaminant Levels, and Tennessee and Federal WQC for human consumption of water and organisms. If the predicted concentration of an analyte in groundwater or surface water exceeds its action level, then this may indicate potential risk to the receptor. For ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks to benthic and epi-benthic organisms. Comparisons of predicted surface water concentrations with literature-derived effects values are used as one line of evidence. If the predicted concentration of an analyte in sediment porewater or epi-benthic surface water exceeds its literature-derived effects value for benthos, fish, or for incidental ingestion by wildlife (birds and mammals), then this may indicate potential risk. The null hypothesis for groundwater is that the average modeled concentration of an ash-related constituent is greater than or equal to its respective action level. The alternative hypothesis is that the average modeled concentration is less than its respective action level.
Specify Limits on Decision Errors	Screening against action levels requires modeling concentrations; because benthic organisms in sediment would be potentially exposed to groundwater concentrations at the point of discharge, concentrations in groundwater are to be determined with detection limits below the action levels. Potentiometric heads is to be determined within 0.1 ft; however gradients are likely less variable than hydraulic conductivities. Hydraulic conductivities are to be determined within one order of magnitude, since the natural variations within the formations are likely greater. Spatial variations are not expected to greatly affect model results; at least one upgradient and three downgradient sampling locations are appropriate to determine expected error range; locations are to be acceptable for longer-term monitoring of the Dredge Cell.
Optimize the Design	Existing data and existing piezometers and wells to be used to maximum extent possible. New temporary well points and/or wells to be installed as follows: • Three new permanent wells to be installed on Pine Ridge: two upgradient bedrock wells, and one upgradient residuum well. Wells to be drilled using hollow-stem auger and air rotary techniques. Well casings to be 2-inch-dia. Sch.40 PVC with 10-ft slotted screens and threaded couplings. • Seven new temporary well points to be installed within the Dredge Cell, Ash Pond, Stilling Pond, and Ash Processing Area. Temporary well points to be installed using hollow-stem auger. Temporary well point casings to be 2-inch-dia. Sch. 40 PVC with prefabricated slotted screens and threaded couplings; temporary wells to be closed after field testing in accordance with TDEC r1200-4-9.16. • 16 new temporary boreholes to be installed within the Dredge Cell, Ash Pond, Stilling Pond, and Ash Processing Area. Boreholes to be installed using either hollow-stem auger or direct push technology (Geoprobe®) techniques. Boreholes to be closed after field testing in accordance with TDEC r1200-4-9.16.
	The stratigraphy of ash deposits, alluvium, residuum, and bedrock within groundwater model domain is to be characterized. Approximately 175 existing borings plus the new boreholes to be used to provide adequate stratigraphy in the Ash Landfill vicinity. The additional well boreholes on Pine Ridge to be used to characterize overburden lithology, thickness, and top of bedrock elevation.

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Data Quality Objectives for Environmental Media

DQO Step	GROUNDWATER
Optimize the Design	Two KIF site-wide temporal snapshots of water levels are to be conducted: once during the higher precipitation period (February thru April) and once during the lower precipitation period (August thru October) to encompass the range of expected water levels. Water levels to be measured across all hydrostratigraphic units from both new and existing piezometers/wells/surface water sites. Locations of existing and new water level measurement points to include: coal ash (60 existing locations), alluvium (88 locations), residuum (4 locations), bedrock (14 locations), and surface water (4 locations). • Flows in river at time of water level sampling to be obtained from TVA River Operations (direct measurement not required). • Natural upward seepage (direction and magnitude of vertical gradient) expected from bedrock to alluvial aquifer to be quantified by measuring hydraulic heads in 8 paired piezometers and/or temporary well points screened separately in bedrock and alluvial aquifers. Pressure transducers with data recorders to be installed in each well to allow continuous measurements for at least one month. Frequency of monitoring thereafter to depend on initial monitoring results
	Total porosity, effective porosity, dry bulk density, and moisture content to be measured by taking undisturbed samples using a thin-walled sampler (ASTM D1587). • Samples of residuum to be collected from the two new upgradient well boreholes; • Samples of alluvium (both clay-silt and sand facies) to be collected from four of the temporary well boreholes located inside the Dredge Cell/Ash Pond and from one borehole/Geoprobe location near well 13B. Ends of sample collection tubes to be sealed by coating with paraffin wax, Saran plastic wrap, or plastic end caps secured with tape. Sample temperature to be maintained at approximately 4º C. Sample packaging for shipment to laboratory to follow ASTM D 4220 to prevent physical damage.
	Hydraulic conductivity (permeability) of coal ash, alluvial clay-silt unit, alluvial sand unit, residuum, shale and limestone of the Lower Conasauga Shale to be characterized using in situ horizontal hydraulic conductivity (K_h) tests. Emphasis to be on K_h measurements since horizontal seepage is expected to be the dominant mode of contaminant transport. K_h tests to be performed in accordance with ASTM D 4050 using one or more of the following methods: single- or multiple-well pumping tests, slug tests, or borehole flowmeter tests. • Coal ash permeability to be taken from approximately 47 existing hydraulic conductivity measurements available from the KIF site. No further data required. • Alluvial clay-silt unit permeabilities to be taken from a mixture of previously published site values (8 for K_h, 6 for K_v), and borehole flow metering results (for K_h) of three new temporary well points located within the Dredge Cell/Ash Pond. • Alluviual sand unit permeabilities to be taken from a mixture of previously published site values (5 for K_h, 3 for K_v), and planned borehole flow meter testing (for K_h) of four new temporary well points located the Dredge Cell/Ash Pond and southwest of the Ash Processing Area. • Residuum hydraulic conductivity values to be taken from aquifer testing on existing upgradient well AD1, existing downgradient well AD2, and the new residuum upgradient well. Aquifer tests (for K_h) to be performed at each well; one undisturbed soil sample to be collected from the new upgradient well borehole for laboratory analysis of K_v. • Bedrock hydraulic conductivity values to be taken from previously published site values (3 for K_h) and aquifer testing of the two new upgradient bedrock wells on Pine Ridge (single-well pump testing or slug test) and three new temporary well points (by borehole flow metering).

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DQO Step	GROUNDWATER
Optimize the Design	Ash leaching behavior to support groundwater transport modeling to be characterized by collecting eight ash composites samples for laboratory sequential batch extraction and/or column leaching tests. Six of the ash samples to be collected within the Ash Landfill and Stilling Pond areas; the remaining two ash samples to be obtained from the Ash Processing Area. Ash samples to be obtained using hollow-stem auger drilling method with plastic-lined split-barrel sampler with sample catch on lower end (ASTM D1586). Ends of sample collection liners to be sealed by coating with paraffin wax, Saran plastic wrap, or plastic end caps secured with tape. Sample temperature to be maintained at approximately 4° C.
	Attenuative capacity of alluvium and residuum to be characterized using site-specific geochemical data currently available for three alluvial clay-silt samples, two alluvial sand samples, and two residual soil samples. Additional samples to be collected for laboratory analysis: four samples of alluvial clay-silt and five samples of alluvial sand from the Ash Landfill area. Ash samples to be obtained using hollow-stem auger drilling method with either a thin-walled sampler (ASTM D1587) and a plastic-lined split-barrel sampler with sample catch on lower end (ASTM D1586). Multiple samples may be needed at each location to provide sufficient quantity of sample for analysis. Ends of sample collection liners will be preserved by coating with paraffin wax, Saran plastic wrap, or plastic end caps secured with tape. Sample temperature will be maintained at approximately 4° C. Sample packaging for shipment to laboratory will follow ASTM D 4220 to prevent physical damage. Samples to be analyzed for mineral composition, cation exchange capacity, exchangeable cations, free iron oxide, calcite equivalent, soluble salts, and soil pH.
	Aqueous phase constituent concentrations of groundwater in contact with ash to be determined by collecting in situ samples of from 18 new temporary borehole or Geoprobe locations completed in coal ash deposits. Samples to be filtered in-line and analyzed for dissolved metals, including mercury, radionuclides, TSS, TDS, major and minor ions (chloride, fluoride, sulfate, nitrate-nitrite, and ammonia-N), and field parameters (pH, ORP, Eh, temperature).
	Aqueous phase concentrations/activities in alluvial, residual and bedrock aquifers to be determined for use as transport model conditions. Nineteen groundwater samples to be collected from the six existing wells, three new wells, seven new temporary well points in vicinity of the Ash Landfill and Ash Processing Area, and three Geoprobe® boreholes. Samples to be filtered in-line and analyzed for dissolved metals, including mercury, radionuclides, TSS, TDS, major and minor ions (chloride, fluoride, sulfate, nitrate-nitrite, ammonia-N), and field parameters (pH, ORP, SC, temperature).
	Applicable SOPs: • ASTM D 4050: Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems • ASTM D 1587: Standard Practice for Thin-Walled Shelby Tube Sampling of Soils for Geotechnical Purposes. • EPA/600/R-98/058: Application of the Electromagnetic Borehole Flowmeter • TVA-KIF-SOP-02 *Groundwater Sampling* • TVA-KIF-SOP-39 *Installation of Groundwater Monitoring Wells* • TVA-KIF-SOP-42 *Slug Testing*

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DQO Step	BENTHIC INVERTEBRATES
State the Problem	Naturally-occurring metals (e.g., As, Se) and radionuclides (e.g., Ra-226, Th-228) in ash may accumulate in invertebrates inhabiting the river system to concentrations that pose an unacceptable risks ecological receptors who regularly consume these organisms or their emergent life stages.
Identify the Decision	The principal study question is: Do levels of ash-related constituents in benthic invertebrates and their emergent adult life stages pose unacceptable risks to ecological receptors?
Identify Inputs to the Decision	• Concentrations of ash-related constituents of interest: metals, radionuclides, and legacy constituents. • Exposure parameters to evaluate potential intake of constituents by ecological receptors. • Bioavailability of these constituents (e.g., biosurveys).
Define the Study Boundaries	The ecological receptor populations of interest are birds and mammals that feed on benthic invertebrates or emergent insects. The spatial boundaries are those areas impacted by the ash spill, upstream to downstream. The following sections are differentiated for data needs: • Background ("reference") locations upstream of ERM 6.0. Also upstream of CRM 4.5 and upstream of TRM 568. • Emory River sections; ERM 0.0 to 6.0. • Clinch/Tennessee River sections; CRM 0.0 to 4.5; TRM 566 to 568. There is no temporal boundary of the study. Concentrations of bioaccumulative ash-related constituents may increase in benthic invertebrates overtime and therefore collection of data over more than one sampling period may be necessary for long-term management. However, comparison to data from samples collected immediately after the ash spill provide an indication of trends in bioaccumulation.
Develop a Decision Rule	Ecological screening levels (action levels) are not available for concentrations in benthic invertebrates or emergent insects. However, benthic invertebrates represent a critical link in evaluation of food web exposures from ash/sediment to sediment porewater, and ultimately to wildlife. For higher-trophic level ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. The following lines of evidence are used to evaluate risks: • Dietary exposure estimates will be modeled based on measured concentrations in the benthic invertebrate prey for comparison with literature-derived effects values. If the modeled dietary exposure exceeds its literature-derived effects value for ingestion by fish or insectivorous birds and mammals, then this may indicate potential risk. • Comparison of biosurveys of benthic invertebrate communities in site-related locations with those in reference locations. If differences in taxa abundance, richness, or diversity are observed in site-related locations, then this may indicate environmental stress and potential risk.
Specify Limits on Decision Errors	Concentrations in benthic invertebrates to be determined with detection limits below the respective risk-based levels for fish or wildlife. However, limited sample volumes typically drive the best available technology. A minimum of one composite sample per reach is needed for evaluation of food web exposures.

DQO Step	BENTHIC INVERTEBRATES
Optimize the Design	Samples of larval mayflies to be collected by taking multiple Ponar samples of sediment and selectively removing the target organisms. Samples of snail to be collected by hand from structures near the shoreline. Individual specimens then to be composited into a single sample representative of a particular reach of the river system. Up to four replicates of larval mayflies and aquatic snails may be collected at each sample location to evaluate variability at that location. Snails and larval mayflies to be depurated in the laboratory before analysis. Samples of emergent adult mayflies to be collected by hand from vegetation, sweep nets, or light trap sampling; sampling likely required along a larger stretch of the river to obtain sufficient volume. Samples then to be composited into a sample representative of each reach of the river. If sample volumes are sufficient at some locations, replicate samples to be collected to evaluate variability at that location.
Optimize the Design	TVA has already established benthic invertebrate sampling locations for metals analysis, which are to be modified as described below: • Background (reference) locations; one location upstream in the Emory River (ERM 6.0), one location upstream in the Clinch River (CRM 6.0), one location upstream in the Tennessee River (TRM 574.0). Locations may be modified to coincide with reference sediment, porewater, and surface water locations. • Emory River sections: three locations within impacted reaches (ERM 1.0, 2.5, and 4.0). • Clinch River sections: two locations (CRM 1.5 and 3.5).
	Composite samples of depurated larval mayflies and snails, and non-depurated adult mayflies to be analyzed for whole body metals (including mercury). Results to be reported on a wet weight basis. Samples not to be analyzed for radionuclides or legacy constituents due to small sample volume; bulk sediment and/or surface water analyses to be used to estimate concentrations of these constituents in the food web.
	Benthic invertebrate community surveys to be done at upstream and downstream locations in the Emory, Clinch, and Tennessee Rivers. TVA has already been conducting such biosurveys at 6 cross-channel transects in the Emory and Clinch Rivers, which are to be modified to coincide with sediment, porewater, and surface water locations. These are located near ERM 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0; CRM 0.5, 1.5, 3.0, 4.0, and 6.0; and TRM 566.5 and 574.0. Biosurvey samples to be collected by taking Ponar samples of sediment at each of 10 locations across each transect. Samples to be analyzed in the laboratory for taxonomic identification and enumeration of benthic invertebrates, with results reported for taxa abundance, richness, and diversity.
	Applicable SOPs: • TVA-KIF-SOP-05 *Sediment Sampling* • TVA-KIF-SOP-29 *Mayfly Nymph Sampling* • TVA-KIF-SOP-30 *Aquatic Snail Sampling* • TVA-KIF-SOP-35 *Benthic Macroinvertebrate Sampling for Community Survey*

Appendix A
Data Quality Objectives for Environmental Media

DQO Step	FISH
State the Problem	Naturally-occurring metals (e.g., As, Se) and radionuclides (e.g., Ra-226, Th-228) in ash may accumulate in fish to concentrations that pose an unacceptable risk to human or ecological receptors who regularly consume fish from the river system.
Identify the Decision	The principal study question is: Do levels of ash-related constituents in fish pose unacceptable risks to human or ecological receptors?
Identify Inputs to the Decision	• Concentrations of ash-related constituents in fish, both pelagic (open water) and epibenthic (river bottom near the sediment-water interface): metals, radionuclides, and legacy constituents. • Exposure parameters to evaluate potential intake of constituents by human receptors. • Bioavailability of these constituents (e.g., biosurveys).
Define the Study Boundaries	The human receptor populations of interest are recreational users who consume fish from the river system. The ecological receptor populations of interest are pelagic and benthic fish communities, and aquatic- and riparian-feeding birds and mammals that feed primarily on fish. The spatial boundaries are those areas impacted by the ash spill, upstream to downstream. The following sections are differentiated for data needs: • Background ("reference") locations upstream of ERM 6.0, CRM 4.5, and TRM 568 • Emory River sections, ERM 0.0 to 6.0 • Clinch/Tennessee River sections; CRM 0.0 to 4.5; TRM 566 to 568 There is no temporal boundary of the study. Concentrations of bioaccumulative ash-related constituents may increase in fish tissue overtime and therefore collection of data over more than one sampling period may be preferred to a single round. However, comparison to data from samples collected immediately after the ash spill provide an indication of trends in bioaccumulation.
Develop a Decision Rule	Available screening levels (action levels) for protection of human receptors are risk-based screening levels for consumption of fish. If the concentration of a constituent exceeds its action level, then there may be potential risk for the corresponding receptor and the analyte will be retained for inclusion in the risk assessment. For ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. The following lines of evidence will be considered for characterizing risks to pelagic and benthic fish communities: • Bioaccumulation studies of largemouth bass, blue gill, channel catfish, and gizzard shad (whole body collections). Comparisons are made of concentrations in fish in downstream areas with those in reference upstream areas, of concentrations in fish at higher trophic levels, and of concentrations in fish over time. If concentrations downstream are greater, if concentrations in higher trophic levels are greater, or if concentrations show increasing trends, then constituents may be bioaccumulating in fish. • Comparison of biosurveys of pelagic and benthic fish communities in site-related locations with those in reference locations and comparisons of biosurveys over time. If differences in species abundance, richness, diversity, or physical condition are observed in site-related locations or changes are observed over time, then this may indicate environmental stress and potential risk. • Comparison of laboratory bioassays with sediments and surface water using larval fathead minnows (see sediment and surface water environmental media).

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DQO Step	FISH
Develop a Decision Rule	The following lines of evidence will be considered for characterizing risks to aquatic- and riparian-feeding birds and mammals that feed primarily on fish: • Dietary exposure estimates will be modeled based on measured concentrations in the fish as prey for comparison with literature-derived effects values. If the modeled dietary exposure exceeds its literature-derived effects value for ingestion by piscivorous birds and mammals, then this may indicate potential risk. The null hypothesis for fish is that the average concentration of an ash-related constituent is greater than or equal to its respective action level. The alternative hypothesis is that the average concentration is less than its respective action level.
Specify Limits on Decision Errors	Concentrations in fish to be determined with detection limits below the respective risk-based levels. The probability limit for a false rejection decision is 5%. The probability limit for a false acceptance decision is 20%. This means there is <5% chance that the risks may be calculated to be acceptable when they are actually unacceptable, and <20% chance that the risks may be calculated to be unacceptable when they are actually acceptable. To guide sampling design, Visual Sampling Plan estimated a minimum of nine samples needed based on the action limits, probability limits, and standard deviations of the ash-related constituents.
Optimize the Design	TVA has been conducting bioaccumulation studies of largemouth bass, bluegill, channel catfish, and gizzard shad, which are to continue in 2010. Historical samples primarily fish filet; future sampling to be whole body reconstruction; filet data used for human health evaluation and whole body samples used for ecological evaluation. Samples to be collected of each of these four species (representative of both pelagic and benthic fish communities) and threadfin shad (representative of planktiforous fish) using combination of electroshock, seining, or other methods as required to obtain sufficient volume for analysis. Up to five replicates of each species may be collected at each location to evaluate variability within that reach.
	TVA has already established fish sampling locations, which are to be modified as described below: • Background (reference) locations; one location upstream in the Emory River (ERM 8.0) and one location upstream in the Clinch River (CRM 8.0). Locations may be modified to coincide with reference sediment, porewater, and surface water locations. • Emory River sections: three locations within impacted reaches (ERM 1.0, 2.5, and 4.5). • Clinch River sections: two locations (CRM 1.0 and 3.5).
	Bioaccumulation study samples to be composited if individual fish specimen are insufficient in volume. Samples of each species (bass, sunfish, catfish) to be deconstructed by separately removing filet (muscle tissue) from non-filet portions; gut contents to be removed. Filet and non-filet portions to be analyzed for whole body metals (which includes mercury) and speciation for arsenic. To the extent sample volume allows, 25% of the samples to be analyzed for legacy constituents (PCBs and pesticides). For filet samples only if sample volume allows, 25% of the filet samples to be analyzed for radionuclides (K-40, Ra-series, Th-series, U-series). Twenty-five percent of filet samples in Clinch River to be analyzed for Cs-137 and Co-60. Results to be reported on a wet weight basis for each filet and non-filet portion; total weight and moisture content of each portion to be reported so that whole body mass can be reconstructed.
	Samples of gizzard shad and threadfin shad to be composite of 10 individual fish specimens from the same locations. Up to three composite samples from each site to be taken. Only whole body samples (with gut contents removed) to be analyzed for metals and speciation for arsenic; 25% of samples to be analyzed for PCBs and pesticides.

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Data Quality Objectives for Environmental Media

DQO Step	FISH
Optimize the Design	TVA has been conducting fish community biosurveys in the Emory and Clinch Rivers. Biosurveys conducted in fall of 2001, 2003, 2004, 2005, 2007, and 2009; to continue in 2010. These same locations will be surveyed to be consistent with historical studies. • Reference community surveys will be based on historic biosurveys conducted within the impacted reaches before the ash spill and assessments conducted Valley-wide • Emory River Reach B (ERM 1.5 to 3.5) • Confluence of Emory and Clinch Rivers (ERM 0.0 to 1.0 and CRM 4.0 to 5.0) • Clinch River Reach A (CRM 0.0 to 2.0) Biosurvey samples of both pelagic and benthic fish to be collected using the same methods as bioaccumulation samples, with multiple collections occurring within each reach. Specimens to be analyzed in the field for taxonomic identification and enumeration of fish, with results reported for species abundance, richness, diversity, age-class structure, and physical condition (abnormalities).
	Applicable SOPs: • TVA-KIF-SOP-31 *Fish Sampling with Gill Nets* • TVA-KIF-SOP-32 *Fish Sampling with Seines* • TVA-KIF-SOP-33 *Fish Sampling – Boat Mounted Electrofishing*

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Data Quality Objectives for Environmental Media

DQO Step	WILDLIFE
State the Problem	Naturally-occurring metals (e.g., As, Se) in ash may accumulate in wildlife (aquatic- and riparian-feeding birds and mammals) inhabiting the river system to concentrations that pose an unacceptable risk to these ecological receptors or ecological receptors who regularly consume these organisms.
Identify the Decision	The principal study question is: Do levels of ash-related constituents in wildlife pose unacceptable risks to themselves or other ecological receptors?
Identify Inputs to the Decision	• Concentrations of constituents of interest in wildlife: metals and to the extent practical, legacy constituents. • Exposure parameters to evaluate potential intake of ash-related constituents by ecological receptors. • Standardized ecological screening levels are not available for concentrations in wildlife blood or tissue samples. Potential literature-derived ecotoxicological effects data may be available for some constituents (including Se) for survival, growth, and reproduction. • Dietary effects values, which may include no-observed-adverse-effect levels and lowest-observed-adverse levels, for survival, growth, and reproduction.
Define the Study Boundaries	There are no human receptor populations of interest who consume wildlife (aquatic- and riparian-feeding birds and mammals) from the river system. The ecological receptor populations of interest are aquatic- and riparian-feeding birds and mammals. The spatial boundaries are those areas impacted by the ash spill, upstream to downstream. The following sections are differentiated for data needs: • Background (“reference”) locations upstream of ERM 6.0. Also upstream of CRM 4.5 and upstream of TRM 568. • Emory River sections, ERM 0.0 to 6.0. • Clinch/Tennessee River sections; CRM 0.0 to 4.5; TRM 566 to 568. The temporal boundaries of the study include pre-release (data used as a reference for previous conditions), post-release (data collected during removal), and post-removal data (data collected following completion of the removal action. While comparison to data from samples collected immediately after the ash spill should provide an indication of trends in bioaccumulation, concentrations of bioaccumulative ash-related constituents may increase in wildlife over time and therefore collection of data over more than one sampling period may be necessary for long-term management. At a minimum, two to three years of sampling may be necessary in order to characterize potential bioaccumulation risks to higher trophic level wildlife.
Develop a Decision Rule	For ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. The following lines of evidence will be considered for characterizing risks to wildlife: • Dietary exposure estimates will be modeled based on measured concentrations in prey (fish or benthic invertebrates) for comparison with literature-derived effects values. If the modeled dietary exposure exceeds its literature-derived effects value for ingestion by birds and mammals, then this may indicate potential risk. • Comparison of concentrations of bioaccumulative constituents in wildlife with literature-derived effects values, to the extent feasible. If concentrations exceed effects values, then this may indicate food web exposure and potential risk. Data may provide only supplementary evidence of exposure due to limited availability of effects values.

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Data Quality Objectives for Environmental Media

DQO Step	WILDLIFE
Develop a Decision Rule	• Comparison of biosurveys of bird nestlings in site-related locations with those in reference locations and comparisons of biosurveys over time. If differences in clutch size, hatchling success, or physical condition are observed in site-related locations or changes are observed over time, then this may indicate environmental stress and potential risk.
Specify Limits on Decision Errors	Concentrations in wildlife to be determined with detection limits below the respective risk-based levels for wildlife. However, due to limited availability of effects values, the analytical method offering the lowest quantitation limit to be used. A minimum of one composite sample per reference site suggested for evaluation of food web exposures.
Optimize the Design	TVA has collected blood, organ (liver/kidney), and/or whole body samples of mammals, reptiles, and amphibians. Existing data to be used for comparison with limited available effects values or for estimating dietary exposures to predators. No additional sampling of these species needed to support risk assessment.
	Concentrations in bird eggs and nestlings to be measured as biomarkers of exposure and for comparison with effects values in birds (insectivorous and piscivorous). Egg contents and/or nestlings to be sampled of tree swallows and herons. Nesting colonies to be sampled where present near the site and at offsite (reference) locations depending on presence of habitat and individual animals. Only one egg or nestling to be taken from any one nest within the colony (approximately 10 samples from each colony). • Tree swallow egg/nestling: two background (reference) locations (Melton Hill Dam and Fort Loudon Dam); six colonies (near CRM 2.5, CRM 3.5, ERM 1.5, ERM 2.5, and two near ERM 3.0). • Heron egg/nestling samples: one background (reference) location (Tennessee River near TRM 569.5); 2 colonies near ERM 3.0 and CRM 2.5.
	Egg contents (excluding shells) and/or whole body nestling samples to be analyzed for metals (including mercury). Results to be reported on wet weight basis.
	Nestling biosurveys to be done at same locations (colonies) as sampling. All nests within each colony to be surveyed. Nests to be observed in the field for clutch size, hatchling success, and physical condition (abnormalities).
	Applicable SOPs: • TVA-KIF-SOP-15 *Collecting and Processing Heron and Osprey Eggs* • TVA-KIF-SOP-28 *Nestling Sampling*

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DQO STEP	AQUATIC VEGETATION
State the Problem	Naturally-occurring metals (e.g., As, Se) and radionuclides (e.g., Ra-226, Th-228) in ash may accumulate in vegetation in direct contact with sediment and surface water in the river system to concentrations that pose unacceptable risks to ecological receptors who regularly consume them.
Identify the Decision	The principal study question is: Do levels of ash-related constituents in aquatic vegetation pose unacceptable risks to ecological receptors?
Identify Inputs to the Decision	• Concentrations of ash-related constituents of interest: metals. • Exposure parameters to evaluate potential intake of constituents by ecological receptors. • Bioavailability of these constituents.
Define the Study Boundaries	The ecological receptor populations of interest are fish, birds, and mammals that feed on aquatic vegetation. The spatial boundaries are those areas impacted by the ash spill, upstream to downstream. The following sections are differentiated for data needs: • Background ("reference") locations upstream of ERM 6.0. Also upstream of CRM 4.5 and upstream of TRM 568.0. • Emory River Reaches; ERM 0.0 to 6.0. • Clinch River Reaches; CRM 0.0 to 4.5. • Tennessee River Reaches; TRM 550.0 to 568.0. There is no temporal boundary of the study. Concentrations of ash-related constituents may increase in aquatic vegetation overtime and therefore collection of data over more than one sampling period may be necessary for long-term management.
Develop a Decision Rule	Ecological screening levels (action levels) are not available for concentrations in aquatic vegetation. However, aquatic vegetation represents a critical link in evaluation of food web exposures from ash/sediment to sediment porewater, surface water, and ultimately to wildlife. For higher-trophic level ecological receptors, a weight-of-evidence process is used to characterize the magnitude and likelihood (uncertainty) of risks. The following line of evidence is used to evaluate risks: • Dietary exposure estimates will be modeled based on measured concentrations in the aquatic vegetation for comparison with literature-derived effects values. If the modeled dietary exposure exceeds its literature-derived effects value for ingestion by fish or herbivorous birds and mammals, then this may indicate potential risk.
Specify Limits on Decision Errors	Concentrations in aquatic vegetation to be determined with detection limits below the respective risk-based levels for fish or wildlife. However, limited sample volumes typically drive the best available technology. A minimum of one composite sample per reach is needed for evaluation of food web exposures.
Optimize the Design	Samples of aquatic vegetation will be collected by taking samples of periphyton and emergent vegetation. Samples of emergent vegetation will be collected from along the shoreline. Two types of emergent vegetation will be collected: those rooted in sediment below the summer pool water level and those rooted at the summer pool shoreline. Individual specimens then will be composited into a single sample representative of the sample location. Up to three sample locations for both types of emergent vegetation will be collected in each reach. Samples of periphyton will be collected on artificial substrates (e.g., glass slides) suspended in the water column to obtain sufficient volume. Up to three replicates of periphyton may be collected at each sample location to evaluate variability at that location.

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DQO STEP	AQUATIC VEGETATION
Optimize the Design	TVA has not established aquatic vegetation sampling locations for metals analysis, therefore, sample locations will be selected to coincide with seasonally exposed sediment and benthic invertebrate sampling. Emergent vegetation: • Background (reference) locations; three locations upstream in the Emory River (ERM 6.0), three locations upstream in the Clinch River (CRM 6.0),and three locations upstream in the Tennessee River (TRM 574.0). Locations may be modified to coincide with reference sediment locations. • Emory River Reaches: three locations within each impacted reach. • Clinch River Reaches: three locations within each impacted reach. • Tennessee River Reaches: three locations within each impacted reach. • Sample locations for emergent vegetation will be selected based on the availability of vegetation. Periphyton: • Background (reference) locations; one location upstream in the Emory River (ERM 6.0) and one location upstream in the Clinch River (CRM 6.0). Locations to be co-located with aquatic snail sample locations. • Emory River Reaches: one locations within each impacted reach. • Clinch River Reaches: one locations within each impacted reach. • Tennessee River Reaches: one location within each impacted reach. • Sample locations for periphyton to be co-located with aquatic snail sample locations.
	Samples of aquatic vegetation will be analyzed for metals (including boron, molybdenum, and mercury). Results to be reported on a wet weight basis. Samples will not be analyzed for radionuclides or legacy constituents due to small sample volume; bulk sediment and/or surface water analyses to be used to estimate concentrations of these constituents in the food web.
	Applicable SOPs: • TVA-KIF-SOP-38 *Aquatic Vegetation Sampling* • TVA-KIF-SOP-59 *Periphyton Sampling*

Note:
For definitions, see the Sampling and Analysis Plan, List of Acronyms.

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Baseline Ecological Risk Assessment Methodology

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List of Acronyms

ASTM	American Society for Testing and Materials
BERA	Baseline Ecological Risk Assessment
BAF	bioaccumulation factor
BCF	bioconcentration factor
COI	Constituent of Interest
COPEC	constituent of potential ecological concern
CRM	Clinch River Mile
CSM	conceptual site model
DOE	U.S. Department of Energy
DQO	data quality objective
dw	dry weight
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	Ecological Risk Assessment
ERM	Emory River Mile
ESV	ecological screening value
HPAH	high molecular weight PAH
HQ	hazard quotient
KIF	Kingston Fossil Plant
L	liter
LOAEL	lowest-observed-adverse-effect level
LPAH	low molecular weight PAH
mg/kg	milligram per kilogram
mg/L	milligram per liter
mg/kg	milligram per kilogram
NOAEL	no-observed-adverse-effect level
ORNL	Oak Ridge National Laboratory
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
ppb	parts per billion
ppm	parts per million
RFAI	Reservoir Fish Assemblage Index
SAP	Sampling and Analysis Plan
SFF	site foraging frequency
SMDP	scientific management decision point
SLERA	Screening-Level Ecological Risk Assessment
SMAV	species mean acute value
SSS	Spring Sport Fish Survey
TDEC	Tennessee Department of Environment and Conservation
TOC	total organic carbon
TRM	Tennessee River Mile
TRV	toxicity reference value
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
UCL	upper confidence limit
USGS	U.S Geological Survey
USFWS	U.S. Fish and Wildlife Service
UT	University of Tennessee

VA Tech	Virginia Polytechnic Institute and State University
µg/g	microgram per gram
µg/L	migrogram per liter

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1. INTRODUCTION

This appendix describes the methodology and activities necessary to support decision-making on the restoration of the river system impacted by the spilled fly ash at the Tennessee Valley Authority's (TVA) Kingston Fossil Plant (KIF). On May 11, 2009, an Administrative Order and Agreement on Consent was signed between the U.S. Environmental Protection Agency (EPA) and TVA, providing the regulatory framework for the restoration efforts. A significant portion of the restoration efforts are currently underway and being conducted as a time-critical removal action. This methodology addresses the Ecological Risk Assessment (ERA) steps necessary for the remaining non-time-critical removal activities within the river system.

In accordance with EPA guidance (EPA 1997), an ERA is comprised of a Screening-Level ERA (SLERA) and, if necessary, a Baseline ERA (BERA). Figure B-1 provides an overview of the EPA eight-step ERA process (EPA 1997). An expanded view of the components of each step is provided on Figure B-2 (EPA 1999a, 2000a).

The ERA guidance (EPA 1997) includes clearly identified points in the process for stakeholder communication and decision-making, consistent with EPA guidelines (EPA 1998, 1999a, 2000a). These scientific management decision points (SMDPs) allow for collaborative decision-making that results in the efficient use of time and resources. These decisions must then be captured in subsequent decision-making documents and actions. Generally, the following types of decisions are considered at the SMDPs:

- Whether no further action is appropriate based on concerns for ecological receptors;
- Whether further ERA is warranted; and
- Whether remedial actions can be implemented to reduce or prevent risks to wildlife.

1.1 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

The SLERA consists of Steps 1 and 2 of the ERA process, providing a conservative estimate of potential ecological risks and compensating for uncertainty by incorporating numerous conservative assumptions. The purpose of the SLERA is to determine whether there is a high probability that there are no ecologically significant risks (EPA 1997, 2000a); otherwise, a BERA is warranted, except where early actions will reduce potential ecological risks to acceptable levels. If need for a BERA is indicated, the information developed in the SLERA is used to focus the BERA. The BERA is more complex than the SLERA and uses more realistic and site-specific information about potential exposures and effects in order to evaluate potential ecological risks.

The screening-level problem formulation provides information used to establish the overall goals of an ERA (EPA 1998, 1999a). In addition, once these goals are established, the problem formulation is used to develop a conceptual site model (CSM) for the ERA. The specific goal of this effort is a conservative evaluation of the likelihood for adverse effects (and the ecological significance of predicted adverse effects) to wildlife that may be exposed to site-related constituents.

1.2 BASELINE ECOLOGICAL RISK ASSESSMENT

The BERA is designed to more realistically identify the nature and extent of ecological risks in order to support informed environmental management decision-making (EPA 1997, 2000a). By contrast, the SLERA is designed to conservatively rule out further evaluation of constituents and media that clearly do not pose an ecological risk. Therefore, Steps 3 through 7 in the BERA focus on the constituents and media identified as constituents of potential ecological concern (COPECs) at the conclusion of the SLERA (EPA 2000a). In Step 3, the results of the SLERA and additional site-specific information are

used to determine the scope and goals of the BERA. Steps 3 through 7 are required only where the SLERA indicates a need for further ecological risk evaluation.

The BERA for the river system is being conducted in a manner consistent with the following guidelines and guidance:

- "ECO-Update: Role of Screening-level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments," (EPA 2001a);
- "Ecological Risk Assessment Guidance for Superfund" (EPA 1997); and
- "Guidelines for Ecological Risk Assessment" (EPA 1998a).

This ERA includes a strategy for refining the media of concern in order to:

- Identify and characterize the potential threats to the environment from a hazardous substance release;
- Evaluate the ecological impacts of alternative remediation strategies; and
- Establish cleanup levels in the selected remedy that will protect those natural resources at risk.

This BERA methodology provides an adaptive approach to evaluating the potential risks associated with evolving site conditions and ongoing removal actions. Unlike assessments of historic releases, the river ecosystem has not yet stabilized following the ash release. The time-critical removal of ash in the Emory River will accelerate the transition to more stable conditions in the river system. Because the BERA is to evaluate post-dredging conditions, an adaptive assessment methodology makes use of ongoing studies and readily-collected post-dredging data to perform the BERA for the river system in a timely manner.

Notable aspects of this adaptive approach include: postponing refinement of COPECs to a more focused list of constituents once post-dredging data are available, proceeding with problem formulation and ecological studies in order to document potential trends in exposure and effects data, anticipating the use of ongoing studies to accelerate verification and improvement of the sampling design, and using an iterative process of progressively more detailed risk characterization techniques. Given the adaptive approach to this BERA methodology, some characterization methods can only be generally defined at this time. For example, the rigorous literature review and effects characterization warranted for this BERA cannot reasonably be performed until the list of COPECs is further refined. Therefore, strategies for refining the characterization methods are provided in this methodology and, where appropriate, interim deliverables will be provided to document the progress of the assessment.

The following interim deliverables will be provided to the Technical Work Group:

- A refined screening of the current list of COPECs, which included at least 19 metals, various radionuclides, and selected evaluation on the primary risk drivers can be effectively accomplished.
- Detailed toxicological profiles, including a description of the literature-based toxicological reference values (TRVs) that will be used for comparison to site data. No-observed-effect-levels (NOAELs) and lowest-observed-adverse-effect-levels (LOAELs) should also be presented along with the rationale for their selection.
- Detailed exposure profiles for reach of the ecological receptors to be evaluated in the BERA that includes specific information for each of the food web model parameters, such as intake rates, dietary fractions, body weights, site foraging frequency, etc.

As noted above, this approach considers the biological characterization, monitoring, and assessment data available from previous, current, and proposed long-term studies at the Site. Long-term monitoring demonstrates TVA's commitment to environmental stewardship and presents an opportunity for insight rarely available in the ERA process. This approach will appropriately streamline and focus the BERA.

2. SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

The SLERA for the river system was conducted as part of the *Non-Time Critical Removal Action Scope and Engineering Evaluation/Cost Analysis (EE/CA) Work Plan* (Jacobs 2009). The SLERA evaluated the potential risks to ecological receptors exposed to detected constituents in ash and surface water in the vicinity of the site. To be conservative, the SLERA evaluated potential exposures to ash as if it were sediment (ash as sediment). The SLERA also evaluated potential exposures to constituents in surface water, broken into separate evaluations of the Emory River, Clinch River, and Tennessee River. The Emory River data represents the most robust data set and conservative exposure assumptions; therefore, results for surface water were based on concentrations from the Emory River.

To estimate risk in the SLERA, hazard quotients (HQs) were calculated for each medium. An HQ is the unitless ratio of a constituent concentration in a medium to the screening ecotoxicity value considered protective of wildlife for that constituent in that medium. Maximum constituent concentrations and conservative screening ecotoxicity values were used for ash as sediment and surface water. The following sources of screening values were identified for use in the screening-level ecological effects characterization for this site:

- Soil: EPA Ecological Soil Screening Levels (EPA 2008a; and EPA Region 4 Ecological Soil Screening Values (ESVs) (EPA 2001b).
- Sediment: EPA Region 4 Ecological Sediment Screening Values (EPA 2001b); and
- Surface Water: National Recommended Water Quality Criteria (EPA 2006) and EPA Region 4 Ecological Surface Water Screening Values (EPA 2001b).

Constituents with HQs greater than 1 were identified as COPECs and carried forward into the BERA. Also selected as COPECs were ten inorganics identified as constituents of interest (COIs) based on their common association with fly ash. The burning of coal in coal-fired power plants generates coal combustion byproducts including fly ash and bottom ash. The trace metals commonly found in fly ash, by relative frequency, are vanadium, zinc, copper, chromium, nickel, lead, arsenic, and mercury (EPA 1999a, 2008b). Selenium and thallium were identified by the EE/CA Technical Working Group as additional constituents in fly ash that are of interest in ecological risk assessment. Therefore, these COIs were carried forward regardless of the SLERA HQ screening results.

Results of the SLERA within the EE/CA Work Plan (Jacobs 2009) identified 17 inorganic constituents as COPECs in ash as sediment, and 17 constituents as COPECs in surface water, as presented in Table B-2-1.

Table B-2-1. Summary of COPECs for the SLERA

Analyte	Ash as Sediment	Surface Water
Aluminum	Yes	Yes
Arsenic[1]	Yes	Yes
Barium	Yes	Yes
Beryllium	Yes	Yes
Boron	Yes	No
Chromium	Yes	Yes
Cobalt	Yes	Yes
Copper[1]	Yes	Yes
Iron	Yes	No
Lead[1]	Yes	Yes
Manganese	Yes	Yes
Mercury[1]	Yes	Yes
Molybdenum	No	Yes
Nickel[1]	Yes	Yes
Selenium[1]	Yes	Yes
Silica	No	Yes
Thallium[1]	Yes	Yes
Vanadium[1]	Yes	Yes
Zinc[1]	Yes	Yes

Note: [1] Identified as a contaminant of interest (COI) in fly ash.

The results of the SLERA for the river system indicated that the possibility of adverse ecological risks for ecological receptors potentially exposed to COPECs in ash as sediment or surface water could not be excluded. Given that the available data for the river system was not adequate to make a decision at this stage of the ERA process, the SLERA concluded that a BERA was warranted for this area of the site.

The SLERA also stated that the general types of information that will likely be needed to support a decision for the aquatic environment include the following: concentrations of COPECs in the ash and sediment, biogeochemical data for the ash and sediment, fate and transport information for the ash and COPECs, bioavailability of COPECs in the ash and sediment, concentrations of COPECs in fish, concentrations of COPECs in aquatic and riparian prey species, information on dietary exposures for birds and mammals, and community survey information for fish and benthic invertebrates. These types of data were specifically considered during development of the Sampling and Analysis Plan (SAP) for the BERA. In addition, while potential ecological risks associated with groundwater releases to porewater and surface water were not evaluated as part of the SLERA, this evaluation will be included in the BERA for the river system.

3. STEP 3: BASELINE ECOLOGICAL RISK ASSESSMENT PROBLEM FORMULATION

Step 3 is a refinement of the SLERA Step 2 exposure estimates and risk characterization, focusing on the COPECs and media that progress beyond the SLERA. The assumptions used in Step 3 are refinements of the conservative estimates of exposure and toxicological effects used to prepare site-specific (or receptor-specific) risk calculations (EPA 2001a).

3.1 PROBLEM FORMULATION PROCESS

The problem formulation process in Step 3 establishes the goals and direction of the BERA, identifying assessment endpoints and important ecological resources. Step 3 addresses the ecological risk questions that must be evaluated in order to assess these endpoints and resources. These risk questions are based on the potentially complete exposure pathways and effects present at the site. Problem formulation in the BERA includes a multitude of inputs, including:

- Refining preliminary COPECs;
- Further characterizing ecological effects of constituents;
- Reviewing and refining constituent fate and transport, complete exposure pathways, and ecosystems potentially at risk;
- Selecting assessment endpoints; and
- Developing a CSM with working hypotheses or questions that the field investigation will address.

These inputs are described in more detail in the subsections below.

3.2 REFINEMENT OF CONTAMINANTS OF POTENTIAL ECOLOGICAL CONCERN

The refinement of the COPECs identified in the SLERA helps to focus further risk assessment activities on the constituents likely to pose the greatest potential risk to ecological receptors. This refinement process is consistent with EPA guidelines and guidance (EPA 1997, 2000a, 2001a). It is intended as an "incremental iteration of exposure, effects, and risk characterization" (EPA 2001a). The ultimate outcome of this refinement is that constituents are either excluded as COPECs or retained for further evaluation in the BERA process. Given the need for an adaptive BERA methodology for this site, the selection of COPECs for detailed evaluation cannot be completed until post-dredging data are available.

The process for refining the COPECs typically consists of evaluating each constituent separately in the context of the following criteria:

- Comparison to background concentrations;
- Frequency of detection;
- Comparison of the exposure point concentration (EPC) to SLERA screening toxicity values; and
- Bioavailability.

The remainder of this section discusses (in broad terms) the decision logic used for refining the COPECs in groundwater or porewater, surface water, and sediment (submerged and seasonally-exposed). Additional information is also provided that explains the process for identifying bioaccumulative COPECs. As many of the steps are similar for the various media (for example, comparison to background, frequency of detection), the refinement of COPECs is discussed in terms of the refinement criteria, rather than by media.

3.2.1 Comparison to Background Concentrations

Background concentrations of constituents are those concentrations found in areas surrounding a site, but are unrelated to site releases. These constituent concentrations typically occur due to natural sources or anthropogenic sources. EPA Region 4 Risk Assessment Bulletins (EPA 2001b) state: "For naturally occurring inorganics and radionuclides, compare the on-site maximum detected concentration to two times the average site-specific background concentration. Eliminate the chemical as a COPEC if it is less than two times the background level. It should be noted that one background sample, if elevated, is usually not acceptable for comparison or elimination purposes."

For Step 3 of this risk assessment, background concentrations were not used to eliminate COPECs; rather, background was used in the uncertainty analysis of the risk assessment to place the risk estimates in context with local or regional concentrations. As a result, constituents present at concentrations greater than the background concentrations, including constituents not detected in background, were retained for further consideration. Background concentrations may be reconsidered for screening in Steps 6 and 7 of the BERA, particularly in surface water and sediment.

3.2.2 Frequency of Detection

Constituents that are infrequently detected in the data may be due to problems with sampling or analytical analysis, and therefore may not be site-related contaminants. Commonly, constituents detected in less than 5% of the samples in a given medium are eliminated as COPECs because they are not expected to pose a significant risk to receptors.

For Step 3 of this risk assessment, frequency of detection was not used to eliminate COPECs, but was included in the uncertainty analysis of the risk assessment. Frequency of detection may be reconsidered for screening purposes in Steps 6 and 7 of the BERA.

3.2.3 Comparison of Exposure Point Concentrations to Screening Ecotoxicity Values

EPA (1989) defines the EPC as "the arithmetic average of the concentration that is contacted over the exposure period." To ensure that the estimate of the average (or mean) is conservative and not underestimated, EPA (1989, 1992) recommends using the 95% upper confidence limit (UCL_{95}) of the mean as an estimate for the EPC for each exposure area of a site. The UCL_{95} represents an upper bound estimate of average exposure conditions, which is an appropriate estimate for mobile wildlife species and for exposures of plant and animal communities (rather than individuals). The calculation of EPCs tends to eliminate constituents that may have a hazard quotient only marginally above the benchmark of 1.

Statistical software provided by EPA (i.e., ProUCL 4.0 [EPA 2007]) has, to some extent, automated the process of calculating UCLs and selecting the most representative statistic based on characteristics of the data set such as sample size, measures of variance, and frequency of detection. Typically, an EPC is calculated for each constituent separately, and these EPCs are compared with the relevant SLERA screening toxicity values. However, the UCL_{95} may not be considered the appropriate comparative statistic if the data set is small. In this case, the maximum detected concentration is considered the appropriate comparative statistic. In cases where the UCL_{95} is greater than the maximum detected concentration, the maximum detected concentration is used as the EPC. Constituents with EPCs greater than the SLERA screening ecotoxicity value, and constituents for which there are no screening ecotoxicity values are typically retained for further consideration.

For Step 3 of this risk assessment, EPCs were not used to eliminate COPECs, but were addressed in the uncertainty analysis of the risk assessment. EPCs will be calculated and considered for screening in Steps 6 and 7 of the BERA.

3.2.4 Bioavailability

Bioavailability is the extent to which a constituent in a given medium is free for uptake. The bioavailability and concentration of a constituent determines the exposure that an organism will experience, which in turn dictates the probability and intensity of potential effects to the receptor. In Steps 1 and 2 of the risk assessment process, bioavailability of constituents is assumed to be 100%; however, within Step 3, literature values are typically used to more accurately estimate the percent availability of a particular constituent within each medium.

For Step 3 of this risk assessment, bioavailability of constituents of ash was assumed to be 100% and, therefore, was not used to eliminate COPECs. Bioavailability was included in the uncertainty analysis of the risk assessment and will be considered in more detail in Steps 6 and 7 of the BERA.

3.2.5 Additional COPECs

In addition to the COPECs identified in the SLERA, naturally-occurring radionuclides and legacy constituents were also considered within the BERA. Naturally-occurring radionuclides commonly associated with coal ash byproducts include isotopes of potassium-40, radium-226 and -228, thorium-228 and -232, and uranium-234, -235, and -238. These constituents were conservatively carried forward as COPECs in Step 3 of the BERA.

The Emory and Clinch Rivers are on the state list of impaired waters because of contaminated sediments before the ash spill occurred. This legacy contamination includes polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), and chlordane from industrial point sources; mercury from atmospheric deposition and other sources; and impacts from agriculture or development. Some of this legacy contamination occurs as a result of past U.S. Department of Energy (DOE) actions at the Oak Ridge National Laboratory (ORNL), which resulted in contamination of sediments by radionuclides and other wastes. These legacy radionuclides include cobalt-60 and cesium-137. As a result, these legacy constituents were carried forward as COPECs in Step 3 the BERA.

For Step 3 of this risk assessment, naturally-occurring radionuclides and legacy constituents were all considered COPECs in the BERA to conservatively estimate total potential risk to ecological receptors in the river system. These additional COPECs were included in the uncertainty analysis of the risk assessment and will be considered in more detail in Steps 6 and 7 of the BERA.

3.2.6 Summary

The process of refining the COPECs identified in the SLERA typically includes consideration of constituent concentrations in the background, frequency of detection, the EPC compared with the screening toxicity values, and the bioavailability of constituents. For conservative purposes, COPECs were not eliminated in Step 3 of this risk assessment; however, these considerations may be evaluated in Steps 6 and 7 of the BERA process. Table B-3-1 presents a summary of constituents that will be retained for further evaluation in the BERA.

Table B-3-1. Summary of COPECs for the BERA

Analyte	Ash as Sediment	Surface Water
Aluminum	Yes	Yes
Arsenic[1]	Yes	Yes
Barium	Yes	Yes
Beryllium	Yes	Yes
Boron	Yes	No
Chromium[1]	Yes	Yes
Cobalt	Yes	Yes
Copper[1]	Yes	Yes
Iron	Yes	No
Lead[1]	Yes	Yes
Manganese	Yes	Yes
Mercury[1]	Yes	Yes
Molybdenum	No	Yes
Nickel[1]	Yes	Yes
Selenium[1]	Yes	Yes
Silica	No	Yes
Thallium[1]	Yes	Yes
Vanadium[1]	Yes	Yes
Zinc[1]	Yes	Yes
Potassium-40[2]	Yes	Yes
Radium-226[2]	Yes	Yes
Radium-228[2]	Yes	Yes
Thorium-228[2]	Yes	Yes
Thorium-232[2]	Yes	Yes
Uranium-234[2]	Yes	Yes
Uranium-235[2]	Yes	Yes
Uranium-238[2]	Yes	Yes
Polychlorinated Biphenyls[2]	Yes	Yes
Polyaromatic Hydrocarbons[2]	Yes	Yes
Chlordane[2]	Yes	Yes
Cobalt-60[2]	Yes	Yes
Cesium-137[2]	Yes	Yes

Notes:

[1] Identified as a constituent of interest (COI) in fly ash.

[2] Identified as a naturally-occurring radionuclide or a legacy constituent.

3.3 CHARACTERIZING ECOLOGICAL EFFECTS

In order to characterize potential ecological effects within the river system, the effects of constituent concentrations (or stressors) on a receptor must be identified and linked to an assessment endpoint. These effects must then be evaluated with varying stressor levels to assess how the magnitude of the effects changes with varying stressor levels. The ecological effect of an exposure is a function of the amount of the constituent within the cells or organs of a receptor that causes a toxicological effect. Understanding the relationship between stressors and resulting responses of receptors in the river system requires an understanding of the general toxicity and mode of action that the stressor may have on the receptor.

Discussions of toxicity and bioaccumulation potential for the COPECs are presented in the subsections below.

3.3.1 General Toxicity

The toxicity of a constituent can cause adverse ecological effects in many ways. Toxic effects could result in lethal effects (organism death) or cause adverse sublethal effects (e.g., reduced growth, reduced lifespan, reduced reproductive success, or behavioral changes). A constituent might act directly on an organism, causing lethal or sublethal effects, or the constituent might act indirectly by damaging the food, habitat, predator-prey relationships, or competition of the organism in its community. Toxic effects on an organism could occur after exposure for a short period of time (acute effects) or over a long period of time (chronic effects). The tolerance of individual organisms and communities to constituents and other changes in the habitat varies widely.

Metals are naturally present in the environment and therefore differ from other potentially toxic constituents. The ash that was released into the Emory River originates from the coal burned in boilers for power production at KIF. The coal, in its natural state, contains various inorganics that can be retained with the ash after burning. The ash itself is primarily composed of fine silica particles very similar to sand. Trace amounts of arsenic, chromium, copper, lead, mercury, nickel, selenium, thallium, vanadium, zinc, and other metals which occur naturally in the coal remain in the ash after coal combustion. Naturally-occurring radionuclides, such as isotopes of potassium, radium, uranium, and thorium, may also remain in the ash after coal combustion. These metals and radionuclides are typically bound to the ash. The use and release of these metals may have increased the concentration of metals in the environment and as a result, may have altered the speciation or biochemical form of the metals.

Most metals affect multiple systems and vary in their toxicity and mode of action. General toxicity profiles for the COPECs identified in the SLERA are provided in Attachment B-1, and include the general mode of toxicity as well as other influencing environmental factors on toxicity. Consistent with the adaptive assessment strategy, detailed toxicity profiles will be developed for constituents identified as COPECs based on the more robust data set collected under the River System SAP. These quantitative profiles will be based on a thorough review of the scientific literature and will include a range of deterministic effects values for the relevant chemical forms and ecological receptors at the site. This adaptive assessment methodology may identify constituents and receptors for which distributional or stochastic risk characterization is warranted. The profiles for these constituents will include distributions of the available lethal and sublethal effects values.

Radionuclides are unstable isotopes of elements (e.g., uranium) that produce ionizing radiation via radioactive decay. Ionizing radiation is radiated energy that is energetic enough to eject one or more orbital electrons from the target atom or molecule (i.e., the radiation ionizes the target). Ionization can produce free radicals, which are chemically unstable atoms or molecules that have an odd number of electrons (Hinton 1998). These highly reactive products scavenge electrons by breaking chemical bonds, including those in cell membranes and DNA molecules. Reproductive processes and the early stages of development (i.e., gametogenesis through embryonic) are generally the most sensitive to ionizing radiation (i.e., radiosensitive), because many cells are dividing and differentiating. Affects on these processes are likely to be the most limiting endpoint in terms of population maintenance of ecological receptors (IAEA 1992).

PAHs are a group of constituents that are ubiquitous in the environment and that can be found in the air, water, and soil (ATSDR 1995). PAHs are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances. PAHs vary greatly in regard to their toxicity, mechanism of action, bioaccumulative potential, and susceptibility to being metabolized. Most PAHs are sorbed to solid

particles in the environment, which radically reduces the bioavailability and toxicity of the sorbed PAHs. PAHs have been shown to cause changes in liver enzymes and to perturb cell membranes, but in general, are not viewed as acutely toxic.

PCBs (like Aroclor 1260 and Aroclor 1254) were designed for use in "closed" electrical systems like transformers, capacitors, and vacuum pumps. These compounds typically have low solubility, and low vapor pressures, and therefore tend to sorb to solid, organic material in the aquatic environment. However, PCBs can be transported in the air, and have been known to be present in measurable quantities in remote areas, far from where they were produced or used (Niimi 1994). PCBs are known to bioaccumulate and biomagnify; however, they usually do not cause acute toxic responses, and their major effects are thought to be sublethal. In addition, PCBs are currently under scrutiny for endocrine disruption, and effects on the nervous and immune systems in higher order taxa within the food chain (Fontenot 1999a,b; Niimi 1994).

Some organochlorine pesticides, such as chlordane, exhibit acute toxicity although most toxicity is due to long-term, chronic effects (ATSDR 1994). These effects may include reduced fecundity, chronic lethality, neurological effects, cessation of feeding, and bone degeneration (Nimmo and McEwen 1994; Fontenot 1999a,b). The mode of action for most organochlorine pesticides is to disrupt electrolyte balance in neurons and prevent them from conducting nerve impulses normally (Ware 1994). This manifests neurological effects such as reduced mobility, tremors, loss of equilibrium, convulsions, abnormal flexure, and lethargy or prostration. In addition, pesticides are well-known for causing eggshell thinning in birds and, thereby, reducing reproductive success (Newman 1998; Sample et al. 1996). In general, the organochlorine pesticides have very low water solubility and are considered insoluble (Nimmo 1985). However, they are soluble in non-polar solvents, and will preferentially move into fatty tissues. This fact, combined with the very slow breakdown rates, indicates that they will bioconcentrate into organisms in the lower levels of the food chain (such as worms) and will biomagnify into organisms in the higher levels of the food chain (such as raptors).

3.3.2 Identification of Bioaccumulative COPECs

Each of the constituents identified as COPECs for direct contact were also evaluated for the potential to bioaccumulate. Bioaccumulation is the buildup of a constituent concentration from one trophic level to the next due to concentrations in food. Various physical (e.g., diffusion and resuspension), chemical (e.g., molecular size and polarity), and biological factors (e.g., organism burrowing and feeding behaviors) influence the bioaccumulate potential of a constituent.

Food web modeling may be needed to supplement field-collected data for the purpose of evaluating exposures to higher trophic levels. The approach, components, and application of food web calculations are presented later in Steps 6 and 7 of the BERA. The list of bioaccumulative constituents presented within the EPA (2000b) "*Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment*" was used to identify potential bioaccumulative COPECs, as presented in Table B-3-2.

Table B-3-2. Bioaccumulative Constituents of Potential Ecological Concern

Constituent	Bioaccumulation [1] (Yes/No)
Inorganics	
Aluminum	No
Arsenic	Yes
Barium	No
Beryllium	No
Boron	No
Chromium	Yes
Cobalt	No
Copper	Yes
Iron	No
Lead	Yes
Manganese	No
Mercury	Yes
Molybdenum	No
Nickel	Yes
Selenium	Yes
Silica	No
Thallium	No
Vanadium	No
Zinc	Yes
Potassium-40	No
Radium-226	Yes[2]
Radium-228	Yes[2]
Thorium-228	Yes[2]
Thorium-232	Yes[2]
Uranium-234	Yes[2]
Uranium-235	Yes[2]
Uranium-238	Yes[2]
Polychlorinated Biphenyls	Yes
Polyaromatic Hydrocarbons	Yes
Chlordane	Yes
Cobalt-60	Yes[2]
Cesium-137	Yes

Notes:

[1] EPA (2000b) used to identify bioaccumulative constituents of potential ecological concern (COPECs).
[2] Although not identified by EPA (2000b) as bioaccumulative, may be bioaccumulative based on professional judgment.

3.4 CONSTITUENT FATE AND TRANSPORT

The spatial distribution of constituents is based on a variety of physical, chemical, and biological transport and fate mechanisms that move the released constituents from their primary and secondary sources to other locations or media throughout the site. Constituents are most commonly transported either by means of a solution (i.e., constituents dissolved in water); attached to sediment or other particulate matter; or via biological matrices (i.e., constituents bioaccumulated in organisms). Several factors influence the transport and fate of constituents, including the chemical forms and phases in which they occur in the environmental media. In addition to the constituent's chemical properties, the specific environmental conditions at the site (e.g., temperature, pH, total suspended solids, and dissolved oxygen

content) also influence the fate and transport of each constituent. In the subsections below, the specific media of concern for the river system are discussed, along with the exposure pathways present at the site.

3.4.1 Media of Concern

The process of identifying and refining media of concern focuses the BERA on the media that may be associated with potentially significant ecological exposure pathways, and therefore, potentially contribute to significant ecological risks. The considerations for the identification and refinement of media of concern are listed below, by medium.

Sediment: Exposure to sediment was included as a potential pathway for ecological receptors by direct contact and incidental ingestion. Sediment evaluated in the SLERA was considered ash as sediment; however, sediment evaluated in the BERA will be collected after the time-critical removal action is complete, and the majority of ash has been removed. Therefore, sediment evaluated in the BERA no longer refers to ash as sediment. Sediment was broken down into submerged sediment and shallow or seasonally-exposed sediment. Submerged sediment refers to the sediment that is below water year-round. Seasonally-exposed sediment refers to the sediment exposed on the river banks during the times that the reservoir levels are low (i.e., winter months December to April). These sediments are submerged during the remainder of the year in shallow water near the riverbank. For Step 3 of this risk assessment, only ash as sediment was evaluated. However, sediment will be divided into submerged sediment and shallow or seasonally-exposed sediment and considered for screening in Steps 6 and 7 of the BERA. In addition, , both submerged and seasonally-exposed sediment will be evaluated separately for the Emory, Clinch, and Tennessee Rivers.

Groundwater: Exposure to groundwater was included as a potential pathway for ecological receptors by direct contact and incidental ingestion of sediment porewater and surface water. Constituent releases to groundwater typically occur through leaching and infiltration of constituents in soil down through the soil column. At TVA's Kingston site, constituents in groundwater could potentially be leaching through the soil column and releasing into the sediments of the river bottom. This leaching and infiltration could, in turn, generate higher concentrations of constituents within the sediment porewater than in the surface water. Sediment porewater refers to the interstitial water present between grains of sediment that is the primary source of ash-related constituents for biouptake to benthic invertebrates (particularly burrowing benthos), aquatic plants, and detritivores (organisms feeding primarily along the sediments). The purpose of evaluating sediment porewater separately from whole sediment is to understand the factors involved in desorption of constituents from the ash/sediment and biotoxicity of the constituents apart from any physical effects of ash on organism growth. For Step 3 of this risk assessment, groundwater was not evaluated because groundwater data were not available for this pathway. However, groundwater discharging to sediment porewater and surface water will be modeled and considered for screening in Steps 6 and 7 of the BERA.

Surface Water: Exposure to surface water was included as a potential pathway for ecological receptors by direct contact and ingestion. Exposure to surface water refers to the conditions occurring in the river following completion of dredging, and can be divided into two discrete depth intervals, mid-depth water column and epibenthic water. For Step 3 of this risk assessment, surface water was evaluated as one depth; however, surface water will be divided into mid-depth water column and epibenthic water and considered for screening in Steps 6 and 7 of the BERA. In addition, surface water will be evaluated separately for the Emory, Clinch, and Tennessee Rivers.

Soil: Exposure to soil was not included as a potential pathway for ecological receptors because soil is not an impacted medium in the river system. Ecological receptors in the riparian zone of the river system will be evaluated for their potential direct contact and incidental ingestion of seasonally-exposed sediments.

3.4.2 Complete Exposure Pathways

Exposure pathways identified in Steps 1 and 2 of the SLERA are further refined in Step 3 of the BERA. Ecological receptors at the site could potentially come into contact with constituents through a variety of exposure pathways. Potential complete exposure pathways include direct contact with ambient media (sediment [seasonally-exposed and submerged], porewater, and surface water [epibenthic and water column]; ingestion of constituents in food items or surface water; and incidental ingestion of ambient media (sediment [seasonally-exposed and submerged] and porewater).

Although inhalation and dermal contact were previously listed as a possible exposure route, under most exposure conditions the inhalation and dermal contact pathways do not represent a significant contribution to receptor risk (EPA 2005) and are not evaluated quantitatively under most circumstances. While fugitive dust is a potential release mechanism from seasonally-exposed sediments, inhalation of fugitive dust from seasonally-exposed sediments is not anticipated to present a significant contribution to ecological receptor risk associated with the river system. Feathers of birds, fur on mammals, and scales on reptiles are thought to reduce dermal exposure by limiting the contact of the skin surface with the COPECs in the river system (EPA 2005). As a result, inhalation and dermal contact will not be explicitly evaluated within the BERA.

3.5 ASSESSMENT ENDPOINTS

Assessment endpoints include important ecological resources that, if damaged, would significantly impact the ability of the ecosystem to function. Assessment endpoints are selected based on key ecosystems, communities, or ecological functions; constituents present; the extent and magnitude of contamination; mechanisms of toxicity; and potential exposure pathways. The selection and definition of assessment endpoints are vital within a risk assessment because they focus the risk assessment design and analysis. Assessment endpoints provide a link between the measurement endpoints and the risk management process.

Individual assessment endpoints typically revolve around a key ecological trophic level, community, or specific ecological function while, collectively, these assessment endpoints are representative of the entire river ecosystem. Assessment endpoints (receptors) for the river system include:

- Pelagic fish communities;
- Benthic fish communities;
- Benthic invertebrate communities;
- Aquatic plant communities;
- Aquatic- or riparian-feeding herbivorous bird populations;
- Aquatic- or riparian-feeding insectivorous (omnivorous) bird populations;
- Aquatic- or riparian-feeding carnivorous (piscivorous) bird populations;
- Aquatic- or riparian-feeding herbivorous mammal populations;
- Aquatic- or riparian-feeding insectivorous (omnivorous) mammal populations;
- Aquatic- or riparian-feeding carnivorous (piscivorous) mammal populations;
- Aerial-feeding insectivorous (omnivorous) bird populations;
- Aerial-feeding insectivorous (omnivorous) mammal populations;
- Aquatic- or riparian-feeding reptiles; and
- Aquatic- or riparian-feeding amphibians.

The subsections below discuss groups of ecological receptors potentially occurring at the TVA Kingston Ash Release site that are considered as assessment endpoints. These receptors include species that 1)

potentially occupy existing habitats at the site; 2) are instrumental to the structure and function of the site ecosystem; and 3) that are potentially exposed to constituents at the site or are otherwise toxicologically sensitive.

3.5.1 Pelagic Fish Communities

Pelagic fish are fish living in the water column above the bottom of the river system. These fish, such as bass, often times swim continuously, usually well offshore, and do not consistently remain in one area. Pelagic fish can make up all levels of the food chain, including planktivorous, omnivorous, and carnivorous (piscivorous) species. They can act as both predators to smaller species, as well as being prey items for higher trophic level predators. As a result, pelagic fish are vital to a balanced ecosystem by helping to maintain aquatic vegetation, invertebrate, and fish communities, as well as regulating other mid- to upper trophic level organisms.

Some piscivorous pelagic fish are upper trophic level predators, and as a result, they are especially susceptible to exposure to constituents that may bioaccumulate in their prey organisms. Concentrations of these constituents in tissue increase with each trophic level due to a process known as bioaccumulation. Fish in particular have been shown to accumulate constituents that are present in aquatic ecosystems. Therefore, fish that consume smaller fish have the potential to accumulate large concentrations of constituents in their tissues.

Pelagic fish have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic level consumers. They can make up a large component of the aquatic food chain base, providing an important food resource for piscivorous organisms such as larger fish, birds, and mammals. As a result, the viability of the pelagic fish community was selected as a valid assessment endpoint for this risk assessment.

3.5.2 Benthic Fish Communities

Benthic fish are fish that commonly live and graze along the river bottom. These fish, such as catfish, forage on plant material, benthic invertebrates, or other bottom-feeding fish. Benthic fish can make up all levels of the food chain, including planktivorous, omnivorous, and carnivorous (piscivorous) species. They can act as both predators to smaller species, as well as being prey items for higher trophic level predators. As a result, benthic fish are vital to a balanced ecosystem by helping to maintain aquatic vegetation, invertebrate, and fish communities, as well as regulating other mid- to upper trophic level organisms.

Some piscivorous benthic fish are upper trophic level predators, and as a result, they are especially susceptible to exposure to constituents that may bioaccumulate in their prey organisms. Concentrations of these constituents in tissue increase with each trophic level due to the process known as bioaccumulation. Fish in particular have been shown to accumulate constituents that are present in aquatic ecosystems. Therefore, fish that consume smaller fish have the potential to accumulate large concentrations of constituents in their tissues.

Benthic fish have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic level consumers. They can make up a large component of the aquatic food chain base, providing an important food resource for piscivorous organisms such as larger fish, birds, and mammals. As a result, the viability of the benthic fish community was selected as a valid assessment endpoint for this risk assessment.

3.5.3 Benthic Invertebrate Communities

Benthic macroinvertebrates live within and on top of sediment, consuming plankton (both phytoplankton and zooplankton), algae, detritus, and various macrophytes. This community of organisms plays a key role in nutrient cycling and organic matter processing, in addition to providing a food source for other macroinvertebrates, fish, and wildlife. Concentrations of constituents in sediment and surface water are also known to accumulate in invertebrate tissue, providing a means of trophic transfer of constituents to predators. As a result, benthic invertebrates are vital to a balanced ecosystem by helping to maintain energy flow, materials cycling, and plankton, algae, and macrophytes communities.

Benthic invertebrates have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic level consumers. They can make up a large component of the aquatic food chain base, providing an important food resource for aquatic organisms such as fish, birds, and mammals. As a result, the viability of the benthic invertebrate community was selected as a valid assessment endpoint for this risk assessment.

3.5.4 Aquatic Plant Communities

Aquatic plants, or macrophytes, found within the aquatic system can include both vascular and nonvascular plants. These plants can live completely within the water column (submerged), or only partially within the water column (emergent). Macrophytes provide habitat and food to other aquatic and riparian organisms that are dependent on these ecosystems. They are most commonly exposed to constituents via root uptake from surface water and sediment porewater.

Aquatic plants have the potential for direct exposure and adverse effects. They make up a large component of the aquatic food chain base, providing an important food resource for herbivorous and omnivorous organisms. As a result, the viability of the aquatic plant community was determined to be an appropriate assessment endpoint for this risk assessment.

3.5.5 Aquatic- or Riparian-Feeding Herbivorous Bird Populations

Aquatic- and riparian-feeding herbivorous bird populations, such as wood ducks, rely primarily on aquatic vegetation as forage. They inhabit the shallow or seasonally-exposed sediments of riverbanks and other water bodies, feeding primarily along the shore and on mudflats. Herbivores play an essential role in an aquatic ecosystem by transferring the energy available in plant tissue (primary producers) to animal tissue, in turn making it available to upper trophic level organisms. These organisms regulate vegetation density, species abundance, and diversity through feeding, in addition to serving as prey items for upper trophic level predators. Therefore, aquatic- and riparian-feeding herbivorous birds are vital to a balanced ecosystem by helping to maintain aquatic vegetation communities.

Aquatic- and riparian-feeding herbivorous birds have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic level consumers. They make up a large component of the aquatic food chain base, providing an important food resource for carnivorous organisms such as larger birds and mammals. As a result, the viability of the aquatic- and riparian-feeding herbivorous bird community was determined to be an appropriate assessment endpoint for this risk assessment.

3.5.6 Aquatic- or Riparian-Feeding Insectivorous (Omnivorous) Bird Populations

Aquatic- and riparian-feeding insectivorous (omnivorous) bird populations consume plants and invertebrates. In addition to linking energy pathways in an aquatic ecosystem, omnivores foraging on

insects, invertebrates, and vegetation regulate the population density of these groups. They inhabit the shallow or seasonally-exposed sediments of riverbanks and other water bodies, feeding in the water, along the shore, and on mudflats. Common species include mallards and killdeer. Omnivorous birds may also serve as the prey items for upper trophic level predators. As a result, aquatic- and riparian-feeding omnivorous birds are vital to a balanced ecosystem by helping to maintain aquatic vegetation and invertebrate communities.

Aquatic- and riparian-feeding omnivorous birds have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic levels. As a result, the viability of the aquatic- and riparian-feeding omnivorous bird community was selected as a valid assessment endpoint for this risk assessment.

3.5.7 Aquatic- or Riparian-Feeding Carnivorous (Piscivorous) Bird Populations

Aquatic- and riparian-feeding carnivorous (piscivorous) bird populations rely primarily on fish as forage, but also consume small mammals, amphibians, and reptiles. Piscivorous species such as the osprey feed by hovering over the water and diving feet first to catch their prey with their talons while other species, such as the great blue heron, feed by wading in the shallow or seasonally-exposed sediments of riverbanks and other bodies of water. Piscivores play an essential role to an ecosystem by transferring the energy available in animal tissue to upper trophic levels. These populations of birds regulate fish and other aquatic organisms' density, species abundance, and diversity, but may also serve as prey items for upper trophic level predators. As a result, aquatic- and riparian-feeding piscivorous birds are vital to a balanced ecosystem by helping to maintain fish and aquatic organism communities.

Some piscivorous birds are upper trophic level predators, and as a result, they are especially susceptible to exposure to constituents that may bioaccumulate in their prey organisms. Concentrations of these constituents in tissue increase with each trophic level due to a process known as bioaccumulation. Fish in particular have been shown to accumulate constituents that are present in aquatic ecosystems, such as the COPECs associated with the river system. Therefore, birds that consume fish have the potential to accumulate large concentrations of constituents in their tissues.

Aquatic- and riparian-feeding piscivorous birds are important in energy transfer within the ecosystem, and they also regulate the population size of fish and aquatic organisms. They also have to potential for bioaccumulation of constituents within their tissue. Based on its ecological role and the potential for exposure and adverse effects in higher trophic level organisms, the viability of the aquatic- and riparian-feeding piscivorous bird community was determined to be a valid assessment endpoint for this risk assessment.

3.5.8 Aquatic- or Riparian-Feeding Herbivorous Mammal Populations

Aquatic- and riparian-feeding herbivorous mammal populations, such as muskrats, rely primarily on aquatic and riparian vegetation as forage. They feed primarily along shorelines and within emergent vegetation, and make their burrows in river banks, tree root cavities, or rock or brush piles found along aquatic systems. Herbivores play an essential role in an ecosystem by transferring the energy available in plant tissue (primary producers) to animal tissue, in turn making it available to upper trophic level organisms. These organisms regulate vegetation density, species abundance, and diversity through feeding, in addition to serving as prey items for upper trophic level predators. Therefore, aquatic- and riparian-feeding herbivorous mammals are vital to a balanced ecosystem by helping to maintain aquatic and riparian vegetation communities.

Aquatic- and riparian-feeding herbivorous mammals have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic level consumers. They make up a large component of the aquatic and riparian food chain base, providing an important food resource for carnivorous organisms such as larger birds and mammals. As a result, the viability of the aquatic- and riparian-feeding herbivorous mammal community was determined to be an appropriate assessment endpoint for this risk assessment.

3.5.9 Aquatic- or Riparian-Feeding Insectivorous (Omnivorous) Mammal Populations

Aquatic- and riparian-feeding insectivorous (omnivorous) mammal populations, such as raccoons, consume plants and animals. They feed primarily along the shoreline, within the shallow or seasonally-exposed sediments of riverbanks and other water bodies, and make their dens in tree cavities, or rock or brush piles found adjacent to aquatic systems. In addition to linking energy pathways in aquatic and riparian ecosystems, omnivores foraging on insects, invertebrates, and vegetation regulate the population density of these groups. Conversely, omnivorous mammals may also serve as the prey items for upper trophic level predators. As a result, aquatic- and riparian-feeding omnivorous mammals are vital to a balanced ecosystem by helping to maintain aquatic and riparian vegetation and invertebrate communities.

Aquatic- and riparian-feeding omnivorous mammals have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic levels. As a result, the viability of the aquatic- and riparian-feeding omnivorous mammal community was selected as a valid assessment endpoint for this risk assessment

3.5.10 Aquatic- or Riparian-Feeding Carnivorous (Piscivorous) Mammal Populations

Aquatic- and riparian-feeding carnivorous (piscivorous) mammal populations, such as mink, rely primarily on fish as forage, but also consume small mammals, amphibians, and reptiles. They feed primarily along shorelines and within emergent vegetation, and make their burrows in river banks, tree root cavities, or rock or brush piles found along aquatic systems. Piscivores play an essential role to an ecosystem by transferring the energy available in animal tissue to upper trophic levels. These populations of mammals regulate fish and other aquatic organisms' density, species abundance, and diversity, but may also serve as prey items for upper trophic level predators. As a result, aquatic- and riparian-feeding piscivorous mammals are vital to a balanced ecosystem by helping to maintain fish and aquatic organism communities.

Some piscivorous mammals are upper trophic level predators, and as a result, they are especially susceptible to exposure to constituents that may bioaccumulate in their prey organisms. Concentrations of these constituents in tissue increase with each trophic level due to a process known as bioaccumulation. Fish in particular have been shown to accumulate constituents that are present in aquatic and riparian ecosystems. Therefore, mammals that consume fish have the potential to accumulate large concentrations of constituents in their tissues.

Aquatic-and riparian-feeding piscivorous mammals are important in energy transfer within the ecosystem, and they also regulate the population size of fish and aquatic organisms. They also have the potential for bioaccumulation of constituents within their tissue. Based on its ecological role and the potential for exposure and adverse effects in higher trophic level organisms, the viability of the aquatic- and riparian-feeding piscivorous mammal community was determined to be a valid assessment endpoint for this risk assessment.

3.5.11 Aerial-Feeding Insectivorous (Omnivorous) Bird Populations

Aerial-feeding insectivorous birds, such as tree swallows, feed primarily on emergent insects (mayflies). In addition to linking energy pathways in an aquatic ecosystem, aerial-feeding insectivorous birds foraging on insects regulate the population density of these insects. Conversely, these organisms may also serve as the prey items for upper trophic level predators. As a result, aerial-feeding insectivorous birds are vital to a balanced ecosystem by helping to maintain emergent insect communities, as well as regulating other mid- to upper trophic level organisms.

Aerial-feeding insectivorous birds have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic levels. As a result, the viability of the aerial-feeding insectivorous bird community was selected as a valid assessment endpoint for this risk assessment.

3.5.12 Aerial-Feeding Insectivorous (Omnivorous) Mammal Populations

Aerial-feeding insectivorous mammals, such as gray bats, feed primarily on emergent insects (mayflies). In addition to linking energy pathways in an aquatic ecosystem, aerial-feeding insectivorous mammals foraging on insects regulate the population density of these insects. Conversely, these organisms may also serve as the prey items for upper trophic level predators. As a result, aerial-feeding insectivorous mammals are vital to a balanced ecosystem by helping to maintain emergent insect communities, as well as regulating other mid- to upper trophic level organisms.

Aerial-feeding insectivorous mammals have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic levels. As a result, the viability of the aerial-feeding insectivorous mammal community was selected as a valid assessment endpoint for this risk assessment.

3.5.13 Aquatic- or Riparian-Feeding Reptile Populations

Reptiles can inhabit both aquatic and riparian habitats. They consume a variety of plants, invertebrates, other reptiles and amphibians, fish, small birds, and small mammals in both ecosystems. Reptiles, such as turtles and snakes, can include herbivores, omnivores, invertivores, and carnivores. Throughout their lifespan, reptiles can act as both predators to smaller species, as well as being prey items for higher trophic level predators. As a result, reptiles are vital to a balanced ecosystem by helping to maintain aquatic and riparian vegetation, invertebrate, and fish communities, as well as regulating other mid- to upper trophic level organisms.

Reptiles have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic level consumers. They can make up a large component of the aquatic and riparian food chain base, providing an important food resource for organisms such as larger fish, birds and mammals. As a result, the viability of the reptile community was selected as a valid assessment endpoint for this risk assessment.

3.5.14 Aquatic- or Riparian-Feeding Amphibian Populations

Amphibians can inhabit both aquatic and riparian habitats, depending on their life stage. Within their early life stages, amphibians are generally aquatic, consuming mainly plants and insects. However, as they mature, amphibians develop lungs and their diet changes to a variety of aquatic and terrestrial organisms. Amphibians, such as frogs and salamanders, can include herbivores, omnivores, invertivores, and carnivores. Throughout their lifespan, amphibians can act as both predators to smaller species, as well

as being prey items for higher trophic level predators. As a result, amphibians are vital to a balanced ecosystem by helping to maintain aquatic and riparian vegetation, invertebrate, and fish communities, as well as regulating other mid- to upper trophic level organisms.

Amphibians have the potential for direct exposure and adverse effects, as well as the potential for accumulation and transfer of constituents to higher trophic level consumers. They can make up a large component of the aquatic and riparian food chain base, providing an important food resource for organisms such as larger fish, birds and mammals. As a result, the viability of the amphibian community was selected as a valid assessment endpoint for this risk assessment.

3.6 CONCEPTUAL SITE MODEL AND RISK QUESTIONS

The CSM presents complete exposure pathways to be evaluated within the BERA, and depicts relationships between measurement endpoints and assessment endpoints. The CSM leads to the development of ecological risk questions, which are then used to direct the study design and remaining site assessment.

3.6.1 Conceptual Site Model

The ecological CSM identifies the potential sources of contamination at the site and the chemical, physical, and biological processes that could potentially occur as a result of contaminant releases. The CSM represents the current understanding of potential sources in the river system based on the best available information, and depicts how constituents from these sources move through the ecosystem to receptors that make up the assessment endpoints. Primary components of the CSM (i.e., sources, release and transport mechanisms, exposure media, exposure pathways, and ecological receptors) are depicted on Figure B-3. This CSM presents only viable exposure media and pathways for the river system.

3.6.2 Risk Questions

Ecological risk questions within the BERA are based on the assessment endpoints and how they will respond to constituents of concern. The risk questions provide a basis for developing the study design, as discussed in Step 4, and for evaluating the field investigation and risk characterization presented in Steps 6 and 7, respectively. The ecological risk questions established for the site are as follows:

1. Do concentrations of ash-related constituents in surface water or food items pose unacceptable risks to pelagic fish communities?
2. Do concentrations of ash-related constituents in surface water, submerged sediment, shallow sediment (seasonally-exposed), or food items pose unacceptable risks to benthic fish communities?
3. Do concentrations of ash-related constituents in surface water, submerged sediment, sediment porewater, or shallow sediment (seasonally-exposed) pose unacceptable risks to benthic invertebrate communities?
4. Do concentrations of ash-related constituents in surface water, submerged sediment, shallow sediment (seasonally-exposed), or sediment porewater pose unacceptable risks to aquatic plant communities?
5. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic-or riparian-feeding herbivorous bird populations?

6. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic-or riparian-feeding omnivorous (invertivorous) bird populations?
7. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic-and riparian-feeding carnivorous (piscivorous) bird populations?
8. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic- or riparian-feeding herbivorous mammal populations?
9. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic- or riparian-feeding omnivorous mammal populations?
10. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic- or riparian-feeding carnivorous (piscivorous) mammal populations?
11. Do concentrations of ash-related constituents in surface water or food pose unacceptable risks to aerial-feeding insectivorous bird populations?
12. Do concentrations of ash-related constituents in surface water or food pose unacceptable risks to aerial-feeding insectivorous mammal populations?
13. Do concentrations of ash-related constituents in surface water, submerged sediment, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic- or riparian-feeding reptile populations?
14. Do concentrations of ash-related constituents in surface water, submerged sediment, shallow sediment (seasonally-exposed), or food pose unacceptable risks to aquatic- or riparian-feeding amphibian populations?

3.7 SCIENTIFIC MANAGEMENT DECISION POINT

At the end of Step 3, a SMDP is developed, consisting of an agreement on the COPECs, the assessment endpoints, the exposure pathways, and the risk questions that must be answered. The constituents identified as COPECs in surface water and sediment are presented in Table B-3-1. Further investigation of surface water will include identifying COPECs for mid-depth water column and epibenthic water. Further investigation of sediment will include identifying COPECs for shallow (seasonally-exposed) sediment and submerged sediment. In addition, further investigation of groundwater will include identifying COPECs for groundwater discharging to porewater and surface water.

The assessment endpoints and exposure pathways are depicted in the CSM (Figure B-3). The risk questions identified in Section 3.6.2 were designed to evaluate the potential risks associated with each assessment endpoint and exposure pathway.

3.8 UNCERTAINTIES ASSOCIATED WITH STEP 3 OF THE BASELINE ECOLOGICAL RISK ASSESSMENT

Uncertainties associated with the refinement of COPECs were considered and discussed below. As appropriate and needed, the uncertainties will be reevaluated as they relate to the BERA conclusions later in Steps 6 and 7 (EPA 2000a).

3.8.1 Refinement of Constituents of Potential Ecological Concern

Background Concentrations: Background concentrations of naturally occurring metals were not used for screening of COPECs; rather, they were used for comparative purposes only. As a result, constituents found above screening values could in part be attributed to these background concentrations, allowing an overestimate of potential risk to ecological receptors. Refinement of COPECs using background concentration may be reconsidered later in the BERA process.

Frequency of Detection: Frequency of detection is commonly used to eliminate COPECs that are unlikely to present significant risk to ecological receptors. While several constituents were detected in 2009 sampling at low frequencies within various media, all detected constituents were carried through into the BERA despite the uncertainty that these constituents were site-related or would likely pose a risk to ecological receptors. Frequency of detection may be reconsidered later in the BERA process.

Exposure Point Concentrations: Upper bound estimates of average exposure conditions, EPCs, are typically compared to ecological screening values in order to evaluate the potential for risk at a site. However, the maximum concentrations of constituents detected in all media in 2009 sampling were compared to screening values, which in turn may conservatively skew the calculated risks, allowing an overestimate of potential risk to ecological receptors. The calculation of EPCs may be reconsidered later in the BERA process.

Bioavailability: Bioavailability of constituents in ash, particularly within the aquatic system at the site, is currently unknown; as a result, bioavailability was assumed to be 100% for all constituents detected in any medium, allowing an overestimate of potential risk to ecological receptors. Continual testing is being conducted in order to better understand the forms, species, and bioavailability of constituents present in ash. Refinement of bioavailability may be reconsidered later in the BERA process.

Additional COPECs: Naturally-occurring radionuclides (potassium-40; radium-226, and -228; thorium-228 and -232; and uranium-234, -235, and -238) and legacy constituents (PAHs, PCBs, chlordane, cobalt-60, and cesium-137) were carried forward into the BERA in order to conservatively estimate total potential risk to ecological receptors in the river system. The effects of these additional COPECs will be considered in more detail in Steps 6 and 7 of the BERA.

3.8.2 Characterizing Ecological Effects

Uncertainty may be associated with characterizing effects to ecological receptors. The general toxicity and potential to bioaccumulate can vary between species and within a given population of receptors. Certain species may be more physiologically sensitive to a given constituent due to the adverse affect that the constituent has on a particular system or function within the organism. A population or species that has pre-existing stressors (e.g., feeding competition due to habitat degradation) could also be additionally sensitive due to the added stress of constituents in the ecosystem.

Differences in sensitivity within species or populations can be the result of variations in exposure. Variations in exposure can be the result of differences in behavior and diet among species. For example, species that feed primarily in one area where constituents accumulate or on one type of prey that accumulate constituents within its tissue may have a higher exposure to constituents. Ecological effects were evaluated for groups of similar species and populations; however, sensitivities and stressors or variations in exposure between species or within a population were not taken into consideration.

3.8.3 Refinement of Media

Exposure to seasonally-exposed sediments will only be evaluated for the winter months when the water is drawn down to the "winter pool" level. This event happens at the same approximate time each year and is carefully monitored. Additional exposure to these sediments could occur during extreme periods of drought; however, given the uncertainty associated with these potential occurrences, these occurrences were not taken into consideration when evaluating exposure to seasonally-exposed sediments.

Groundwater was not evaluated within Step 3 of the BERA because a sufficient data set of groundwater discharging to porewater and surface water was not available to address this pathway. Groundwater concentrations discharging to porewater and surface water will be modeled and evaluated later in the BERA process. Potential exposure to constituents detected in groundwater remains an uncertainty until this data gap is filled.

3.8.4 Assessment Endpoints

It is not practical or possible to directly evaluate risks to each of the individual components of the river ecosystem at the Site; as a result, assessment endpoints are selected to help focus the risk assessment on particular components of the ecosystem that could be adversely affected by COPECs. The assessment endpoints established for the river system are based on the key communities within the ecosystem, and encompass groups of species or populations that are representative of each feeding guild present. As a result, adverse affects to individual species may not be adequately addressed within this BERA.

Furthermore, there are several plants, invertebrates, amphibians, reptiles, fish and birds listed as species of conservation concern in Roane County, as evaluated by the TVA Regional Natural Heritage Program (Jacobs 2009). This list of species of concern will be used to inform the process of selecting the representative guilds and surrogate species evaluated as measurement endpoints to be further evaluated in Section 4.1; however, all sensitive species may not be adequately addressed within this BERA.

3.8.5 Conceptual Site Model

The CSM is a graphical representation of the complete exposure pathways identified for the river system. Pathways that are considered to be insignificant or incomplete are not presented or evaluated within the BERA (e.g., dermal and inhalation pathways). Under certain conditions, these exposure pathways may occur, but adequate information is rarely available by which to evaluate them. As a result, risk may be underestimated.

4. STEP 4: STUDY DESIGN AND DATA QUALITY OBJECTIVE PROCESS

The purpose of Step 4 of the BERA is to develop a study design and a data quality objective (DQO) process that is appropriate to the assessment and measurement endpoints identified and developed in the preliminary CSM of Step 3. The standard outputs of Step 4 include a risk assessment work plan and SAP (EPA 1997). For this project, Step 4 is documented in this BERA and the associated SAP. That is, the DQOs were used to develop the BERA methodology, which was then used to identify data needs and develop the SAP (study design). Previous and ongoing site investigations were evaluated in order to refine the BERA and SAP. Table B-4-1 and Attachment B-2 briefly describe the existing ecological field studies and laboratory bioassays for the site.

4.1 MEASUREMENT ENDPOINTS

A measurement endpoint, defined as "a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint", is a measure of biological effects (e.g., mortality, reproduction, growth) (EPA 1997). Measurement endpoints can include both measures of exposure (e.g., constituent concentrations in water) and measures of effect. They are often expressed through the use of numerical observations (e.g., toxicity test results, community diversity measures) that can be compared statistically to a control or reference site to detect adverse responses to a site constituent. Measures of exposure are measurements of the presence of stressors in the environment and their relationship or co-occurrence with the assessment endpoint. Examples of measures of exposure include concentrations of constituents in environmental media, concentrations of constituents measured in prey items used for food web modeling, and concentrations of constituents measured in ecological receptor tissue. Measures of effect are the measurable changes in an aspect of an assessment endpoint (or its surrogate) in response to a stressor to which it is exposed. Examples of measures of effect include survival, growth, and reproduction of ecological receptors.

The use of multiple lines of evidence to evaluate measurement endpoints provides a framework for reaching a conclusion regarding confidence in the risk estimate. More than one line of evidence is often necessary to reasonably demonstrate that constituents from a site or release are likely to cause adverse effects on an assessment endpoint. For the purposes of the BERA, primary and secondary lines of evidence were used to evaluate measurement endpoints in the river system as presented in the subsections below.

4.1.1 Primary Lines of Evidence

Primary lines of evidence provide direct evidence of risk and are commonly used in the decision-making process. The primary lines of evidence for the river system include evaluating literature-derived effects values, conducting bioassays (toxicity testing), and performing biosurveys (field studies) as described below.

Literature-Derived Effects Values

Toxicity data are commonly obtained from the literature rather than generated for site-specific assessments. The data selected should correspond to the assessment endpoints as closely as possible in terms of taxonomy, life stage, response, exposure duration, and exposure conditions. In cases where toxicity data are not available or applicable, tests may be conducted using site-specific media.

Table B-4-1. Biota and Toxicity Study Summary

Biota Studies	
Fish Studies	
FS1:	TVA - Reservoir Fish Assemblage Index Survey
	Electrofishing, gill nets; 3 sites; community metrics, fish condition
	Sampled January 2009; Annual fall sampling
FS2:	TDEC - Fish Tissue Concentration Study
	Largemouth bass, channel catfish, blue catfish (filets; n=5); 4 sites; bioaccumulation, health bioindicators
	Sampled January-April 2009; Annual monitoring proposed
FS3:	TVA, ORNL - TDEC Requested Whole Fish Analysis - Spring 2009
	Largemouth bass, redear (whole; n=4); 1 site; bioaccumulation
	Sampled March 2009
FS4:	TVA, ORNL - Fish Health & Bioaccumulation - Spring
	Largemouth bass, bluegill, channel catfish (filets, organs; n=6-8); 4 sites; bioaccumulation, health bioindicators
	Sampled January-April 2009; Annual monitoring proposed
FS5:	TVA, ORNL - Fish Health & Bioaccumulation - Fall
	Largemouth bass, bluegill, channel catfish (filets, organs; n=6-8); 5 sites; bioaccumulation, health bioindicators
	Sampled September 2009; Annual monitoring proposed
FS6:	TVA, ORNL - Whole Forage Fish Analysis
	Gizzard shad (whole; n=30); 5 sites; bioaccumulation
	Sampled June 2009; Expanded annual monitoring proposed
FS7:	TVA, ORNL, TDEC - Stilling Pond Fish Tissue Concentration Study
	Bluegill, carp, green sunfish (filets, organs, whole; n=3-5); 1 site; bioaccumulation, health and reproduction bioindicators
	Sampled April 2009
FS8:	TVA, ORNL - Reproductive Study of Female Fish - Spring
	Largemouth bass, bluegill, white crappie (filets, organs; n=6-8); 5 sites; bioaccumulation, health and reproduction bioindicators
	Sampled April 2009; Annual monitoring proposed
FS9:	TVA, ORNL - Kingston East Embayment Fish Removal
	Gizzard shad, redear sunfish, bluegill, Largemouth bass (whole, filets; n=1-10 fish per species); 1 site; bioaccumulation
	Sampled June 2009
FS10:	TVA, ORNL - Reservoir Spring Sportfish Survey
	Black bass spp., crappie; electrofishing (n=12, 30 minutes), 2 sites; population metrics, fish condition
	Sampled Spring 2009; Annual monitoring proposed
FS11:	TWRA - Fish Tissue Concentration Study
	Black crappie (whole; n=5); 4 sites; bioaccumulation
	Sampled April 2009
FS12:	TWRA - Fish Tissue Concentration Study
	CHC (filets, organs; n=5); 2 sites; bioaccumulation, reproduction bioindicators
	Sampled June 2009

Table B-4-1 Biota and Toxicity Study Summary
(continued)

Wildlife Studies		
WS1:	TVA, UT - Mammal Tissue Concentration Study	
		Raccoon, muskrat (blood, tissue; n=10); 2 sites; bioaccumulation, health bioindicators
		Sampled August-September, 2009; Annual monitoring proposed
Bird Studies		
BS1:	TVA - Piscivore and Herbivore Egg Concentration Study	
		Osprey, great blue heron, Canada goose (n=1 per nest); 1-6 sites; bioaccumulation
		Sampled April 2009; Annual monitoring proposed
BS2:	TVA, VA Tech - Insectivorous Bird Tissue Concentration Study	
		Tree swallow (contents of egg with no shell, whole-body nestling; n=10); 5 sites; bioaccumulation
		Sampled April-August 2009; Annual monitoring proposed
Reptile and Amphibian Studies		
RS1:	TVA, VA Tech, TWRA - Turtle Tissue Concentration Study	
		Snapping turtle, musk turtle (blood; n=10); 5 sites, 1 reference site; bioaccumulation
		Sampled August-September, 2009; Annual monitoring proposed
RS2:	TWRA - Turtle Tissue Concentration Study	
		Snapping turtle (whole; n=3); 2 sites and multiple reference sites; bioaccumulation
		Sampled August-September, 2009; Annual monitoring proposed
RS3:	TVA - Amphibian Tissue Concentration Study	
		Upland chorus frog, northern cricket frog, American toad (whole; n=10); 3 sites and 2 reference sites; bioaccumulation
		Sampled March-April 2009; Annual monitoring proposed
Invertebrate Studies		
IS1:	TVA, ORNL - Mayfly Larvae Collection	
		Hexagenia bilineata (n=4-6 composites); 6 sites; bioaccumulation
		Sampled Spring/Summer 2009; Annual monitoring proposed
IS2:	TVA, ORNL - Emerging Adult Mayflies	
		Hexagenia bilineata (n=2-4 composites); 6 sites; bioaccumulation
		Sampled Summer 2009; Annual monitoring proposed
IS3:	TVA, ORNL- Snail Tissue Concentration Study	
		Pleurocera canaliculatum (n=4); 5 sites; bioaccumulation
		Sampled August 2009
IS4:	TVA - Assessment of Benthic Macroinvertebrate Community Survey	
		Cross-channel transects (n=10 grabs per transect); 11 sites; community metrics
		Sampled January 2009; Scheduled sampling December 2009; Annual monitoring proposed

Table B-4-1. Biota and Toxicity Study Summary
(continued)

Toxicity Studies	
Sediment	
TX1:	TVA - Vibracore Whole Ash Bioassays: Mussel Tissue Concentration Study *Corbicula fluminea*; 2 sites; 28-d bioaccumulation VB 1 and VB 2 sampled March 2009; VB 3 and VB 4 sampled June 2009
TX2:	TVA - Vibracore Whole Ash Bioassays: Benthic Invertebrate Tissue Concentration Study *Lumbriculus variegatus*; 2 sites; 4-d bioaccumulation VB 1 and VB 2 sampled March 2009; VB 3 and VB 4 sampled June 2009
TX3:	TVA - Vibracore Whole Ash Bioassays: Amphipod Toxicity Test *Hyalella azteca*; 2 sites; 10-d growth and survival VB 1 and VB 2 sampled March 2009; VB 3 and VB 4 sampled June 2009
TX4:	TVA - Vibracore Whole Ash Bioassays: Mussel Toxicity Test Freshwater Juvenile Mussel; 2 sites; 5d, 10-d survival VB 1 and VB 2 sampled March 2009; VB 3 and VB 4 sampled June 2009
TX5:	TVA - Vibracore Ash Elutriate Bioassays: Mussel Toxicity Test Freshwater Juvenile Mussel; 2 sites; 10-d survival VB 1 and VB 2 sampled March 2009; VB 3 and VB 4 sampled June 2009
TX6:	TVA - Vibracore Ash Elutriate Bioassays: Zooplankton Toxicity Test *Ceriodaphnia dubia*; 1 site; 96-h survival VB 1 and VB 2 sampled March 2009; VB 3 and VB 4 sampled June 2009
TX7:	TVA - Vibracore Ash Elutriate Bioassays: Fish Toxicity Test *Pimephales promelas*; 1 site; 96-h survival VB 1 and VB 2 sampled March 2009; VB 3 and VB 4 sampled June 2009
TX8:	USGS, USFWS - Benthic Invertebrate Studies, Whole-Sediment and Elutriate Exposures *Hyalella azteca, Villosa iris, Lampsilis fasciola, Chironomus dilutes*; 10-d, 28-d survival Sampled Winter/Spring 2009
TX9:	U.S. Corps of Engineers, Engineer Research and Development Center - Extended Elutriate Bioassays, Larval (9-d) and Juvenile (3-m) Fathead Minnows *Pimephales promelas*; 10-d bioaccumulation (juveniles only), health bioindicators Sampled Summer 2009
Surface Water	
TX10:	TVA - Emory River Plume Bioassays: Zooplankton Toxicity Test *Ceriodaphnia dubia*; 1 site; 7-d survival, reproduction; 96-h survival Sampled weekly or biweekly during dredging
TX11:	TVA - Emory River Plume Bioassays: Fish Toxicity Test *Pimephales promelas*; 1 site; 7-d survival, reproduction; 96-h survival Sampled weekly or biweekly during dredging
TX12:	TVA - Outfall 001 Bioassays: Zooplankton Toxicity Test *Ceriodaphnia dubia*; 1 site; 7-d survival, reproduction; 96-h survival Sampled weekly or biweekly during dredging
TX13:	TVA - Outfall 001 Bioassays: Fish Toxicity Test *Pimephales promelas*; 1 site; 7-d survival, reproduction; 96-h survival Sampled weekly or biweekly during dredging

Note: For definitions, see the List of Acronyms section.

This line of evidence includes the comparison of: 1) constituent concentrations in ambient media (sediment, sediment porewater, and surface water [epibenthic and water column]) with NOAELs, LOAELs, and chronic values; 2) body burden effects data (whole or organ) with toxicity data found in the literature; and 3) measured or estimated concentrations in prey and in incidentally ingested ambient media with TRVs. In order to evaluate the effects of concentrations in prey and incidentally ingested ambient media, representative species must be selected for food web model calculations. The rationale for selecting representative species associated with the river system for evaluation in the BERA is presented in Attachment B-3.

Bioassays

Toxicity testing is a measure that is often added as a line of evidence in a BERA. Toxicity testing may be appropriate when the evaluation of chemical data indicates that toxicity to fish or invertebrates is possible, but the likelihood of toxicity is uncertain. The factors controlling constituent bioavailability and toxicity in sediment are sufficiently complex that the likelihood of toxicity can be difficult to predict, and toxicity testing may be warranted. Plant toxicity testing is also possible (American Society for Testing and Materials [ASTM] 1998), but standardized plant toxicity tests have been developed primarily for crop species, which are not representative of native aquatic plant communities. If necessary, direct observation of aquatic plant species occurring in the area of interest will be preferred over toxicity testing as a means of evaluating potential sediment or surface water toxicity.

Toxicity tests using surface water may be useful if the constituents of interest have not been studied to any great extent, or are metals for which aquatic bioavailability is strongly affected by site-specific conditions. The bioavailability and toxicity of site constituents can be tested directly with toxicity tests. Toxicity test organisms were selected based on relevance to the site and availability of standard test methods. Unless indicated otherwise, toxicity test organisms will remain the same in future studies.

Sediment: Sediment toxicity testing was conducted using the amphipod *Hyalella azteca*, which is a sensitive benthic invertebrate, and using fathead minnows (*Pimephales promelas*) and cladocerans (*Ceriodaphnia dubia*), which are both standard test organisms (EPA 1994). Additional sediment toxicity tests will be conducted using these same three species. Physical characteristics of the sediment test samples will be compared with the characteristics of the laboratory control sediment using an appropriate reference sample location.

Surface water: Surface water toxicity testing was conducted using *C. dubia* and *P. promelas*, which are both standard text organisms for surface water. *H. azteca* was not included in surface water testing because this species lives primarily in the sediment and not in the surface water column. Additional surface water toxicity testing will be conducted using these same two specimens.

Biosurveys

Biosurveys, or bioassessments, are direct measurements of the quality of the biological community. Biosurvey method development has been focused primarily on aquatic systems (benthic invertebrates and fish). If conducted appropriately, aquatic biosurveys have been shown to be effective in determining adverse impacts due to chemical toxicity and other non-chemical stressors. Aquatic biosurveys are strongly recommended by the EPA:

- "Biological assessment data provide direct measurements of the water quality condition of water bodies . . . this is a distinct advantage of biological assessment data over chemistry and toxicity monitoring data for evaluating water quality conditions" (EPA 1990); and

- "EPA recommends that all States and Tribes use biocriteria and bioassessments in their efforts to determine water quality and to establish protective water quality standards" (EPA 1990).

Where the likelihood of adverse ecological effects is uncertain and the implications of assuming an adverse impact are significant, an aquatic biosurvey may be warranted. Biological studies conducted for the river system include biological characterization, monitoring, and assessment data from a variety of sources, including studies by TVA, as well as by Appalachian State University, Duke University, ORNL, the Tennessee Department of Environment and Conservation (TDEC), Tennessee Wildlife Resources Agency (TWRA), Tennessee Aquarium, U.S. Army Corps of Engineers Engineer Research and Development Center, U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey, University of Tennessee, and Virginia Polytechnic Institute and State University. Examples of studies include bioaccumulation and health assessments for birds, mammals, fish, benthic invertebrates, reptiles, and amphibians; community metric studies of fish and benthic invertebrates; and toxicity testing of benthic invertebrates and fish for surface water and sediment. These types of long-term studies demonstrate TVA's commitment to environmental management, and the resultant data and information present an opportunity for insight rarely available in early stages of the ERA process.

Table B-4-1 briefly identifies field studies and laboratory bioassays performed at the site that may provide additional insight into the characterization of predicted risks. Studies performed or funded by TVA are discussed in greater detail in Attachment B-2, along with general information about how these studies may be used to refine the risk characterization for the site.

4.1.2 Secondary Lines of Evidence

In addition to the primary lines of evidence used in determining the likelihood that a constituent released from the site will cause adverse effects on an assessment endpoint, additional lines of evidence may be used in this decision-making process. These secondary lines of evidence may indicate an exposure or effect on an ecological receptor, but the outcome of that exposure or effect is unknown. Secondary lines of evidence that will be used for the river system include the evaluation of biomarkers and bioindicators.

Biomarkers

Biomarkers are measures of exposure to environmental stressors, indicating whether an exposure to a stressor has occurred. They are primarily evaluated at the suborganismal level (e.g., enzyme levels in fish), by assessing molecular, biochemical, and physiological endpoints. Endpoints that are stressor-sensitive or that respond quickly to a stressor help to identify and define relationships between a stressor and its effect. While biomarkers can be helpful in identifying exposure to an environmental stressor, they often times cannot be used to evaluate effects of environmental stressors over long periods of time and, in general, have low ecological relevance. They also show relatively high variations in response to an environmental stressor due to individual variability, and as a result, can only be used as supplemental support in identifying underlying causes of observed changes in an ecosystem.

Bioindicators

Bioindicators are the measures of the cumulative stress and exposure for an ecological receptor. They include changes in biomolecular, biochemical, or physiological parameters that can be linked to a specific change within a given organism, population-level, or community-level characteristics (e.g., increased levels of stress proteins or reduced species diversity). Within an ecosystem, organisms are exposed to a variety of stressors that can have direct impacts (i.e., through metabolic pathways) or indirect impacts (i.e., availability of habitat). As a result, it is necessary to measure multiple characteristics of health in order to distinguish between anthropogenic stressor-induced effects of natural stressor-induced effects.

While bioindicators can be helpful in measuring cumulative stress and exposure to an ecological receptor, they provide little useful information in the understanding of the fundamental mechanisms between environmental stressors and the effects they have on ecological receptors. Bioindicators have a low sensitivity to individual stressors and have a tendency to potentially combine the effects caused by multiple stressors. As a result, bioindicators can only be used as supplemental support in identifying underlying causes of observed changes in an ecosystem.

4.2 STUDY DESIGN

The BERA study design reflects the assessment and measurement endpoints developed above, as needed. The primary purpose of the study design is to identify additional investigative tasks necessary to the assessment of ecological risks at the site. Spatial and temporal considerations will be evaluated for each of the assessment endpoints established within the BERA, as well as the various types of media needed for each endpoint.

4.2.1 Spatial Considerations

The spatial boundaries of the river system are those areas impacted by the ash spill, upstream to downstream within the Emory, Clinch, and Tennessee Rivers. Each river was divided into reaches to more adequately characterize potential effects to the selected assessment endpoints. The following reaches have been established for each river (Figure B-4):

- **Emory River** – Reach A (Emory River Mile [ERM] 0.0 to ERM 1.5); Reach B (ERM 1.5 to ERM 3.5); Reach C (ERM 3.5 to ERM 6.0)

- **Clinch River** – Reach A (Clinch River Mile [CRM] 0.0 to CRM 3.0); Reach B (CRM 3.0 to CRM 6.0)

- **Tennessee River** – Reach A (Tennessee River Mile [TRM] 550.0 to TRM 566.0; Reach B (TRM 566.0 to TRM 568.0)

The following reference sites were also established for each river to provide an accurate comparison to pre-release conditions:

- **Emory River** – Reference (above ERM 6.0)

- **Clinch River** – Reference (above CRM 4.5)

- **Tennessee River** – Reference (above TRM 568)

4.2.2 Temporal Considerations

The temporal considerations or boundary of the river system is primarily defined by the following events: the December 22, 2008 fly ash release, completion of the dredging associated with the time-critical removal action, and performance of the EE/CA (and associated risk assessments) for the River System (estimated fall 2010). Following are three time periods defined by these events, for which various types of data may be available for use in the ERA:

- **Pre-release Period** – prior to December 22, 2008

– **Time-Critical Removal Period** – from December 22, 2008 to completion of dredging associated with the time-critical removal action

– **Post-Time-Critical Removal Period** – from completion of dredging associated with the time-critical removal action to the River System ERA

While comparison to data from samples collected immediately after the ash spill should provide an indication of trends in bioaccumulation, concentrations of bioaccumulative ash-related constituents may increase in biota overtime and therefore collection of data over more than one sampling period may be necessary for long-term management. Two to three years of sampling may be necessary in order to characterize potential bioaccumulation to higher trophic level receptors.

4.2.3 Sampled Media

The environmental media to be sampled for ecological receptors includes seasonally-exposed sediment, submerged sediment, sediment porewater, surface water (epibenthic and water column), and biota (benthic invertebrates, fish, and wildlife). A discussion of how each medium will be used is provided in Section 2.2 of the SAP.

4.3 DATA QUALITY OBJECTIVES AND STATISTICAL CONSIDERATIONS

The type, quantity, and quality of the environmental data to be collected should be adequate to support the risk management decision-making process. The following are the goals of the DQO process (EPA 1997):

- Clarify the study objective and define the most appropriate types of data to collect;
- Determine the most appropriate field conditions under which to collect the data; and
- Specify acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support risk management decisions.

The DQOs include the number and location of samples to be taken, and the analyses to be performed on each sample. The required number of samples may be based on statistical methods that will be used to analyze the data. Sampling locations ideally involve sampling along a concentration gradient in order to delineate areas that may potentially pose ecological risks. Also, sampling locations should allow the simultaneous co-located collection of biotic and abiotic samples (EPA 2000a).

This will facilitate the consideration of the relationship between constituent concentrations in the abiotic media and the biological effects (tissue residues, toxicity testing, etc.). The analyses preformed on each sample will depend on the manner the data will be used in the ERA (e.g., detection limits should be verified as appropriate for the manner in which the analytical data will be used) and should be based on scientifically defensible methods. DQOs and statistical considerations are defined in the SAP.

4.3.1 Data Quality Objectives

The ecological DQOs identified for the river system are presented in the SAP and are based on the assessment endpoints and risk questions (E-1 through E-14), which are then further characterized by identifying the exposure media, the associated measurement endpoints, including measures of exposure and measures of effects, and the sampling needs for each assessment endpoint. Each risk question, along with the associated measures and data needs, is described in detail below:

E-1. Do concentrations of ash-related constituents in surface water or food items pose unacceptable risks to **pelagic fish communities**?

- Exposure media:
  - Surface water
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: fish community
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Biomarkers of exposure – measured tissue concentrations of selenium (and other bioaccumulators) in whole fish, muscle tissue, liver, ovaries, filets (if no whole fish)
- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, lowest chronic values, screening values, species sensitivity distributions
  - Bioassays with lab fish and site surface water – short-term larval fish tests, subchronic/early life stage tests
  - Biological surveys of site fish – diversity, abundance, age distribution
  - Bioindicators of effects – ovary status, liver enzymes, etc.
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column)
  - Pelagic fish (whole and filet)
  - Fish community metrics

E-2. Do concentrations of ash-related constituents in surface water, submerged sediment, or food items pose unacceptable risks to **benthic fish communities**?

- Exposure media:
  - Surface water
  - Submerged sediment
  - Shallow sediment (seasonally-exposed)
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: fish community
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and total organic carbon (TOC)
  - Biomarkers of exposure – measured tissue concentrations of selenium (and other bioaccumulators) in whole fish, muscle tissue, liver, ovaries, filets (if no whole fish)
- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, lowest chronic values, screening values, species sensitivity distributions

- Bioassays with lab fish and site surface water – short-term larval fish tests, subchronic/early lifestage tests.
- Biological surveys of site fish – richness, abundance, age distribution
- Bioindicators of effects – ovary status, liver enzymes, etc.

- Site-specific sampling needs:
  - Surface water samples (epibenthic water)
  - Submerged sediment samples
  - Seasonally-exposed sediment samples
  - Benthic fish (whole and filet) tissue samples
  - Fish community metrics
  - Submerged sediment bioassays for *Pimephales promelas*

E-3. Do concentrations of ash-related constituents in surface water, submerged sediment, or sediment porewater pose unacceptable risks to **benthic invertebrate communities**?

- Exposure media:
  - Surface water
  - Submerged sediment
  - Shallow sediment (seasonally-exposed)
  - Sediment porewater
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: freshwater clams, freshwater mussels, daphnids, amphipods
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
  - Constituent concentrations in porewater
  - Biomarkers of exposure – measured tissue concentrations of selenium (and other bioaccumulators) in whole body tissue
- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, lowest chronic values, screening values, species sensitivity distributions
  - Bioassays with lab invertebrates and site sediment and surface water – short-term toxicity and bioaccumulation tests
  - Biological surveys of site benthic invertebrates – relative abundance, diversity, trophic relationships
  - Bioindicators of effects – foot and ciliary action, burrowing survival
- Site-specific sampling needs:
  - Surface water samples (epibenthic water)
  - Submerged sediment samples
  - Seasonally-exposed sediment samples
  - Sediment porewater samples
  - Benthic invertebrate tissue samples
  - Benthic invertebrate community metrics
  - Submerged sediment bioassays for *Hyalella azteca* and *Ceriodaphnia dubia*

- Surface water bioassays for *Ceriodaphnia dubia*

E-4. Do concentrations of ash-related constituents in surface water, submerged sediment, shallow sediment (seasonally-exposed), or sediment porewater pose unacceptable risks to **aquatic plant communities**?

- Exposure media:
  - Surface water
  - Submerged sediment
  - Shallow sediment (seasonally-exposed)
  - Sediment porewater
- Measurement endpoints: survival and growth
- Representative receptors: plant community
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
  - Constituent concentrations in porewater
  - Biomarkers of exposure – measured tissue concentrations of selenium (and other bioaccumulators) in plant tissue
- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, lowest chronic values, screening values, species sensitivity distributions
  - Bioaccumulators of effect – chlorophyll levels
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column and epibenthic water)
  - Submerged sediment samples
  - Seasonally-exposed sediment samples
  - Sediment porewater samples
  - Emergent vegetation of periphyton tissue samples

E-5. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to **aquatic- and riparian-feeding herbivorous bird populations**?

- Exposure media:
  - Surface water
  - Shallow sediment (seasonally-exposed)
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: wood duck (*Aix sponsa*)
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of (selenium and arsenic, and TOC

- Measured constituent concentrations of selenium (and other bioaccumulators) in dietary items (vegetation)

- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column)
  - Seasonally-exposed sediment samples

E-6. Do concentrations of ash-related constituents in surface water, shallow sediment (seasonally-exposed), or food pose unacceptable risks to **aquatic- and riparian-feeding omnivorous (invertivorous) bird populations**?

- Exposure media:
  - Surface water
  - Shallow sediment (seasonally-exposed)
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: mallard (*Anas platyrhynchos*) and killdeer (*Charadrius vociferous*)
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
  - Measured or modeled constituent concentrations of selenium (and other bioaccumulators) in dietary items (invertebrates)
- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column)
  - Seasonally-exposed sediment samples
  - Benthic invertebrate tissue samples

E-7. Do concentrations of ash-related constituents in surface water or food pose unacceptable risks to **aquatic- and riparian-feeding carnivorous (piscivorous) bird populations**?

- Exposure media:
  - Surface water
  - Shallow sediment (seasonally-exposed) (great blue heron only)
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: osprey (*Pandion haliaetus*) and great blue heron (*Ardea herodias*)
- Measures of exposure:

- Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
- Measured or modeled constituent concentrations of selenium (and other bioaccumulators) in dietary items (fish)
- Biomarkers of exposure – measured tissue concentrations of selenium (and other bioaccumulators) in eggs and nestlings (whole body)

o Measures of effects:

- Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions
- Biological surveys of site birds – population size, community dynamics
- Bioindicators of effects – egg size, shell thickness, nestling health (size, weight, abnormalities)

o Site-specific sampling needs:

- Surface water samples (mid-depth water column)
- Seasonally-exposed sediment samples
- Fish (whole body) tissue samples
- Egg and nestling samples
- Egg and nestling characteristics

E-8. Do concentrations of ash-related constituents in surface water, submerged sediment, seasonally-exposed sediment, or food pose unacceptable risks to **aquatic-or riparian-feeding herbivorous mammal populations**?

o Exposure media:

- Surface water
- Seasonally-exposed sediment
- Diet

o Measurement endpoints: survival, growth, and reproduction

o Representative receptors: muskrat (*Ondatra zibethicus*)

o Measures of exposure:

- Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
- Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
- Measured constituent concentrations of selenium (and other bioaccumulators) in dietary items (vegetation)

o Measures of effects:

- Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions

o Site-specific sampling needs:

- Surface water samples (mid-depth water column)
- Seasonally-exposed sediment samples

E-9. Do concentrations of ash-related constituents in surface water, submerged sediment, seasonally-exposed sediment, or food pose unacceptable risks to **aquatic- or riparian-feeding omnivorous mammal populations**?

- Exposure media:
  - Surface water
  - Seasonally-exposed sediment
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: raccoon (*Procyon lotor*)
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
  - Measured or modeled constituent concentrations of selenium (and other bioaccumulators) in dietary items (invertebrates)
  - Biomarkers of exposure – measured blood constituent concentrations of selenium (and other bioaccumulators) in raccoon; measured liver, kidney, and ovary (if applicable) constituent concentrations of selenium (and other bioaccumulators) in raccoon
- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions
  - Biological surveys of site mammals – community metrics
  - Bioindicators of effects – blood and organ status, etc.
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column)
  - Seasonally-exposed sediment samples
  - Benthic invertebrate tissue samples

E-10. Do concentrations of ash-related constituents in surface water, submerged sediment, seasonally-exposed sediment, or food pose unacceptable risks to **aquatic- or riparian-feeding carnivorous (piscivorous) mammal populations**?

- Exposure media:
  - Surface water
  - Seasonally-exposed sediment
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: mink (*Neovison vison)*
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
  - Measured or modeled constituent concentrations of selenium (and other bioaccumulators) in dietary items (fish)
- Measures of effects:

- Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions

- Site-specific sampling needs:
  - Surface water samples (mid-depth water column)
  - Seasonally-exposed sediment samples
  - Fish (whole body) tissue samples

E-11. Do concentrations of ash-related constituents in surface water or food pose unacceptable risks to **aerial-feeding insectivorous bird populations**?

- Exposure media:
  - Surface water
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: tree swallows (*Tachycineta bicolor*)
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Measured constituent concentrations of selenium (and other bioaccumulators) in dietary items (emergent mayflies)
  - Biomarkers of exposure – measured tissue concentrations of selenium (and other bioaccumulators) in eggs and nestlings (whole body)
- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions
  - Biological surveys of site tree swallows – population size, clutch size
  - Bioindicators of effects – egg size, shell thickness, nestling health (size, weight, abnormalities)
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column)
  - Emergent insect (mayfly) tissue samples
  - Egg and nestling samples
  - Egg and nestling characteristics

E-12. Do concentrations of ash-related constituents in surface water or food pose unacceptable risks to **aerial-feeding insectivorous mammal populations**?

- Exposure media:
  - Surface water
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: gray bat (*Myotis grisescens)*
- Measures of exposure:

- Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
- Measured constituent concentrations of selenium (and other bioaccumulators) in dietary items (emergent mayflies)

- Measures of effects:
  - Literature-derived toxicity data – NOAELs, LOAELs, BERA TRVs, screening values, species sensitivity distributions
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column)
  - Emergent insect (mayfly) tissue samples

E-13. Do concentrations of ash-related constituents in surface water, submerged sediment, seasonally-exposed sediment, or food pose unacceptable risks to **aquatic- or riparian-feeding reptile populations**?

- Exposure media:
  - Surface water
  - Submerged sediment
  - Seasonally-exposed sediment
  - Diet
- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: no species identified
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
  - Biomarkers of exposure – measured blood constituent concentrations of selenium (and other bioaccumulators) in reptiles
- Measures of effects:
  - Literature-derived toxicity data
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column and epibenthic water)
  - Submerged sediment samples
  - Seasonally-exposed sediment samples

E-14. Do concentrations of ash-related constituents in surface water, submerged sediment, seasonally-exposed sediment, or food pose unacceptable risks to **aquatic- or riparian-feeding amphibian populations**?

- Exposure media:
  - Surface water
  - Submerged sediment
  - Seasonally-exposed sediment
  - Diet

- Measurement endpoints: survival, growth, and reproduction
- Representative receptors: no species identified
- Measures of exposure:
  - Constituent concentrations in surface water (total and dissolved) and speciation of selenium and arsenic
  - Constituent concentrations in sediment, speciation of selenium and arsenic, and TOC
  - Biomarkers of exposure – measured whole body tissue constituent concentrations of selenium (and other bioaccumulators) in amphibians
- Measures of effects:
  - Literature-derived toxicity data
- Site-specific sampling needs:
  - Surface water samples (mid-depth water column and epibenthic water)
  - Submerged sediment samples
  - Seasonally-exposed sediment samples

4.3.2 Statistical Considerations

Sampling locations will be selected "randomly" to characterize an area and along a gradient away from the release (non-randomly), depending on the media and DQOs, as discussed in the SAP. The way in which sampling locations are selected determines which statistical tests, if any, are appropriate for evaluating test hypotheses. In evaluating results of statistical analyses, it is important to note that a statistically significant difference relative to a control or reference population is not necessarily a biologically important or ecologically significant difference.

4.4 SUMMARY OF THE DATA QUALITY OBJECTIVES

At the end of Step 4 of the ERA, the study design should coincide with SAP. The type, quantity, and quality of the environmental data to be collected for both documents should be adequate to support the risk management decision-making process. A summary of the proposed sampling plan is presented in Table B-4-2, connecting each current or proposed type of sampling with the appropriate assessment endpoint.

Table B-4-2. Summary of DQOs and Study Design

Lines of Evidence	Sampling / Testing[1,2]	Assessment Endpoint													
		E-1: Pelagic Fish	E-2: Benthic Fish	E-3: Benthic Invertebrate	E-4: Aquatic Plants	E-5: Herbivorous Birds	E-6: Omnivorous Birds	E-7: Piscivorous Birds	E-8: Herbivorous Mammals	E-9: Omnivorous Mammals	E-10: Piscivorous Mammals	E-11: Aerial-Feeding Birds	E-12: Aerial-Feeding Mammals	E-13: Reptiles	E-14: Amphibians
Measured Concentrations in Ambient Media															
Seasonally-Exposed Sediment	1,2		P	P	P	P	P	P	P	P	P			S	S
Submerged Sediment	1,2		P	P	P									S	S
Porewater	2			P	P										
Epibenthic Surface Water	2		P	P	P									S	S
Mid-Depth Surface Water	1,2	P			P	P	P	P	P	P	P	P	P	S	S
Laboratory Bioassays															
Submerged Sediment															
INV – Bioaccumulation in Laboratory Specimens	1			P,S			P			P		S	S		
INV - Survival and Growth / Reproduction	1,2			P											
FISH - Survival and Growth / Reproduction	1,2		P												
Ash Elutriates															
INV - Survival and Growth / Reproduction	1			P											
FISH - Survival and Growth / Reproduction	1	P	P												
Surface Water															
INV - Survival and Growth / Reproduction	1,2			P											
FISH - Survival and Growth / Reproduction	1,2	P													

Table B-4-2. Summary of DQOs and Study Design
(continued)

Lines of Evidence	Sampling / Testing[1,2]	Assessment Endpoint													
		E-1: Pelagic Fish	E-2: Benthic Fish	E-3: Benthic Invertebrate	E-4: Aquatic Plants	E-5: Herbivorous Birds	E-6: Omnivorous Birds	E-7: Piscivorous Birds	E-8: Herbivorous Mammals	E-9: Omnivorous Mammals	E-10: Piscivorous Mammals	E-11: Aerial-Feeding Birds	E-12: Aerial-Feeding Mammals	E-13: Reptiles	E-14: Amphibians
Field Biosurveys and Measured Concentrations in Biota															
FISH - Bioaccumulation	1,2	P,S	P,S					P			P				
FISH - Reproductive Capacity	1,2	P	P												
FISH - Bioindicators / Biomarkers	1,2	S	S												
FISH - Community Metrics	1,2	P	P												
MAM - Bioaccumulation / Biomarkers	1								S	S					
BIRD – Bioaccumulation	1,2							P,S		P		P,S			
BIRD - Reproductive Capacity	1,2							P				P			
REP - Bioaccumulation	1													S	
AMP - Bioaccumulation	1														S
INV - Bioaccumulation	1,2			S			P			P		P	P		
INV - Community Metrics	1,2			P											
VEG - Bioaccululation	1,2				S	P			P						
VEG - Bioindicators / Biomarkers	1,2				S										

Notes:

[1]Sampling conducted before release (used as reference) or sampling conducted during the time-critical removal action.
[2]Sampling to be conducted after completion of time-critical removal action.

P Primary line of evidence
S Secondary line of evidence
AMP Amphibian
INV Invertebrate
MAM Mammal
REP Reptile

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5. STEP 5: VERIFICATION OF FIELD SAMPLING DESIGN

Step 5 is the opportunity for the EPA to review and provide input from Step 4, acting as a "reality check" of the proposed field efforts before the BERA methodology and SAP are finalized and implemented. Step 5 should verify that the SAP is appropriate to the site, can be implemented at the site, and previously obtained information should be checked and verified (EPA 1997, 2000a).

Some of the proposed sampling necessary for the BERA is a continuation of previous sampling in 2008 and 2009 that was conducted to identify conditions in the river system at that time. For these samples, the verification process entails evaluating the results of previous events and determining if modifications need to be made. Other proposed sampling has not yet been conducted and will therefore require pilot testing of sampling and processing procedures. Specific issues already evaluated or anticipated are discussed below for each media.

5.1 DETERMINE SAMPLING FEASIBILITY

Step 5 includes consideration of sampling feasibility for biotic and abiotic samples and media. For example, if a certain animal population is to be sampled, preliminary assessments of population density may be helpful in determining how long the sampling effort will take to collect the necessary number of individuals. Also, the feasibility of sampling media at the sampling locations should be assessed (EPA 1997). For instance, a sediment sample may not be able to be collected from a reference location due to flow characteristics of the river. Specific issues already evaluated or anticipated are discussed below for each media.

Sediment – Submerged sediment samples will be collected and used for chemical analysis and toxicity testing. The results will be compared to reference sediment locations. Sediment within the various river reaches can vary due to changes in the substrate and flow characteristics of the river and the ecosystem, and as a result, it may be difficult to find comparable reference sediment for each river.

Porewater – Porewater will be collected and used for chemical analysis; however, the collection and filtering of porewater may be difficult given the volume required for testing. Therefore, analytical data requests will be prioritized depending on the volume of porewater obtainable.

Biota – Collection and testing of biota from biosurveys pose sampling feasibility issues. For fish, biosurveys will include collections of specific species for bioaccumulation testing; however, if enough specimens per species are not collected in order to acquire sufficient tissue mass for chemical analysis of COPECs, the analytical results may be limited. Similarly, the collection and analysis of mayfly larvae and adults and vegetation also requires a specific mass of tissue. If an insufficient number of organisms are collected, it may be difficult to acquire enough tissue mass for chemical analysis of COPECs.

In addition, proposed bioassays for the site also present possible sampling feasibility issues. Toxicity testing of whole ash and sediment collected from the site will be evaluated for survival and growth potential of various benthic invertebrates. However, preliminary toxicity tests indicate that the physical characteristics of the sediment prevent the invertebrates from burrowing, which in turn caused death. Consequently, a suitable reference material must be found or created so that the ash is evaluated not only for chemical toxicity but also for physical toxicity. Furthermore, bioassays evaluating the toxicity of Emory River water to fish resulted in pathogen interference common in Emory River toxicity tests. As a result, UV-treated water will be evaluated as a control for the Emory River toxicity tests.

5.2 FINALIZE SAMPLING LOCATION SELECTION

The sampling locations will be finalized with input from field personnel at the site who are familiar with the area. Factors such as site accessibility will be taken into consideration not only for the protection of the health and safety of the field personnel, but also for the effort required for taking the samples (EPA 1997). Consideration of sampling locations with regard to available habitat is critical in the BERA. Reference locations are vitally important and will be chosen with the care. Input from personnel at the Kingston site will be especially important to locate areas that are upstream of or removed from the influence of the ash release.

5.3 REPORTING

Reporting within Step 5 of the ERA includes this BERA methodology and the SAP, along with any changes made to the draft versions, incorporated and documented.

6. STEP 6: FIELD INVESTIGATION AND DATA ANALYSIS

Step 6 will involve the implementation of the SAP, in addition to performing the sampling and testing described in Step 4 (as amended in Step 5) of this BERA methodology. Step 6 is where the analysis of exposure and analysis of effects is conducted. The results of Step 6 will be used to characterize ecological risks in Step 7. This section focuses on the evaluations that will be performed as part of the analysis phase of the BERA.

6.1 FIELD INVESTIGATION

The field investigation will focus on the elements of the CSM, including the assessment endpoints, risk questions, and testable hypotheses. The SAP describes the correlation between measurement and assessment endpoints, as well as discussing specific information on the required number, volume, and types of samples to be collected, and the sampling techniques to be used. In addition, the data reduction and interpretation techniques and the DQOs are also presented in the SAP. Step 5 of the BERA reviewed and tested the feasibility of the sampling design laid out in the SAP; therefore, the investigation will be a direct execution of the designed study.

Unexpected conditions may occur during the field investigation that may require alterations to the SAP. In this case, the feasibility of the sampling design (Section 5.0) will be revisited, and any changes in the collection of specific samples will be documented.

6.2 ECOLOGICAL CHARACTERIZATION

As part of the data evaluation process, the ecological characteristics of the site established during the problem formulation will be further analyzed based on observations and results from the field investigation. These site-specific ecological characteristics, both abiotic and biotic, will be used when evaluating the potential exposure and effects of the COPECs to provide additional understanding on: (1) the fate and transport of these constituents in the environment and (2) the site-specific species or communities of concern. The abiotic and biotic ecosystem characteristics specific to the river system are discussed in the subsections below.

6.2.1 Abiotic Characterization

Abiotic characteristics of the site can influence the potential exposure and effects of the COPECs on the fate and transport of these constituents to the environment and to the site-specific species or communities of concern. Several abiotic characteristics specific to the site make it difficult to correlate ecological exposures to COPECs and the effects of these exposures to the environment and ecological receptors.

The KIF sits on the Emory River, approximately 2.6 river miles above the confluence of the Clinch and Tennessee Rivers. The river system is part of an impoundment. River flow rates are regulated upstream on the Clinch River by Melton Hill and Norris Dams and downstream on the Tennessee River by Watts Bar Dam, which is 39.4 river miles below the KIF. The flow rates can also be influenced by operations of the Tellico and Fort Loudoun Dams on the Tennessee River. In addition, flow characteristics of the lower Emory River are greatly influenced by KIF operations. Water levels in the river system are managed for flood control, which at times can cause a mixing of river waters, the reversal of river flows, and changes in pool depths. The changes in water levels coincide with changes in air and water temperature, which may be a confounding variable with respect to seasonal exposures and observed effects.

The affected reach of Watts Bar Reservoir at the KIF transitions from the upstream riverine (river-like) reaches of the Emory River and the Clinch River to the more lacustrine (lake-like) conditions found in the

impounded portions of the Clinch and Emory River backwaters of Watts Bar Reservoir. This change coincides with the distance from the KIF, and in turn, the concentrations of COPECs in the ecosystem media, which confounds the gradient of exposure.

Natural variations in river substrate (i.e., grain size) and water quality (i.e., water hardness) lead to inherent differences in river hydrology. In addition, the natural variations in river bottom bathymetry not only between rivers but also within each river lead to differences in the distribution and thickness of deposited ash and sediment.

6.2.2 Biotic Characterization

Biotic characteristics of the site can also influence the potential exposure and effects of the COPECs on the fate and transport of these constituents to site-specific species or communities of concern. Several biotic characteristics specific to the site make it difficult to correlate ecological exposures to COPECs and the effects of these exposures to the environment and ecological receptors.

The river system consists of a temperate ecosystem, where migratory species (i.e., birds and fish) are common. The presence or absence of migratory species not only makes monitoring of exposure to these species more difficult, but also influences the ability to draw conclusions from modeled exposures. The activity of migratory species also determines levels of exposure. For instance, species that migrate to the site to reproduce may have a different exposure than those species stopping at the site to forage.

In addition, many species at the site are also considered omnivorous. These species consume a variety of plants and animals as their primary food source and are typically opportunistic, general feeders not specifically adapted to eat and digest either meat or plant material exclusively. This makes evaluation of these species difficult to estimate with modeling because the dietary components can vary greatly among species and within populations.

6.3 ANALYSIS OF ECOLOGICAL EXPOSURES AND EFFECTS

The analysis phase of the BERA will evaluate exposure data and effects data for the environmental stressors and representative receptors previously identified in Step 4. The analysis will use the information collected during Steps 1 through 5 of the BERA, and will evaluate the data, following the data interpretation and analysis methods specified in the SAP.

Site-specific data obtained during the field investigation will be used in place of the assumptions made in Steps 1 and 2 of the SLERA. Additional assumptions or models may be included to help interpret the data as they relates to the CSM.

6.3.1 Characterizing Exposures

Characterizing exposure will involve the evaluation and summary of available data, including exposure-related data on potential ecological receptors collected from TVA and additional agencies. Data collected and provided from non-TVA agencies (i.e., TDEC, TWRA, USFWS) will be evaluated qualitatively within the BERA in order to assess uncertainty and to provide comparisons for TVA-collected data. This characterization will be combined to form an exposure profile, which will present the magnitude and distribution of environmental stressors to which ecological receptors may be exposed. When characterizing exposures, site-specific information will replace assumptions made earlier in the BERA process and the ecological concerns established during problem formulation will be analyzed further. When site-specific information is not available, assumptions and uncertainties will be documented. The

exposure profile and the uncertainties and assumptions associated with the exposure profile will be incorporated into the risk characterization in Step 7.

The exposure-related information for each of the assessment endpoints previously identified as potential receptors for this BERA is described below. These exposure scenarios will be refined for the major representative receptors or receptor groups previously identified. The primary exposure routes of receptors to COPECs evaluated within the river system are direct exposure and dietary exposure.

Direct Exposure – Some organisms can be exposed to constituents by direct uptake (e.g., through or on roots of plants) or by direct contact with ambient media (submerged sediment, seasonally-exposed sediment, and groundwater discharging to sediment porewater). The evaluation of direct exposure to ambient media will be evaluated spatially by reach (Section 4.2.1) by calculating EPCs (Section 3.2.3) for each reach and analyzing the distribution of constituent concentrations within each reach. Site groundwater will be modeled to estimate the potential concentrations of representative COPECs which may discharge to sediment porewater in the vicinity of KIF. Maximum concentrations and, if necessary calculated EPCs, will be compared with aqueous ESVs.

Dietary Exposure – Some organisms can be exposed to constituents by incidental ingestion of contaminated ambient media (submerged sediment, seasonally-exposed sediment, porewater, and surface water) or prey items. Food-web modeling will be used to evaluate key receptors and their dietary exposure to COPECs. The COPECs identified for the river system include a host of inorganic constituents. Many inorganic constituents are not acutely toxic to species; however, long-term exposures may adversely affect individual species, populations, and/or communities of organisms within the river ecosystem as constituents build up in organism tissue. The presence of detectable inorganic constituents in biological tissues is not in itself considered ecologically significant unless such concentrations can be correlated to adverse effects. For the BERA, ecologically significant effects are defined as those effects that adversely influence the survival, growth, or reproduction or an organism. The survival or mortality will be determined in tests of short duration with generally high exposure concentrations (acute toxicity tests) or tests of long duration and comparatively lower exposure concentrations (chronic toxicity tests). Growth and reproductive effects will be evaluated using chronic testing.

Representative species for each feeding guild were selected and will be evaluated using food web models. These species, as discussed in Attachment B-3, were selected because they are common or potential inhabitants of the river system and most likely obtain their food from the river and/or associated riparian habitats. Food web models are used to estimate the average potential dietary exposure for representative species from ingestion of contaminated prey, while also taking into consideration ingestion of surface water and incidental ingestion of other site media (i.e., seasonally-exposed or submerged sediment). A detailed discussion of the food web model and related input parameters is presented in Attachment B-4. Both conservative and realistic exposure assumptions will be used in the BERA. This will include site-specific BAFs where available.

Biomarkers of Exposure – Specific biomarkers will be used to measure the exposure of an ecological receptor to COPECs at the site. Concentrations of COPECs in biological tissue (i.e., whole body organisms, groups of tissues, or select organs) will be collected and analyzed during the field investigation. These concentrations will be compared to literature-derived effects values, when available, in order to evaluate the effects from this exposure. For example, specific information is available for the effects of selenium in birds and mammals. These biomarkers will be used as primary lines of evidence to provide a solid foundation for determining the anticipated effects of constituents on ecological receptors based on their observed concentrations in biological tissue.

Additional biomarkers of exposure, such as enzyme and chlorophyll levels, may suggest an exposure has occurred but provides less concrete evidence of the exposure. These biomarkers will be evaluated as secondary lines of evidence and only support the characterization of ecological exposure.

6.3.2 Characterizing Ecological Effects

Characterizing ecological effects will include an evaluation of data sources and data types, and presents media-specific and ecological effects concentrations for COPECs. Information on effects collected from literature reviews will be evaluated along with the results of site-specific investigations (e.g., toxicity testing and biological surveys) in order to determine whether observed effects are associated with site exposures. This process, known as the exposure-response analysis, serves as the major component in establishing the relationship between ecological stressors and effects. The exposure-response analysis will take into consideration the magnitude, frequency, or duration of a stressor in comparison to the magnitude of the response in the ecosystem. The strength of the correlation between the stressor and response determines the causality, or correlation between a constituent gradient and ecological adverse affects. An exposure-response correlation must be supported by one or more lines of evidence, along with an analysis of the uncertainty associated with the correlation, in order to sufficiently demonstrate causality. The methods to be used to characterize ecological effects in this assessment are described below for each line of evidence.

Literature-Derived Effects Values – Exposure-response data reported in the scientific literature will be used as a primary line of evidence for characterizing risks to ecological receptors. Ecotoxicological profiles developed during problem formulation will be expanded and refined to better characterize potential effects. For constituents identified as COPECs based on data representative of post-dredging conditions, a range of effects values will be presented, when available. For aqueous exposures (surface water and porewater) to aquatic biota this may include LOAELs, NOAELs, and Chronic Values for survival, growth, or reproduction. For constituents in sediment, this may include concentrations representative of threshold effect values and probable effects values. Nonionic organic constituents in sediment also will be evaluated using equilibrium partitioning sediment benchmarks derived from aqueous effects values and measured organic carbon content. Measured concentrations of parent and alkylated PAHs will be evaluated using EPA's procedure for PAH mixtures in sediment (USEPA 2003), which may be adapted to include additional effects values representing a broader effects range. For dietary exposures this may include NOAELs and LOAELs for survival growth and reproduction. For tissue-concentrations, this may include NOAELs and LOAELs associated with survival growth and reproduction.

Bioassays – Toxicity tests of ambient media with standard laboratory test organisms will be used as a primary line of evidence for characterizing risks to benthic invertebrates and fish. The media to be tested include bulk sediment/ash samples, and an ash-sediment dilution series. The resulting data will be evaluated using standard statistical methods and software (i.e., TOXCALC) to identify samples with significantly reduced survival, growth, or reproduction. Ash-related constituents, legacy constituents, and media co-factors (organic carbon, grain size distribution, pH, hardness, etc.) will be measured in the tested media so that exposure-response relationships can be evaluated. Graphical and statistical (e.g., multiple regression analysis) methods will be used where appropriate to evaluate the concordance of observed effects with constituent exposures. In the event that adverse effects are observed and positively correlated with ash-related constituents, site-specific effects levels will be derived for individual constituents and/or ash-sediment ratios.

Biosurveys – Data collected during biosurveys will be used as direct measures of the type, magnitude, and extent of effects on receptors of concern at the site. Several types of surveys are being performed at the site, and will continue. The methods that will be used to evaluate potential exposure-response

relationships will vary depending on the receptors and metrics being studied. For most measures of effects, observations will be made along a gradient from the release site (i.e., by reaches) and at reference locations in order to estimate the magnitude and likelihood of effects due to the fly ash release. This approach will be used for fish reproductive health metrics and community metrics, benthic invertebrate community metrics, tree swallow reproduction and nestling health and heron reproduction and nestling health. The distribution of apparent effects in space and time also will be compared with the distribution of habitat characteristics that may affect these endpoints, particularly with respect to fish and benthic invertebrates. In fish, measured reproductive health of individual fish will also be compared with tissue concentrations in those fish. This body burden-effects relationship also may be used to evaluate reproductive success (clutch size) and nestling health (occurrence of deformities) of tree swallows and herons.

6.4 SCIENTIFIC MANAGEMENT DECISION POINT

The SMDP is only necessary in Step 6 if changes are made to this BERA methodology or the SAP. If the field conditions change or new data becomes available on the nature and extent of constituent migration, changes to the field investigation may be necessary. Despite the most careful planning and analysis, unexpected circumstances might make changes to the sampling plan in the field necessary. Changing field conditions (such as sampling in a different season than originally planned) might make sample collection impossible or unfeasible. Also, initial sampling may reveal that constituents are present in areas that were not previously known, or that additional constituents are present. Any changes made to measurement endpoints could lead to corresponding changes in the hypotheses being tested or the sampling design; therefore, proposed changes will be discussed with the risk manager and risk assessors.

6.5 SUMMARY

Step 6 of the BERA will consist of (1) the field investigation and any deviations from the SAP, (2) ecological characteristics specific to the site that may influence the exposure or effects of COPECs within the ecosystem, and (3) an analysis of the exposure and effects data for the site. The evaluation of exposure and effects will be performed simultaneously, following the data interpretation and analysis methods specified in the SAP. Assumptions made during Steps 1 and 2 will be replaced with site-specific data, helping to establish an exposure-response relationship between constituents and ecological responses at the site. The strength of the exposure-response relationship will be used to establish evidence of causality between the constituents and the environment or ecological receptors. The exposure and effect results of Step 6 will be used to characterize the ecological risks, as discussed in Step 7.

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7. STEP 7: RISK CHARACTERIZATION

Step 7 of the BERA process will focus on risk characterization, integrating the exposure data and effects data presented in Step 6. This step will combine the data generated in the field and laboratory with data collected from the literature in order to determine the likelihood of effects on the environment or an ecological receptor, given the exposure. The integration of exposure and effects information will be carried out for each line of evidence independently. Where multiple lines of evidence are available, a weight-of-evidence process will be used to characterize the overall strength of evidence for each assessment endpoint. This approach will ensure that the strengths and weaknesses of each data set are explicitly considered.

7.1 INTERPRETING LINES OF EVIDENCE

A weight-of-evidence approach is a means to evaluate the value of the information provided by measurement endpoints and observations made about a site (Menzie, et al. 1996). This approach is particularly useful when conflicting predictions of risk are obtained. The strength of evidence provided by site-specific information and literature-derived data will be evaluated to make conclusions regarding risk characterization for the river system.

EPA provides information on issues related to evaluating the ecological significance of risk estimates (EPA 1994). This information includes a general flowchart of considerations that leads to the identification of ecologically significant effects, and those that are not ecologically significant. These considerations include the spatial extent of the ash release, the persistence of the release (i.e., the temporal scale), and natural variability within the system (and whether effects can be measured separate from natural variability). These factors will be evaluated for each line of evidence in order to determine whether the estimated likelihood and magnitude of potential risks are ecologically significant.

Risk characterization will be performed for each assessment endpoint (where data are available) by 1) comparing measured constituent concentrations against toxicological literature-derived effects values and reference concentrations, 2) estimating the potential likelihood and magnitude of effects of the measured constituents, 3) estimating the toxicity of the ambient media based on the media toxicity test results, 4) estimating the effects of exposure on the endpoint biota based on the results of the biological survey data, 5) logically integrating the lines of evidence to characterize risks to the endpoint, and 6) listing and discussing the uncertainties in the assessment.

7.1.1 Literature-Derived Effects Values

This line of evidence will use concentrations of constituents in environmental media (either measured or modeled) to estimate exposure and will use toxicity test data from the scientific literature to estimate the type and magnitude of effects that may occur at the site. Exposure and effects data assembled during the analysis phase will be combined in a step-wise process. First, the constituents will be screened against ecotoxicological benchmarks, against background exposures, and, where possible against characteristics of the source to determine which are COPECs. Although this refinement of COPECs is typically done as part of the BERA Problem Formulation (Step 3), it has been postponed until Step 7 to enhance the completeness and thoroughness of the assessment for this site by using the more robust and representative data sets developed during the subsequent field investigation.

The rationale and process for refining the list of COPECs identified in the SLERA was described in Section 3.1. For this assessment, the process will consist of considering the following for each constituent:

- Comparison with background (upstream reference) concentrations;
- Frequency of detection; and
- Comparison of the EPC to SLERA screening toxicity values.

Unlike the SLERA, these BERA evaluations will be made on a river reach basis, to the extent practicable. Constituents identified as COPECs using this refinement process will then be further evaluated in the BERA by comparing the EPCs with an expanded suite of literature-derived effects values. Whereas the SLERA compensates for uncertainty by using only conservative effects values, the BERA uses a range of effects values (e.g., chronic effects values, probable effects concentrations, LOAECs, etc.) to provide a more reasonable estimate of potential effects.

In addition to point (deterministic) comparisons of exposure and effects, distributional analyses also will be used where: 1) sufficient exposure and effects data are available, and 2) results of the deterministic evaluation are uncertain (i.e., risks are neither clearly acceptable nor clearly unacceptable). For sediments, the distribution of measured sediment concentrations in each reach will be compared with the distribution of effects concentrations from the literature. The overlap of an exposure and an effect distribution will be used to estimate the spatial extent of potential risks within each reach. This will also be true for measured or estimated pore water exposures. For surface water, the distribution of measured constituent concentrations in each reach will be compared with the distribution of effects concentrations from the literature. The overlap of an exposure and an effect distribution will be used to estimate the temporal extent of potential risks within each reach. For endpoints where dietary exposures are estimated using food web models, the distributional analysis of exposures may be performed using Monte Carlo techniques.

The bioavailability of ash-related constituents is a primary uncertainty for the characterization of ecological risks. In surface water and sediment porewater, dissolved concentrations will be used as a measure of the bioavailable fraction of metals for comparison with literature-derived effects values. Site-specific hardness and pH data will be used to evaluate the bioavailability of metals for which aqueous toxicity has been documented in the literature to be dependent on these factors. In sediment, the difference between measured concentrations of acid volatile sulfides and simultaneously extracted metals will be used to identify metals that are not bioavailable. Equilibrium partitioning theory and site-specific organic carbon content will be used to estimate the bioavailability of nonionic organic legacy constituents in sediment (EPA 2003). For selected constituents (arsenic, mercury, and selenium), bioavailability/toxicity has been documented in the literature to be dependent on the chemical form (species) of the constituent. Site-specific chemical speciation data will be compared with chemical species-specific effects data to refine the characterization of risks for these constituents.

Although concentrations in abiotic media constitute the bulk of the literature-derived effects data, the estimation of effects based on tissue concentrations is a growing field of study. Such body burden concentrations have the advantage of being a better indicator of bioavailability. The disadvantage is the paucity of effects data for most constituents. Ash-related constituents and bioaccumulative legacy constituents will be measured in several receptors at the site, including fish, benthic invertebrates (snails and mayflies), vegetation (emergent macrophytes and periphyton), and birds (eggs and nestlings of tree swallows and herons). To the extent practical, these measured tissue concentrations will be compared with literature-derived effects values to estimate risks to the sampled receptor group. Documented effects on survival, growth, and reproduction will be considered primary evidence of potential risks. The ash-related constituents for which such data are most well documented include selenium, lead, and mercury.

7.1.2 Ambient Media Toxicity Tests (Bioassays)

Bioassay results will be evaluated in the analysis phase (Step 6) to determine whether statistically significant effects were observed and the degree to which observed effects could be associated with ash-related and legacy constituents. The resulting exposure-response profiles will form the basis for this line of evidence. For surface water and sediment, multiple species will be used under varying exposure protocols to provide a robust characterization of risks associated with ash-related and legacy constituents. Similarities and differences in results among different species exposed to the same medium will be used to characterize the likely exposure mechanisms, nature of effects, and ecological significance for the assessment endpoint being evaluated. Furthermore, the same species of invertebrate (*Hyalella azteca*) will be used in tests of whole sediment in order to evaluate the likely causes of observed effects.

Toxicity tests may yield erroneous or ambiguous results due to confounding factors, including the physical and nutritional characteristics of the test media. This is known to be an issue for fly ash, based on the results of standard sediment toxicity tests with released ash at the site. Tests of sediment-ash mixtures (i.e., dilution series tests and tests with samples from locations along an exposure gradient) will be used to evaluate the relative influence of constituent concentrations and these other non-toxic cofactors on the observed results of the bioassays. The use of alternative laboratory control media (e.g., polymer-treated ash) is being explored as a means of controlling for physical and nutritional cofactors. Other potentially confounding factors include the presence of pathogens in Emory River water that adversely affect tests with fathead minnow larva.

7.1.3 Biological Surveys

An exposure-response profile will be developed in the analysis phase (Step 6) based on the results of each biological survey at the site. If adverse effects were observed, the degree to which they can be associated with ash-related and legacy constituents will be estimated. Factors that will be considered in this analysis include the association of observed effects with the spatial extent of ash, concentrations of ash-related and legacy constituents, toxicity in bioassays, and habitat characteristics. Mobility of the receptors being surveyed will factored into the evaluation of overlapping spatial distributions of exposure and effects. Exposures for organisms that are relatively sessile (e.g., benthic invertebrates) or have small foraging territories (e.g., bluegill and tree swallows) can be more definitively associated with observed effects than exposures for mobile species (e.g., bass and herons).

The temporal dynamics of release, transport, exposure, and effects also will be considered in the evaluation of biological survey data. Fast-responding receptors, such as benthic invertebrates, are expected to be better indicators of potential effects of a recent release than higher trophic level receptors (slow-responders), especially for bioaccumulative constituents such as selenium. For example, the absence of observed effects on heron reproduction one year after the ash release would be less conclusive than a similar absence of effects on benthic invertebrate abundance and richness.

7.1.4 Weight-of-Evidence

Each line of evidence has inherent strengths and weaknesses with respect to the characterization of potential risks. To the extent practical, multiple lines of evidence will be collected in order to provide a robust assessment of ecological risks. Risks will be characterized separately for each assessment endpoint. Each line of evidence will be characterized as being consistent with ecologically significant risks, inconsistent with ecologically significant risks, or too ambiguous to interpret. Professional judgment will be used to determine the ecological significance of potential risks, with the rationale for such judgments being clearly described and supported with quantitative estimates of risk (e.g., magnitude

and frequency of exceedance of thresholds, degree of overlap of distributional estimates of exposure and effects, statistical significance of bioassay results, and observed reductions in clutch size).

Each line of evidence for each endpoint will also be assigned a qualitative weighting factor ranging from low to moderate to high. The weight of each line of evidence will be determined using professional judgment and the following considerations: relevance, temporal scope, spatial scope, quality, quantity, and uncertainty (adapted from Suter et al. 2000). Relevance of a line of evidence will be based on the degree to which it is related to the assessment endpoint. Biological survey results will generally be considered highly relevant, because they are often direct measures of the assessment endpoints. Biomarkers of exposure and suborganismal bioindicators of non-reproductive effects have low relevance to the endpoints of survival, growth and reproduction. The relevance of literature-derived effects values will be based in part on the degree to which the site media (e.g., ash/sediment) and species (e.g., warm water fish) are related to the tested media and species. The relevance of bioassays will be based in part on the degree to which receptor species and in situ exposures are related to the test species and laboratory exposures. The relevance of bioassays using site media is expected to be at least as high as that of literature-derived effects values.

A line of evidence will be given more weight if the data encompass the temporal variance in conditions at the site. The temporal boundaries that will be considered when evaluating site data are defined by the date of the ash release and completion of the time-critical removal action. This BERA is intended to evaluate conditions in the river system following completion of the time-critical removal action. Therefore, data collected after dredging is finished will generally be given more weight than data collected during dredging. This is more of a concern for surface water and sediment collected in the vicinity of dredging operations and less so for locations upstream or far downstream of the dredges.

A line of evidence will be given more weight if the data encompass the spatial variance in conditions at the site. Areas of the site that define the upper range of potential exposures include locations near the release site, where ash will accumulate in the river, and where groundwater potentially affected by the dredge cell will discharge through sediments. Areas of the site that define the lower range of potential exposures include lower site reaches (e.g., in the Clinch and Tennessee Rivers), reference reaches, and erosional areas.

A line of evidence will be given more weight if the data are of high quality relative to the data quality objectives for the study. The quality assurance and quality control practices for this project include verification and validation of the analytical data. The proper use of standard sampling, testing, and surveying protocols will also garner more weight for the associated line of evidence. However, even properly employed methods can result in lower quality data due to circumstances beyond the control of the operator. For bioassays, this may include systemic mortality of test organisms or infection by naturally-occurring pathogens.

A line of evidence will be given more or less weight based on the adequacy of the number of samples or observations. This is partly a function of representing the spatial and temporal scope of the site, but is also a function of the variance in a measure or response.

A line of evidence will be given more weight if it estimates the assessment endpoint with low uncertainty. This is partly a function of the quantity and quality of the available data, but also a function of the degree to which assessment endpoints must be extrapolated from the measurement endpoints. Factors that will be considered when evaluating biosurveys and bioassays include the representativeness of the measured constituent concentrations (e.g., from same sample, same location, or same reach), measures of confounding factors (habitat or media characteristics), relative range of exposure concentrations, and the relative range of observed responses.

Once each individual line of evidence is characterized regarding both its consistency with the assessment endpoint (or violation of it) and the relative strength of the evidence, then risk for the assessment endpoint will be characterized based on expert judgment as to how the lines of evidence relate to each other and to the endpoint. The final weight-of-evidence will be based on the relative credibility and reliability of the conclusions of the various lines of evidence.

7.2 UNCERTAINTY ANALYSIS

Uncertainties in the risk characterization are influenced largely by the uncertainties in the exposure assessment and effects assessment. The BERA will identify the uncertainties and potential impact on results of the risk assessment. These uncertainties typically fall into one of four main categories:

1. Conceptual model uncertainties – There will be uncertainties associated with the conceptual model used as the basis to investigate the site. The initial characterization of the ecological problems at the site, likely exposure pathways, constituents of concern, and exposed ecological components, requires professional judgment and assumption.

2. Natural variation and parameter error – Parameter values (i.e., water concentrations, tissue residue levels, and food ingestion rates) usually can be characterized as a distribution of values, described by central tendencies, ranges, and percentiles, among other descriptors.

3. Model uncertainty – There can be substantial uncertainty in how well a model (i.e., food web model) is able to predict the relationship between site-specific conditions and ecological receptors. Models available at present tend to be fairly simple and at best, only partially validated with field tests. As a consequence, it is important to identify key model assumptions and their potential impacts on the risk estimates.

4. Data uncertainty – There will be uncertainty associated with the data used in characterizing exposure to ecological receptors. Available data, including exposure-related data on potential ecological receptors collected from TVA and additional agencies, will be used to generate exposure profiles for risk characterization. Data collected and provided from non-TVA agencies (i.e., TDEC, TWRA, USFWS) will be evaluated qualitatively within the BERA, providing a comparison for data collected by TVA. Data comparisons from various agencies identify similarities and differences between collections that can be used to support or refute data interpretations.

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8. REFERENCES

Albers, P.H., L. Sileo, B.M. Mulhern.1986. Effects of environmental contaminants on snapping turtles of a tidal wetland. Arch Environ Contam Toxicol 15: 39-49.

ACGIH (American Conference of Industrial Hygienists) 1986. Threshold limit values and biological exposure indices with intended changes for 1986-87. American Conference of Governmental Industrial Hygienists, Cincinatti, Ohio.

American Society of Testing and Materials (ASTM) 1998. Practice for Algal Growth Potential Testing with Selenastrum capricornutum, ASTM D 3978-80.

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. Toxicological Profile for Chlordane. Atlanta, GA: U. S. Department of Health and Human Services, Public Health Service.

ATSDR. 1995. Toxicological Profile for Polycyclic Aromatic Hydrocarbons. Atlanta, GA: U. S. Department of Health and Human Services, Public Health Service.

ATSDR 1999 (March). Draft Toxicological Profile for Mercury. U. S. Department of Health and Human Services, Public Health Service.

ATSDR. 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). Atlanta, GA: U. S. Department of Health and Human Services, Public Health Service.

ATSDR 2003 (September). Draft Toxicological Profile for Selenium. U. S. Department of Health and Human Services, Public Health Service.

ATSDR 2004 (September). Toxicological Profile for Copper. U. S. Department of Health and Human Services, Public Health Service.

ATSDR 2005 (August). Toxicological Profile for Nickel. U. S. Department of Health and Human Services, Public Health Service.

ARSDR 2007 (August). Toxicological Profile for Lead. U. S. Department of Health and Human Services, Public Health Service.

ATSDR 2008 (September). Draft Toxicological Profile for Manganese. U. S. Department of Health and Human Services, Public Health Service.

Baes, C.F., III, R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Oak Ridge National Laboratory Publication No. 5786.

Barnhart J., 1997 Chromium chemistry and implications for environmental fate and toxicity. J. Soil Contam. 6(6): 561-568.

Barrows ME, Petrocelli SR, Macek KJ, et al. 1978. Bioconcentration and elimination of selected water pollutants by bluegill sunfish. In: Haque R, ed. Dynamics, exposure and hazard assessment of toxic chemicals. Ann Arbor, MI: Ann Arbor Science Publishers, Inc., 379-392.

Belfroid, et al. 1994. Uptake of hydrophobic halogenated aromatic hydrocarbons from food by earthworms (Eisenia andrei). Archives of Environmental Contamination Technology, 27:260-265.

Belfroid, et al. 1995. Modeling the accumulation of hydrophobic organic chemicals in earthworms. Environmental Science and Pollution Research, 2(1)5-15.

Beyer, N. 1990. Evaluating Soil Contamination. U.S. Fish and Wildlife Service, Biological Report, 90(2).

Beyer, W.N., G.H. Heinz, and A.W. Redmon-Norwood (eds). 1996. Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations. Lewis Publishers, Boca Raton, Florida.

Birge, W.J. 1978. Aquatic toxicology of trace elements of coal and fly ash. Energy and Environmental Stress in Aquatic Systems. Symposia Health Nov 2-4, 1977. Thorp & Gibbons, ed, Savannah River Ecology Laboratory, Institute of Ecology, University of Georgia, US Department of Energy, Technical Information Centre. CONF-771114.

Boothman, W.S., W.J. Berry, J.R. Serbst, and P.A. Edwards. 1999. Predicting toxicity of chromium-spiked sediments by using acid-volatile sulfide and interstitial water measurements. Abstract, Society of Environmental Toxicology and Chemistry 20th Annual Meeting, Philadelphia, PA, November 1999.

British Columbia Environmental Department Division (BCEPD). 2008 (February). Ambient Aquatic Life Guidelines for Iron Technical Report. Water Stewardship Division, Ministry of Environment, Province of British Columbia.

BCEPD 2009. Ambient Water Quality Guidelines for Boron Environmental Protection Division, Ministry of Environment, Government of British Columbia. http://www.env.gov.bc.ca/wat/wq/BCguidelines/boron/boron.html.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Molybdenum. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Dean JG, Bosqui FL, Lanoveite KH. 1972. Removing heavy metals from waste water. Environ Sci Technol 6:518-522.

DeFoe, D.L., G.D. Veith, and R.W. Carlson. 1978. Effects of Aroclor® 1248 and 1260 on the fathead minnow (Pimephales promelas). J. Fish. Res. Board Canada 35:997-1002.

Diamond, J.M., Winchester, E.L., Mackler, D.G., Rasnake, W.J., Fanelli, J.K., Gruber, D. 1992. Toxicity of cobalt to freshwater indicator species as a function of water hardness. Aquatic Toxicology. Vol. 22, pp 163-180.

Eisler, R. 1985. Selenium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service. Biological Report 85 (1.5). Report No. 5.

Eisler, R. 1986. Polychlorinated biphenyl hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.7).

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.11).

Eisler, R. 1990. Chlordane Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U. S. Fish and Wildlife Service Department of the Interior Biological Report 85 (1.21).

Eisler, R. 1993. Zinc hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 10. EPA. 1971. Water quality criteria data book. Washington, DC: U. S. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA). 1980. Ambient water quality criteria-for arsenic. EPA-440/S-80-021. National Technical Information Service, Springfield; Virginia.

EPA. 1984. Health Effects Assessment for Barium. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Emergency and Remedial Response, Washington, DC.

EPA. 1986 (Dec). Chemical Fact Sheet for Chlordane, 109. Office of Pesticide Programs, US EPA, Washington, DC.

EPA. 1989 (December). Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Volume 1, Part A. Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

EPA. 1990 (April). Biological Criteria: National Program Guidance for Surface Waters. Office of Water Regulations and Standards. EPA-440-5-90-004.

EPA. 1992. Guidance for Data Usability in Risk Assessment (Part A). Office of Emergency and Remedial Response. Publication 9285.7–09A. PB92-963356. http://www.epa.gov/superfund/programs/risk/datause/parta.htm.

EPA. 1993a,b. Wildlife Exposure Factors Handbook, Volumes I and II. Office of Research and Development. EPA/600/R-93/187. http://cfpub.epa.gov/ncea/cfm/wefh.cfm.

EPA. 1994 (November). "Ecological Risk Assessment Issue Papers," EPA/630/R-94/009.

EPA. 1996. Problems of Aquatic Toxicology, Biotesting and Water Quality Management Proceedings of USA-Russia Symposium, Borqk, Jaroslavl Oblast, July 21-23, 1992. EPA/600/R-96/090.

EPA. 1997 (June). Ecological Risk Assessment Guidance for Superfund – Process for Designing and Conducting Ecological Risk Assessments. Environmental Response Team.

EPA. 1998 (April). Guidelines for Ecological Assessment. Office of Research and Development, EPA/630/R-95/002FA.

EPA. 1999a (October 7). "Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites." Memorandum from Stephen D. Luftig, Director of the Office of Emergency and Remedial Response. http://www.epa.gov/superfund/programs/risk/ecorisk/final99.pdf.

EPA. 1999b (August). Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Solid Waste and Emergency Response. EPA530-D-99-001A.

EPA. 2000a (June 23). "Amended Guidance on Ecological Risk Assessment at Military Bases: Process Considerations, Timing of Activities, and Inclusion of Stakeholders." Memorandum from Ted W. Simon, Ph.D., Office of Technical Services. http://risk.lsd.ornl.gov/homepage/ecoproc2.pdf

EPA. 2000b (February). Bioaccumulation Testing and Interpretation For the Purpose of Sediment Quality Assessment, Status, and Needs. EPA-823-R-00-001.

EPA. 2001a. "ECO-Update: Role of Screening-level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments." Accessed 2001. http://www.epa.gov/superfund/programs/risk/ecoup/slera0601.pdf

EPA. 2001b. "Region 4 Ecological Risk Assessment Bulletins - Supplement to RAGS". http://www.epa.gov/region4/waste/ots/ecolbul.htm. EPA. 2003 (November). Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures, U.S. Environmental Protection Agency, Office of Research and Development,.

EPA. 2004 (November). Draft Aquatic Life Water Quality Criteria for Selenium. U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, D.C. EPA-822-D-04-001.

EPA. 2005 (February). Guidance for Developing Ecological Soil Screening Values. Office of Solid Waste and Emergency Response, Washington DC. OSWER Directive 9285.7-55.

EPA. 2006. "National Recommended Water Quality Criteria." Website: (http://www.epa.gov/waterscience/criteria/wqctable/nrwqc-2006.pdf).

EPA. 2007 (April). ProUCL 4.0. National Exposure Research Lab, EPA, Las Vegas, Nevada.

EPA. 2008a. "Ecological Soil Screening Levels." Website: (http://www.epa.gov/ecotox/ecossl/).

EPA. 2008b (December). "Materials Characterization Paper In Support of the Advanced Notice of Proposed Rulemaking – Identification of Nonhazardous Materials That Are Solid Waste Coal Combustion Products – Coal Fly Ash, Bottom Ash, and Boiler Slag." Website: (http://www.epa.gov/waste/nonhaz/pdfs/ccpash.pdf).

EPA. 2009a. Ecological Toxicity Information. Region 5 Superfund website (http://www.epa.gov/R5Super/ecology/html/toxprofiles.htm#pb).

EPA. 2009b. Integrated Risk Information System (IRIS). U.S. Environmental Protection Agency, Office of Research and Development, National Center of Environmental Assessment. Internet access: [http://www.epa.gov/iris].

Fabacher, D. L., J.M. Besser, C. J. Schmitt, J.C. Harshbarger, P.H. Peterman, and J. A. Lebo. 1991. Contaminated sediments from tributaries of the Great Lakes: chemical characterization and cancer-causing effects in medaka (Oryzias latipes). Arch. Environ. Contam. Toxic. 20:17-35.

Fan R.W.M., The S.J., Hinton D.E., Higashi R.M. 2002. Selenium biotransformations into proteinaceous forms by foodweb organisms of selenium-laden drainage waters in California. Aquatic Toxicol., 57: 65-84.

Fontenot, L.W., T.A. Ayers, C.H. Day, S.B. Ellingson, and S.L. Sager. 1999a. Screening-level Ecological Risk Assessment of Endocrine-disrupting Chemicals to Amphibians: A Regional Approach. Environmental Toxicology and Risk Assessment: 8th Volume. Henshel ed. American Society of Testing and Materials. ASTM STP 1364.

Fontenot, L.W., G.P. Noblet, J.M. Akins, M.D. Stephens, and G.P.Cobb. 1999b. Bioaccumulation of polychlorinated biphenyls in ranid frogs and northern water snakes from a hazardous waste site and a contaminated watershed.

Government of Canada. 1993. Arsenic and its compounds. Canadian Environmental Protection Act Priority Substances List Supporting Document. Health and Welfare Canada and Environment Canada, Ottawa.

Guthrie, B.E. 1982. The nutritional role of chromium. In: Langard, S., Ed. Biological and Environmental Aspects of Chromium. Elsevier Biomedical Press, Amsterdam, pp. 117-148.

Hall, R.J. 1980. Effects of environmental contaminants on reptiles: a review. Washington DC: U.S. Fish and Wildlife Service. Spec Sci Rpt-Wildl 228:1-12.

Hartley, D. and H. Kidd, (eds.). 1983. The agrochemicals handbook. Nottingham, England: Royal Society of Chemistry.

Hayes, W.J. and E.R. Laws (ed.). 1990. Handbook of Pesticide Toxicology, Vol. 3, Classes of Pesticides. Academic Press, Inc., NY.

Hertel, R.F. 1986. Sources of exposure and biological effects of chromium. In: Environmental Carcinogens Selected Methods of Analysis, Vol. 8. International Agency for Research on Cancer, Lyon, pp. 79-92 IARC Scientific Publication No. 71.

Hinton, T. G. (1998). Risks from Exposure to Radiation. In M. C. Newman, Fundamentals of Ecotoxicology (pp. 251-278). Chelsea, MI: Sleeping Bear/Ann Arbor Press.

IAEA, (International Atomic Energy Agency) (1992). Effects of ionizing radiation on plants and animals at levels implied by current radiation protection standards. Technical Report Series No. 332. Vienna.

Jacobs Engineering (Jacobs). 2009 (October). Kingston Ash Recovery Project Non-Time-Critical Removal Action Scope and Engineering Evaluation/Cost Analysis (EE/CA) Work Plan.

Jarvinen, A.W., and G.T. Ankley. 1999. Linkage of effects to tissue residues:development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals. SETAC Technical Publication Series. SETAC Press. Society of Environmental Toxicology and Chemistry, Pensacola, FL.

Keen, C.L. and R.M. Leach. 1988. Manganese. In: Handbook on Toxicity of Inorganic Compounds, eds. H.G. Seiler and H. Sigel, Marcel Dekker, Inc. pp. 405-415.

Kimball, G. 1978. The effects of lesser known metals and one organic to fathead minnows (Pimephales promelas) and Daphnia magna. Department of Entomology, Fisheries and Wildlife, University of Minnesota.

Langard, S. 1982. Absorption, transport and excretion of chromium in an and animals. In: S. Langard, Ed. Biological and Environmental Aspects of Chromium. Elsevier Biomedical Press, Amsterdam, pp. 149-169.

Lemly, A.D. 1993. Metabolic stress during winter increases the toxicity of selenium to fish. Aquat. Toxicol. (Amsterdam) 27(1-2):133-158.

Lie R., Thomas R., Scott J., 1960. "The distribution and excretion of thallium-204 in the rat, with suggested mpc's and a bioassay procedure." Health Phys 2:334-340.

MacLatchy, J. 1992. Overview of smelters and refineries based on Priority Substances List data for Cd, As, Cr, Hg, Ni and Pb. Environment Canada, Industrial Programs Branch, Ottawa.

Marr, J.C.A, Hansen, J.A., Meyer, J.S., Cacela, D., Podrabsky, T., Lipton, J., Bergman, H.L. 1998. Toxicity of cobalt and copper to rainbow trout: application of a mechanistic model for predicting survival. Aquatic Toxicology. Vol. 43, pp 225-238.

Menzie, C.A., M. Hope Henning, J. Cura, K. Finkelstein, J. Gentile, J. Maughan, D. Mitchell, S. Petron, B. Potocki, S. Svirsky, P. Tyler. 1996. Special report of the Massachusetts weight-of-evidence workgroup: A weight-of-evidence approach for evaluating ecological risks. Human and Ecological Risk Assessment: (HERA): 2(2)277-304.

National Academy of Sciences (NAS). 1977. Medical and biologic effects of environmental pollutants, arsenic. Washington, DC: National Research Council, National Academy of Sciences.

National Park Service (NPS). 1997. Environmental contaminants encyclopedia: Chromium VI (hexavalent chromium). National Park Service, Water Resources Division, Fort Collins, Colorado.

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: February 9, 2010).

Newman, M. 1998. Fundamentals of Ecotoxicology. Ann Arbor Press, Ann Arbor, Michigan.

Nieboer, E. and A.A. Jusys. 1988. Biological chemistry of chromium, In : Chromium in the Natural and Human Environments, J.O. Nriagu and E. Nieboer (eds.), John Wiley & Sons, New York, NY, pp. 21-79.

Niimi, A.J. 1994. PCBs, PCDDs, And PCDFs. In: Handbook of Ecotoxicology, Volume 2. P.I. Calow, ed. Blackwell Scientific Publishing, Cambridge, MA.

Nimmo, D.R. 1985. Pesticides. Fundamentals of Aquatic Toxicology. Rand, G.M., and Petrochelli, S.R., eds. Taylor and Francis Publishing.

Nimmo, D.R., and McEwen, L.C. 1994. Pesticides: Handbook of Ecotoxicology. P. Calow, ed. Blackwell Scientific Publications.

Nriagu, J.O. 1989. Effects of atmospheric trace metal deposition on aquatic ecosystems. Background paper prepared for a workshop on The Effects of Atmospheric Contaminants on Aquatic and Terrestrial Ecosystems. Centre for Clean Air Policy, Washington, DC.

O'Conner, J. M. and R.J. Huggett. 1988. Aquatic pollution problems, North Atlantic coast, including Chesapeake Bay. Aquatic Toxicology. 11:163-190.

Rowe, C.L., A.Heyes, and W.Hopkins. 2009. Effects of dietary vanadium on growth and lipid storage in a larval anuran: results from studies employing ad libitum and rationed feeding. Aquatic Toxicology 91 179:186.

Sample, B.E., Opresko, D.M., Suter II, G. W. 1996. Toxicological Benchmarks for Wildlife, 1996 Revision. USDOE, Risk Assessment Program, Health Sciences Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sample, B., M. Alpin, R. Efroymson, G. Suter, and C. Welsh. 1997. Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants. Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 4650.

Sparling, D. W., T. P. Lowe, and P. G. C. Campbell. 1997. In Robert A. Yokel and Mari S. Golub, editors. Research issues in aluminum toxicity. Taylor & Francis, Washington, D.C. xi, 256; Pages 47-68.

Sparling, D.W., G. Linder, and C.A. Bishop (eds). 2000. Ecotoxicology of Amphibians and Reptiles. Society of Environmental Toxicology and Chemistry (SETAC) Press, Pensacola, Florida.

Standen A., (ed.) 1967. Kirk-Othmer Encyclopedia of Chemical Technology. Interscience Publishers, New York. As cited in USEPA 1980.

Stokinger, H.E. 1981. The Metals. In Patty's Industrial Hygiene and Toxicology, Vol. 2A, eds. G.D. Clayton and F.E. Clayton, john Wiley & Sons, New York. pp. 1749-1769.

Suter, G.W., II, R.A. Efroymson, B.E. Sample, and D.S. Jones. 2000. Ecological Risk Assessment for Contaminated Sites. Lewis Publishers, Boca Raton, Florida.

Tennessee Valley Authority (TVA). 2009 (March). Kingston Fossil Plant Fly Ash Recovery Project Sampling Plan for Phase I Dredging Operations. Office of Environment and Research, Environmental Resources and Services.

Travis, C.C., and A.D. Arms. 1988. Bioconcentration of Organics in Beef, Milk, and Vegetation. Environ. Sci. Technol. 22:271-274.

U.S. Air Force (USAF). 1990. Nickel. In: Installation Restoration Program Toxicology Guide, Vol. 5. Harry G. Armstrong Aerospace Medical Research Laboratory, Wright Patterson AFB, OH.

U.S. Army Center for Health Promotion and Preventive Medicine. 2007. Wildlife Toxicity Assessment for Thallium. Project No. 39-EJ1138-01O. U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), Aberdeen Proving Ground, Maryland.

Venugopal B. Luckey TD. 1978. Metal toxicity in mammals. Vol. 2. Chemical toxicity of metals and metalloids. New York, NY: Plenum Press, p. 101.

Ware, G.W. 1994. The Pesticide Book, 4th Edition. Thompson Publications, Fresno, California.

Weeks, B.A. and J. E. Warinner. 1986. Functional evaluation of macrophages in fish from a polluted estuary. Vet. Immun. Immunopathol. 12:313-20

Weast R.C. (ed.). 1975. Handbook of Chemistry and Physics. 56th ed. CRC Press. Cleveland Ohio. As cited in USEPA 1980.

Windholz M. (ed.). 1976. The Merck Index. 9th Edition. Merck and Co., Inc. Rathway, New Jersey. As cited in USEPA 1980.

West Virginia Department of Environmental Protection (WVDEP). 2009a. Chemical Safety Fact Sheet. http://gis.wvdep.org/tri/cheminfo/csfs97.txt.

WVDEP 2009b. Chemical Safety Fact Sheet. http://gis.wvdep.org/tri/cheminfo/csfs201.txt

WVDEP 2009c. Chemical Safety Fact Sheet. http://gis.wvdep.org/tri/cheminfo/csfs207.txt

WVDEP 2009d. Chemical Safety Fact Sheet. http://gis.wvdep.org/tri/cheminfo/csfs210.txt

WVDEP 2009d. Chemical Safety Fact Sheet. http://gis.wvdep.org/tri/cheminfo/csfs199.txt

WVDEP 2009f. Chemical Safety Fact Sheet. http://gis.wvdep.org/tri/cheminfo/csfs212.txt

World Health Organization (WHO). 1984. Chromium. In: Guidelines for Drinking-Water Quality, Vol. 2. World Health Organization, Geneva, pp. 91-96.

Zitko, V., W. V. Carson, and W. G. Carson. 1975. Thallium: occurrence in the environment and toxicity to fish. Bulletin on Environmental Contamination and Toxicology. 13:23-30.

Zitko, V., Carson WV. 1975. Accumulation of thallium in clams and mussels. Bull Environ Contam Toxicol 14:530-533.

FIGURES

Figure B-1. Eight-Step Ecological Risk Assessment Process
TVA Kingston Fly Ash Recovery Project

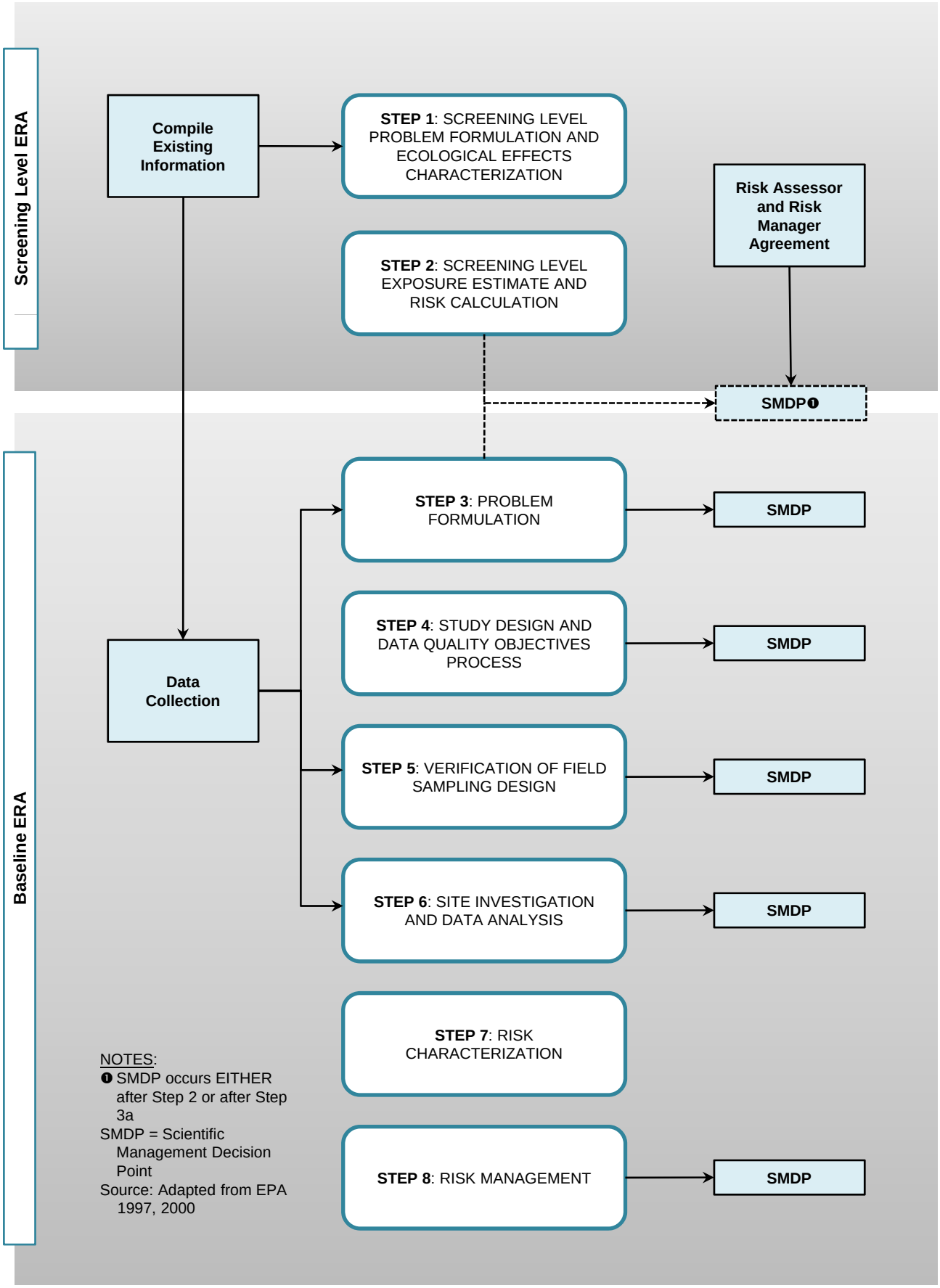


Figure B-2. Expanded Eight-Step Ecological Risk Assessment Process
TVA Kingston Fly Ash Recovery Project

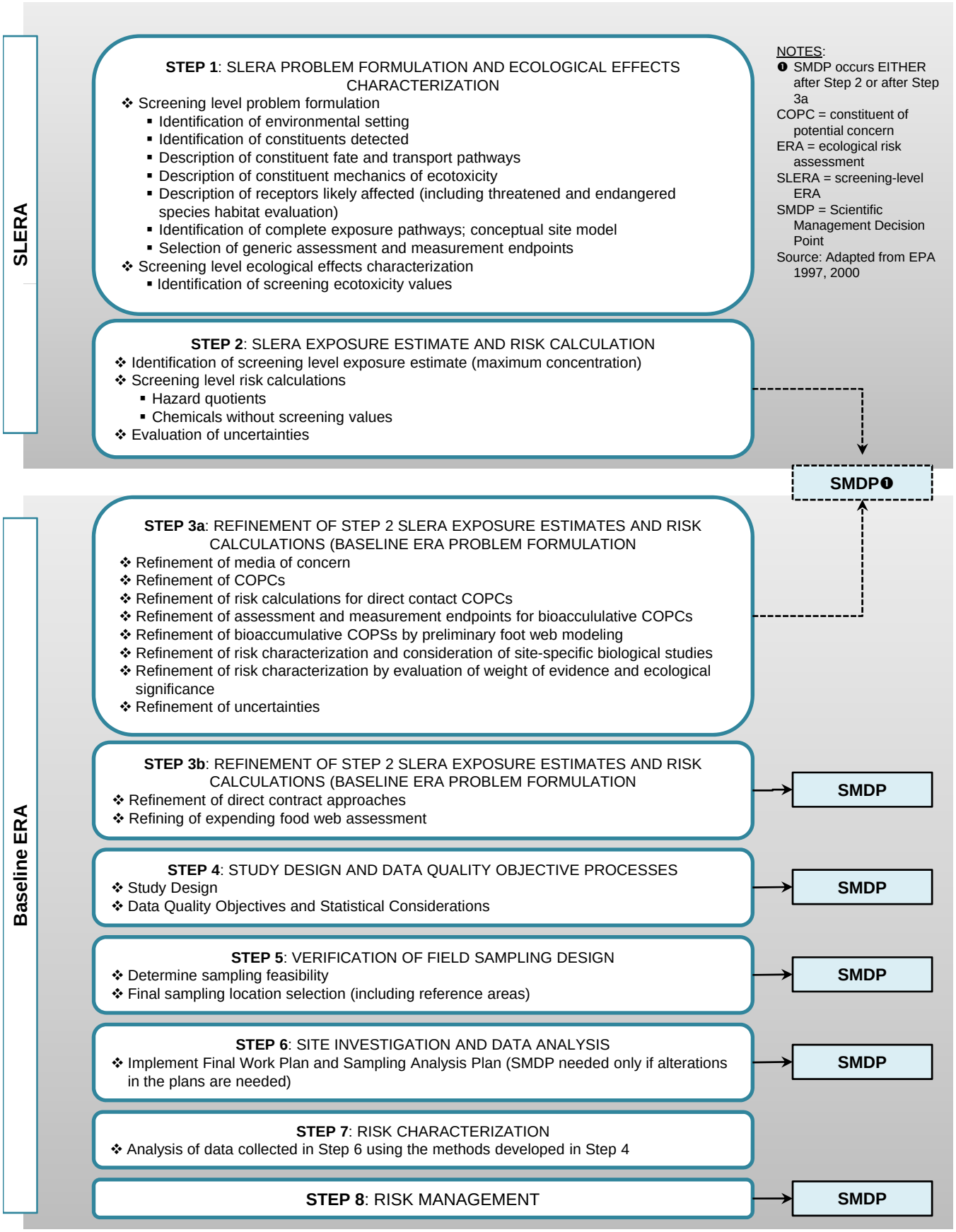
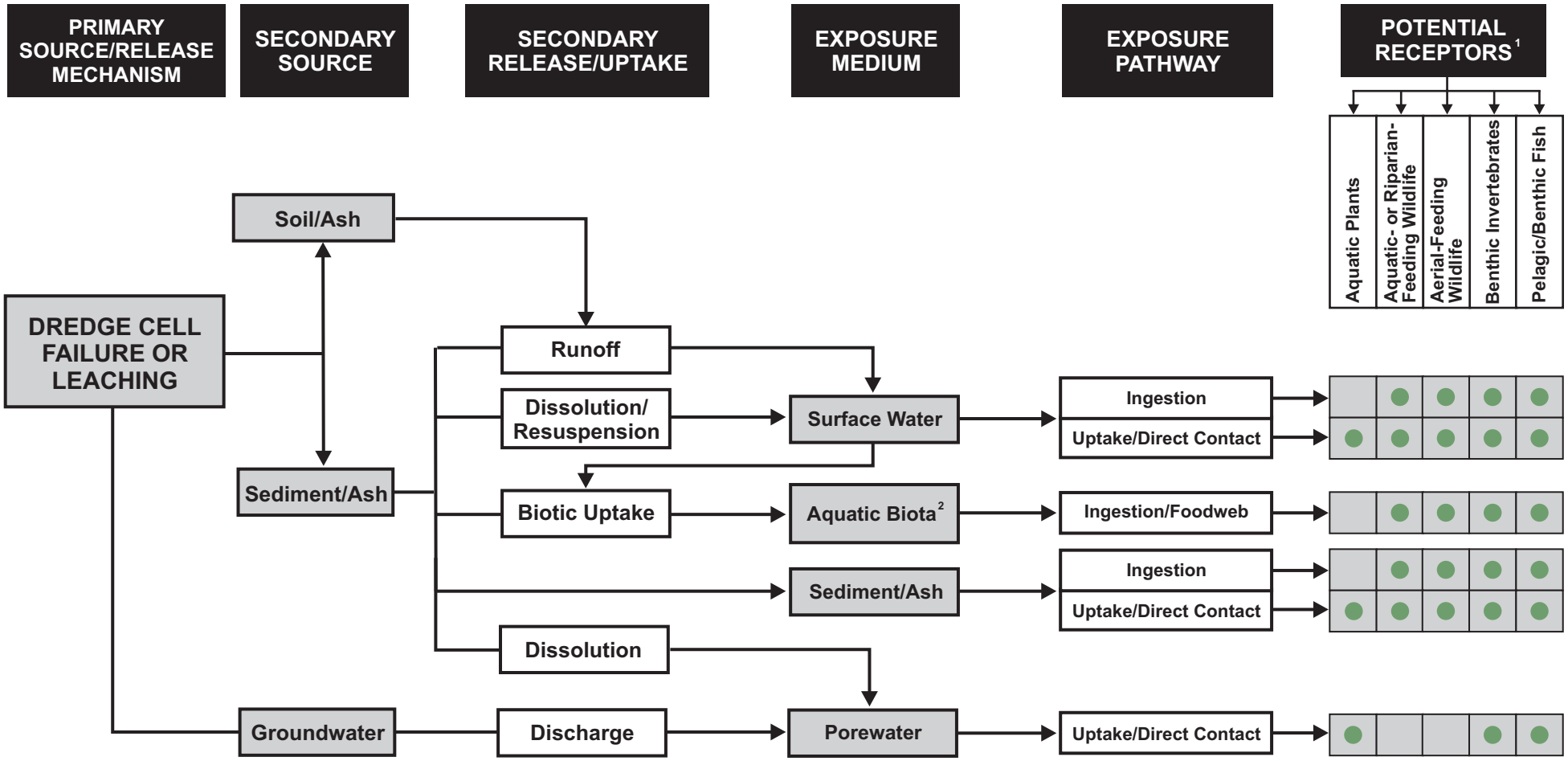


Figure B-3. Ecological Conceptual Site Model for the River System



1 Ecological receptor groups include aquatic plants (sediment and surface water exposures), aquatic- or riparian-feeding wildlife (e.g., birds, mammals, amphibians, and reptiles), aerial-feeding wildlife (e.g., birds and mammals), benthic invertebrates (e.g., mussels, infauna, and epibenthic invertebrates), and pelagic/benthic fish.

2 Aquatic biota includes fish, benthic invertebrates, emergent insects, and aquatic plants.

● Indicates potentially complete exposure pathway for this receptor.

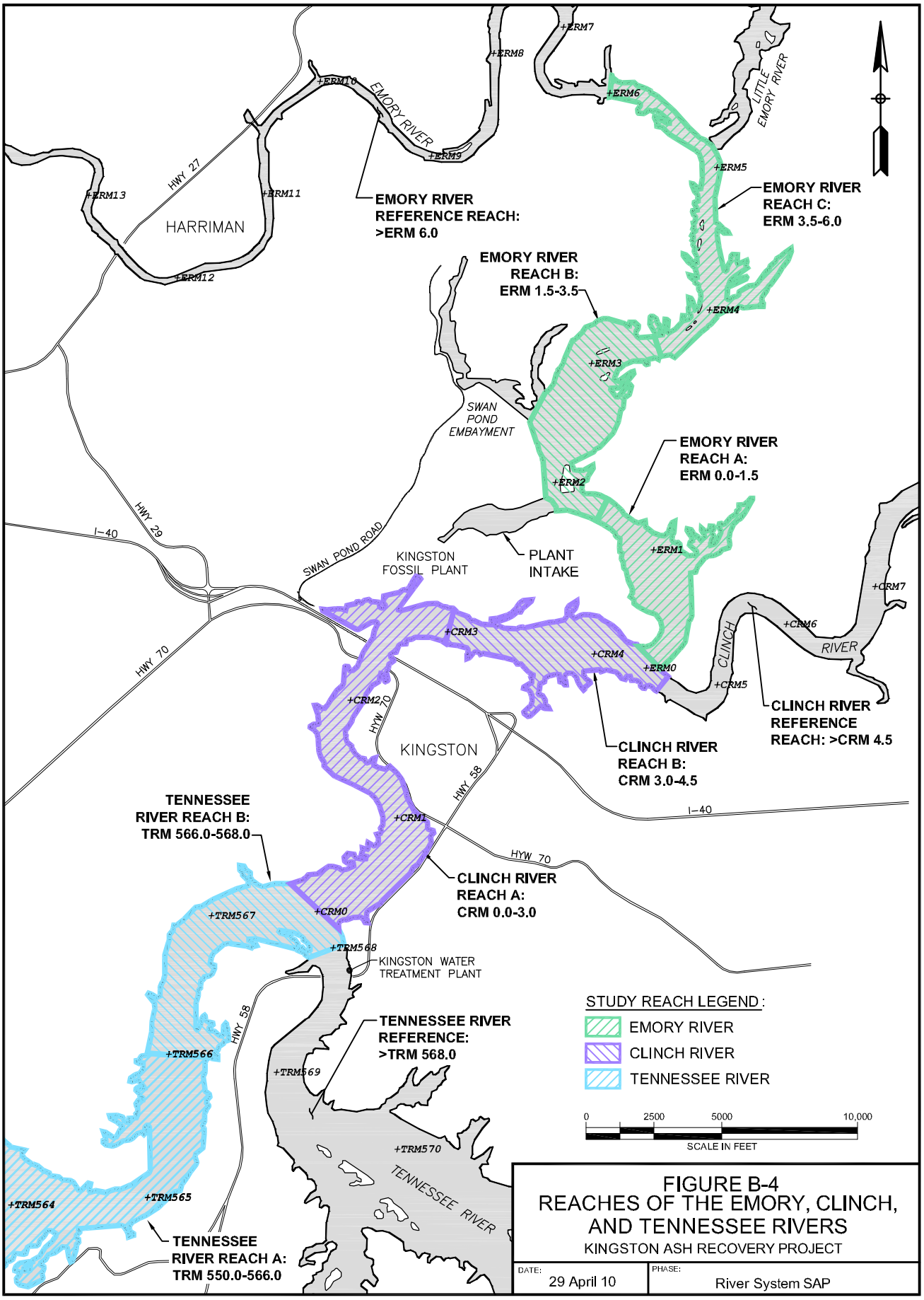


FIGURE B-4
REACHES OF THE EMORY, CLINCH, AND TENNESSEE RIVERS
KINGSTON ASH RECOVERY PROJECT

DATE: 29 April 10
PHASE: River System SAP

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ATTACHMENT B-1

Toxicological Profiles

Attachment B-1
General Toxicological Profiles

ALUMINUM

Aluminum does not exist as a free metal in nature due to its reactivity, but rather partitions between the solid and liquid phases by reacting with water, chloride, fluoride, sulfate, nitrate, phosphate, humic materials and clay. In water, aluminum undergoes hydrolysis to form hydroxyl aluminum species, which include both relatively water-insoluble complexes and water-soluble complexes. Aluminum adsorbs to suspended solids and sediment, binding to organic matter or fulvic acid, if present. The pH of the water determines which hydrolysis products are formed (EPA 1999b).

One common species, aluminum oxide, occurs naturally in the aquatic environment in the minerals bauxite, baerites, boehmite, corundum, diaspore, and gibbsite. Additional sources can include discharges from spills or industry, where it is used as an absorbent, desiccant, abrasive, and filler for paints and varnishes; in the manufacture of alloys, ceramic materials, and electrical gems; and as a catalyst for chemical reactions. Aluminum oxide is only slightly soluble in water; however, it is highly persistent with a half-life greater than 200 days (WVDEP 2009a).

Toxicity of Aluminum to Aquatic Biota: Aluminum can be highly toxic to aquatic biota under some circumstances, but its toxicity is strongly dependent on pH, hardness, and organic matter content. Aluminum is more soluble in both acidic and basic solutions than in neutral (amphoteric) solutions. The EPA's water quality criteria for aluminum assumes a pH range of 6.5 to 9.0, within which aluminum occurs primarily in the form of monomeric, dimeric, and polymeric hydroxides. Toxicity of aluminum in the field may be substantially lower than indicated by dissolved aluminum analysis values because of complexation with humic and fulvic acids. At pH values below 6.5, however, aluminum may be substantially more toxic than the EPA criteria because low pH favors the formation and solubulization of cationic aluminum (Al^{+3}).

Exposure routes for aquatic organisms include ingestion, gill uptake, and dermal absorption. Aluminum is also known to bioconcentrate in aquatic species (EPA 1999b). While toxicity information about aluminum is generally lacking, it has been determined that fish tend to be more sensitive to aluminum toxicity than aquatic invertebrates (Sparling et al 1997). Aluminum oxide has slight acute toxicity to aquatic life, but its toxicity increases under alkaline conditions. Between pH 6.5 and 9.0, acute toxicities of aluminum reported by EPA range between 1.9 milligrams per liter (mg/L) (*Ceriodaphnia dubia*) and >79.9 mg/L (midge larvae, *Tanytarsus dissimilis*). Acute toxicities for fish ranged from 3.6 mg/L (juvenile brook trout, *Salvelinus fontinaalis*) to >50.0 mg/L (juvenile green sunfish, *Lepomis cyanellus*). Chronic toxicities reported by EPA ranged from 0.742 mg/L (*Daphnia magna*) to 3.288 mg/L (fathead minnow, *Pimephales promelas*).

Toxicities to aquatic plants fall within roughly the same ranges: 6.48 mg/L caused mortality of the diatom *Cyclotella meneghiniana,* and concentrations from 0.40 to 0.90 mg/L were chronically toxic to *Cyclotella meneghiniana* and the green algae *Selenastrum capricornutum.* Bioconcentration factors from 50 to 231 were obtained in tests with young brook trout. Toxicities of body burdens were not determined.

ARSENIC

Due to its complex chemistry, arsenic exists in the environment in many different inorganic and organic forms, each with different toxicological and physicochemical properties. Inorganic arsenic exists as either the trivalent (Ar^{+3}) form or the pentavalent (Ar^{+5}) form. The inorganic trivalent arsenic forms are more toxic than the pentavalent forms. Conversely, elemental arsenic (the metalloid -0+) is essentially nontoxic even at high intakes (EPA 1999b). Under natural conditions in surface water, soluble inorganic arsenate

(As^{+5}) is the dominant form of inorganic arsenic and is more stable than arsenite (As^{+3}) or elemental arsenic (As^{+0}) (EPA 1980).

The movement and partitioning of arsenic in water depends on the chemical form of arsenic and on interactions with other materials present. Soluble forms of arsenic remain dissolved in the water column or adsorb onto sediments or soils, especially those containing clays, iron oxides, aluminum hydroxides, manganese compounds, and organic matter. Sediment bound arsenic is released back into the water by chemical or biological interconversions. This interconversion is influenced by the oxidation-reduction potential (Eh), pH, temperature, other metals, salinity, and biota. Arsenate is transformed by microbes to arsenite and methylated arsenicals (EPA 1999b).

Arsenic is used in metallurgical applications, manufacturing wood preservatives, as well as herbicide, pharmaceutical, and glass manufacturing (Government of Canada 1993). All of which could contribute to arsenic concentration in the environment, however smelting and refining industries are the largest anthropogenic sources (MacLatchy 1992). The largest natural source of arsenic entering surface waters is that from weathered rocks and soils (Nriagu 1989).

Toxicity of Arsenic to Aquatic Biota: Exposure routes for aquatic organisms include gill uptake, ingestion of arsenic suspended on particles in the water column or deposited in sediment, and ingestion of plant matter and lower trophic level aquatic species. When ingested or absorbed, arsenic is distributed to all tissues where it interferes with normal enzymatic activity or disrupts the functioning of other cellular macromolecules. Arsenic bioconcentration in aquatic organisms is low because fish and shellfish rapidly metabolize arsenic to non-toxic forms. As a result, biomagnification does not readily occur in aquatic food chains (EPA 1999b).

In plants, arsenic has been shown to cause wilting, chlorosis, browning, dehydration, mortality, and inhibition of light activation. Arsenic is present in the earth's crust at approximately 2 parts per million (ppm), but tissues of animals generally contain an average of <0.5 ppm (Venugopal and Luckey 1978). Evaluating the potential for arsenic toxicity from exposure to low levels is complicated by the current understanding that arsenic is an essential element in some mammalian species, and that arsenic deficiency may result in adverse reproductive and developmental effects (EPA 1999b). For example, a study conducted on goats indicated that growth, survival, and reproduction are poor if the diet contains <0.05 ppm arsenic (NAS 1977). In mammals, arsenic is a carcinogen (cancer-causing), teratogen, and possible mutagen (causing mutations in genes/deoxyribonucleic acid [DNA]). Chronic exposure can result in fatigue, gastrointestinal distress, anemia, neuropathy, and skin lesions that can develop into skin cancer in mammals. In addition, cancer-causing and genetic mutation-causing effects can occur in aquatic organisms, including behavioral impairments, growth reduction, appetite loss, and metabolic failure (EPA 2009a).

Avian tolerance to arsenic varies among species, but effects include destruction of gut blood vessels, blood-cell damage, muscular coordination impairment, debility, slowness, jerkiness, falling, hyperactivity, fluffed feathers, drooped eyelids, immobility, seizures, and systemic, growth, behavioral, and reproductive problems (EPA 2009a).

BARIUM

Barium is a divalent alkaline-earth metal found only in combination with other elements in nature. The most important of these combinations involve the following: peroxide, chloride, sulfate, carbonate, nitrate, and chlorate. Due to the element's tendency to form salts with limited solubility in soil and water,

it is expected to have a residence time of hundreds of years and is not expected to be very mobile. Acidic conditions, however, will increase the solubility of some barium compounds, facilitating their movement from the soil to the groundwater (EPA 1984). Trace amounts of barium were found in over 99% of the surface waters and finished drinking water samples (average values of 43 micrograms per liter [µg/L], and 28.6 µg/L, respectively) across the United States (NAS 1977).

Barium and its salts have a wide variety of applications, including uses in nuclear reactors, electronic tubes, as additives in lubricating oils, in the manufacture of pyrotechnics and explosives, in tanning and finishing leathers, as a mordant for fabrics and dyes, in electroplating, aluminum refining, and rubber manufacture; and in the production of paints and enamels (WVDEP 2009b).

Toxicity of Barium to Aquatic Biota: Elevated levels of barium can induce a wide range of effects in mammals including gastrointestinal distress, muscular paralysis, and cardiovascular effects. Barium does not bioaccumulate, and concentrations in higher species rarely exceed 10 milligrams per kilogram (mg/kg) (EPA 2009a). The concentration of barium found in fish tissues is expected to be about the same as the average concentration in the water from which the fish was taken (WVDEP 2009b).

Insufficient data are available to evaluate or predict the short- term effects of barium or its salts to plants, birds, or land animals, although barium and its salts do tend to have moderate acute toxicity to aquatic life. Chronic toxic effects may include shortened lifespan, reproductive problems, lower fertility, and changes in appearance or behavior (WVDEP 2009b).

BERYLLIUM

Beryllium is a gray, light metal with chemical properties similar to aluminum. Beryllium is highly soluble and highly persistent in water, with a half-life of greater than 200 days. It is used to make light alloys, in nuclear reactors, in radio tube parts, in aerospace structures, and in inertial guidance systems. The major source of beryllium in the environment is burning fossil fuels, some of which may enter the aquatic environment through atmospheric fallout. Beryllium may also enter the aquatic environment through the weathering of rocks and soils and through discharges from industrial and municipal operations (WVDEP 2009c).

Toxicity of Beryllium to Aquatic Biota: Beryllium and its compounds have high acute toxicity to aquatic life and tend to be more toxic in soft water than in hard water (WVDEP 2009c). Beryllium in water with low pH causes gill abnormalities in fish, including hyperplasia resulting in epithelial thickening, increased mucous production, and changes in chloride cell and mucous cell number and structure (EPA 1996).

The concentration of beryllium found in fish tissues is expected to be somewhat higher than the average concentration of beryllium in the water from which the fish was taken (WVDEP 2009c).

BORON

Boron is a naturally occurring dark brown/black substance found throughout the environment. It only occurs in combined form, usually as borax, colemanite, boronatrocalcite, and boracite (BCEDP 2009). The highest concentrations of boron are found in sediments and sedimentary rock; particularly clay rich marine sediments. Boron is less persistent in light textured acidic soils and in areas with high rainfall because of its tendency to leach. As a result boron toxicity tends to be more of a problem in arid climates.

Anthropogenic sources of boron in the environment include sewage sludge and effluents, coal combustion, glass, cleaning compounds and agrochemicals (BCEDP 2009).

Toxicity of Boron to Aquatic Biota: Boron is an essential trace element for the growth of terrestrial crop plants and some algae, fungi and bacteria, but can be toxic in excess. Toxicity to aquatic organisms, including vertebrates, invertebrates and plants can vary depending on the organism's life stage and environment. Early stages are more sensitive to boron than later ones, and the use of reconstituted water shows higher toxicity in lower boron concentrations than natural waters (BCEDP 2009).

CHROMIUM

Chromium exists primarily in the Cr^{+3} (trivalent) and Cr^{+6} (hexavalent) valence forms in environmental and biological media. Chromium is predominantly found in nature as the trivalent form (Barnhart 1997). The hexavalent state is the second most stable state, but rarely occurs in nature (NPS 1997) with the majority being man-made and released into the environment by industrial emissions (WHO 1984; Hertel 1986). Based on research conducted by EPA, if acid volatile sulfide (AVS) is present in sediment, then the sediments represent a reducing environment, and all chromium is present as the trivalent form (Boothman et al. 1999). Also, the pH and Eh (reduction/oxidation potential) environment of carbon-based biological systems reduce hexavalent chromium to trivalent chromium (Nieboer and Jusys 1988; Barnhart 1997). Therefore, all chromium present in biological tissue is in the trivalent form. Hexavalent chromium is not expected to be present in surface water in the absence of a direct source, due to the very slow kinetics of oxidation.

Chromium exists in soil primarily in the form of insoluble oxides with very limited mobility. In the aquatic phase, chromium may be in the soluble state or attached to clay-like or organic suspended solids. In water, Cr^{+6} occurs in the soluble state or as suspended solids adsorbed onto clay-like materials, organics, or iron oxides. Cr^{+6} persists in water for long periods of time, but is eventually reduced to Cr^{+3} by organic matter or other reducing agents in water (EPA 1999b).

Toxicity of Chromium to Aquatic Biota: There are a wide range of adverse effects from chromium in aquatic organisms. In benthic invertebrates there has been observed reduced fecundity and survival, growth inhibition, and abnormal movement patterns. Fish experienced reduced growth, chromosomal aberrations, reduced disease resistance, and morphological changes (EPA 2009a). The toxic effects of chromium are primarily found at the lower trophic levels. The main potential ecological impacts result from direct exposure of algae, benthic invertebrates, and embryos and fingerlings of freshwater fish and amphibians to chromium. Chromium inhibits growth in duckweed and algae, reduces fecundity and survival of benthic invertebrates, and reduces growth of freshwater fingerlings. It is cancer-causing, mutation-causing, and teratogenic (EPA 2009a).

Exposure routes for aquatic organisms include ingestion, gill uptake, and dermal absorption. Chromium is also known to bioconcentrate in aquatic organisms. The biomagnification and toxicity of Cr^{+3} is low relative to Cr^{+6} because of its low membrane permeability and non-corrosivity. Bioaccumulation occurs in aquatic receptors; however biomagnification does not occur in aquatic food chains. Chromium is not metabolized, but undergoes various changes in valence states by binding with ligands and reducing agents in vivo. Elimination of chromium from the receptor is slow via the kidney/urine and the bile/feces (Guthrie 1982; Langard 1982) (EPA 1999b).

Attachment B-1
General Toxicological Profiles

COBALT

Cobalt is a natural element present in certain ores of the earth's crust, and is essential to life in trace amounts. It can exist in six oxidation states, but in aquatic environments the +2 and +3 valence states predominate and form organic and inorganic salts (Nagpal, 2004). The salts are highly persistent in water, with a half- life greater than 200 days. The water solubility of cobalt and its salts range from highly soluble to practically insoluble (WVDEP 2009d). Cobalt and its salts are used in nuclear medicine, enamels and semiconductors, grinding wheels, painting on glass and porcelain, hygrometers and electroplating; as a foam stabilizer in beer, in vitamin B12 manufacture, as a drier for lacquers, varnishes, and paints, and as a catalyst for organic chemical reactions (WVDEP 2009d).

Toxicity of Cobalt to Aquatic Biota: Relatively little is known about the toxicity of cobalt (Kimball, 1978). Acute and chronic toxicity tests using fathead minnows *(Pimephales promelas)* and *Daphnia magna* were conducted in relatively hard water[1]. Acute toxicity values for cobalt ranged from 3.61 mg/L for juvenile fathead minnows to 6.68 mg/L for *D. magna.* Chronic toxicity values ranged from 0.0011 mg/L for fathead minnows to 0.0051 mg/L for *D. magna.*

Chronic LC50 values established for rainbow trout (*Oncorhynchus mykiss*) include 470 µg/L (Birge 1978) and 490 µg/L (Birge et al., 1980) for 28 day embryo-larval toxicity tests. Effect concentrations for acute toxicity tests using rainbow trout include a 96-hour LC50 of 1,406 µg/L (Marr et al. 1998). Marr et al (1998) also reported that a temporal pattern to cobalt toxicity in rainbow trout existed. Cobalt concentrations that would eventually cause 100% lethality caused no lethality until at least 72 hours of exposure. As stated above, the 96-hour LC50 was 1,406 µg/L, however the time-independent concentration resulting in 50% lethality was 346 µg/L (Marr et al. 1998).

A frog embryo teratogenic assay evaluating the effects of cobalt on the clawed frog (*Xenopus laevis*) reported an EC50 for malformations of 1,473 µg/L and a LOEC for growth of 2,475 µg/L. An embryo-larval study of the toxicity of cobalt to narrow-mouth toad (*Gastrophryne carolinensis*) found a 7-day LC50 of 50 µg/L (Birge 1978).

COPPER

Copper occurs naturally in many animals and plants and is an essential element that is widely distributed in animal and plant tissues. Although most copper salts occur in two valences states, as cuprous (Cu^{+0}) or cupric (Cu^{+2}) ions, the biological availability and toxicity of copper is most likely associated with the divalent state (ATSDR 2004). Copper ($^{+1}$) is unstable and, in aerated water over the pH range of most natural waters (6 to 8), oxidizes to the Cu^{+2} state. In the aquatic environment, the fate of copper is determined by the formation of complexes, especially with humic substances, and sorption to hydrous metal oxides, clays, and organic materials. The amount of copper able to remain in solution is directly dependent on water chemistry, especially pH and temperature, and the concentration of other chemical species (EPA 1999b).

Copper strongly adsorbs to organic matter, carbonates and clay, which reduces its bioavailability. The majority of copper released to surface waters settles out or adsorbs to sediments. Copper is affected by photolysis. Some copper complexes undergo metabolism however, biotransformation of copper is low (EPA 1999b).

[1] There is some evidence that there is a relationship between hardness and cobalt toxicity (Diamond et al 1992).

Because of its high electrical and thermal conductivity, copper is widely used in the manufacture of electrical equipment. Common copper salts, such as the sulfate, carbonate, cyanide, oxide, and sulfide are used as fungicides, as components of ceramics and pyrotechnics, for electroplating, and for numerous other industrial applications (ACGIH 1986).

Toxicity of Copper to Aquatic Biota: Copper is highly toxic in aquatic environments and has effects in fish, invertebrates, and amphibians, with all three groups equally sensitive. Copper is highly toxic to amphibians (including mortality and sodium loss), with adverse effects in tadpoles and embryos. Copper has the potential to bioconcentrate in many different organs in fish and mollusks; there is low potential for bioconcentration in fish, but high potential in mollusks. Copper sulfate and other copper compounds are effective algaecides (free copper ions are the lethal agent). Single-cell and filamentous algae and cyanobacteria are particularly susceptible to the acute effects, which include reductions in photosynthesis and growth, loss of photosynthetic pigments, disruption of potassium regulation, and mortality. Sensitive algae may be affected by free copper at low parts per billion (ppb) concentrations in freshwater. There is a moderate potential for bioaccumulation in plants and no biomagnification (EPA 2009a).

IRON

Iron is the fourth most abundant element by weight in the earth's crust, and is often a major constituent of soils (especially clays) and can be found naturally at high concentrations in water ways. Solubility of iron in water varies with compound and temperature (as well as pH and other physical factors). The relationship between the relative proportions of the almost insoluble ferric (Fe^{+3}) iron and the bioavailable and bioactive ferrous (Fe^{+2}) (II) iron varies with a wide range of factors including pH, dissolved oxygen, dissolved and total organic carbon ratio, color, humic and other organic acids, exposure to sunlight and chloride concentration. It is, therefore, extremely important when discussing iron concentrations in water to distinguish between iron in an ionic state (dissolved iron) and iron in a suspended particulate state (measured typically as total iron). In general, dissolved (Fe^{+2}) iron occurs at low concentrations in well-oxidized waters with near-neutral pH (BCEDP 2008).

Toxicity of Iron to Aquatic Biota: Although naturally abundant in some water bodies, iron can also be potentially toxic at high concentrations. Iron's ability to donate and accept electrons means that if iron is free within the cell, it can catalyze the conversion of hydrogen peroxide into free radicals. Free radicals can cause damage to a wide variety of cellular structures, and ultimately kill the cell. To prevent that kind of damage, life forms have evolved a biochemical protection mechanism by binding the iron atoms to proteins. This allows the cells to use the benefits of iron, but also limit its ability to do harm. The most important group of iron-binding proteins is the heme molecules, all of which contain iron at their centers. Organisms use variants of heme to carry out redox reactions and electron transport processes. Iron is required for oxidative phosphorylation, the process that is the principal source of energy for cells; without it, cells would die. In higher organisms, iron is also an essential component of myoglobin which stores oxygen in muscle cells (BCEDP 2008).

Iron is bioavailable as ferrous iron, which only exists at low pH levels. The pH level in a natural stream is usually around 8. At this pH and available dissolved oxygen conditions, the ferrous iron is oxidized rapidly to the ferric ion which is insoluble in water (IDNR 2005).

Iron hydroxides produced in water and iron-humus colloids can affect fish by clogging gills and reducing respiratory potential and subsequent survival, food availability by benthos, altering the structure and quality of aquatic benthic habitats. Reduced abundance and species diversity of periphyton, benthic

invertebrates and fish are typically reported as consequences of high iron concentration in freshwater (BCEDP 2008).

LEAD

Lead exists naturally in small amounts on the Earth's surface and is found mainly in ore galena. As a solid, lead can bind with other chemicals to form lead compounds or salts. While some of these chemical compounds can be broken down by environmental processes, pure lead is not affected by environmental weathering. In its metal form, lead does not dissolve in water, is resistant to corrosion except in very acidic or very basic water, and is resistant to environmental interaction with harsh chemicals such as sulfuric acid. Because of these properties, lead is considered an extremely unreactive metal (ATSDR 1999, 2007). One of the major sources of lead contamination in the air, soil, and water is combustion of fuel containing lead additives.

Toxicity of Lead to Aquatic Biota: Lead adversely affects the survival, growth, reproduction, development, behavior, learning, disease resistance, and metabolism of most species (Eisler 1988). Numerous physical, chemical, and biological variables substantially influence its effects. In general, organically complexed lead is more toxic than inorganic lead salts, biomagnification of lead is negligible, and younger, immature individuals are more susceptible to lead exposures than are mature individuals. The main potential ecological impacts from lead result from direct exposure to algae, benthic invertebrates, and embryos and fingerlings of freshwater fish and amphibians. Adverse effects resulting from lead exposure of amphibians include loss of sodium, reduced learning capability, and developmental problems. Fish exposed to high levels of lead exhibit a wide-range of effects including muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis. Lead adversely affects invertebrate reproduction and algal growth. Lead partitions primarily to sediments, but becomes more bioavailable under low pH, hardness and organic matter content (among other factors). Lead bioaccumulates in algae, macrophytes and benthic organisms, but the inorganic forms of lead do not biomagnify (EPA 2009a).

Although lead occurs in a variety of forms in the aquatic environment, the relative toxicities of these forms are not well defined. Acute and chronic lead toxicity increases as hardness decreases. Lead is known to bioconcentrate in aquatic species; however, lead poisoning in higher organisms has been associated with lead shot and organolead compounds, and not with food chain exposure to inorganic lead (other than lead shot, sinkers or paint). There are complex interactions with other contaminants and diet. Lead poisoning in higher organisms primarily affects hematologic and neurologic processes (EPA 2009a).

MANGANESE

Manganese does not exist in nature as an elemental form, but is found mainly as oxides, carbonates, and silicates in over 100 minerals, with pyrolusite (manganese dioxide) as the most common naturally-occurring form. Comprising approximately 0.1% of the earth's crust, it is the twelfth most abundant element and the fifth most abundant metal. It can exist in oxidation states from Mg^{-3} to Mg^{+7}, with the most common being Mg^{+4} in the chemical form of manganese dioxide (Keen and Leach, 1988). The oxides and peroxides are used in industry as oxidizers, and the metal is used for manufacturing metal alloys to increase hardness and corrosion resistance. In living systems, manganese is an essential element that is found most often in the Mg^{+2} valence state (Keen and Leach 1988, Stokinger 1981). Manganese and its compounds vary in their solubility in water from being very soluble to insoluble. Manganese and its compounds are highly persistent in water, with half-lives greater than 200 days (WVDEP 2009e).

Attachment B-1
General Toxicological Profiles

Toxicity of Manganese to Aquatic Biota: Manganese, an essential trace element for aquatic and terrestrial biota, is only slightly to moderately toxic to aquatic organisms in excessive amounts. It is present in almost all organisms, and often ameliorates the hazard posed by other metals. Manganese has been shown to cross the blood-brain barrier and a limited amount of manganese is also able to cross the placenta during pregnancy, enabling it to reach a developing fetus. Nervous system disturbances have been observed in animals after very high oral doses of manganese, including changes in behavior (ATSDR 2008).

MERCURY

Mercury is a metal with no known biological function and exists in three valence states: mercuric (Hg^{+2}), mercurous (Hg^{+1}), and elemental (Hg^{+0}) mercury. It is present in the environment in both inorganic and organic forms**.** The predominant form of mercury in surface waters is Hg^{+2}. Nonvolatile mercury in surface water binds to organic matter and sediment particles. Sorption to suspended and bed sediments is one of the most important processes determining the fate of mercury in aquatic systems; sorption onto organic materials is the strongest for Hg^{+2}. As a result, mercury is generally complexed to organic compounds and is not readily leached from either organic-rich or mineral-rich soils. Most mercury compounds can be remobilized in aquatic systems by microbial conversion to methyl and dimethyl forms. Conditions reported to enhance microbial conversion include large amounts of available mercury, large numbers of bacteria, absence of strong complexing agents, near neutral pH, high temperatures, and moderately aerobic conditions (ATSDR 1999).

Mercury is a naturally occurring metal found throughout the environment. Mercury enters the environment as the result of the normal breakdown of minerals in rocks and soil from exposure to wind and water, and from volcanic activity. Human activities (e.g., mining, burning of fossil fuels) have resulted in additional release of mercury to the environment. Mercury may be released to surface waters in effluents from a number of industrial processes, including chloralkali production, mining operations and ore processing, metallurgy and electroplating, chemical manufacturing, ink manufacturing, pulp and paper mills, leather tanning, pharmaceutical production, and textile manufacture (Dean et al. 1972; EPA 1971).

Toxicity of Mercury to Aquatic Biota: Sorption at the gill surface is the major pathway of mercury entry in aquatic organisms. In aquatic organisms, bioaccumulation is rapid and elimination is slow. Biomagnification occurs in the aquatic food chain. Absorbed mercury is distributed to the blood and ultimately the internal organs. Mercury which is not absorbed is eliminated rapidly in the feces. The biological half-life of mercury in fish is approximately 2 to 3 years. In general, mercury accumulation is enhanced by elevated water temperatures, reduced water hardness or salinity, reduced water pH, increased age of the organism, reduced organic matter content of the medium, and the presence of zinc, cadmium, or selenium in solution.

All mercury compounds interfere with metabolism in organisms, causing inhibition or inactivation of proteins containing thiol ligands and ultimately leading to miotic disturbances. Mercury also binds strongly with sulfhydryl groups. Phenyl and methyl mercury compounds are among the strongest known inhibitors of cell division.

Mercury is a mutagen (mutation-causing), teratogen, and carcinogen (cancer-causing), with toxicity and environmental effects varying with the form of mercury, dose, and route of ingestion, and with the exposed organism's species, sex, age, and general condition. There is a high potential for bioaccumulation

and biomagnification with mercury, with biomagnified concentrations reported in fish up to 100,000 times the ambient water concentrations.

Methylmercury is the most toxic form of mercury. Inorganic mercury is methylated primarily by bacteria in both anaerobic and aerobic environments. The organic mercury compounds are more readily absorbed and poorly excreted in comparison with inorganic forms. The primary targets of acute exposures are the central nervous system and kidneys in fish, birds, and mammals. In water, at concentrations at or well below even 1 ppb, mercury can cause effects including: loss of appetite, brain lesions, cataracts, abnormal motor coordination, and behavioral changes. There are also effects on reproduction, growth, behavior, metabolism, blood chemistry, osmoregulation, and oxygen exchange at relatively low concentrations of mercury. Juveniles are commonly more susceptible than adults. In invertebrates, effects range from non-observable to chromosomal abnormalities in some flies and reduced segment regeneration in worms. Mercury can inhibit frog metamorphosis.

Upper trophic level fish, birds and mammals are particularly vulnerable because of the pronounced biomagnification of organomercury. There are numerous effects in birds, including delayed testicular development, altered mating behavior, reduced fertility, reduced survivability and growth in young and gonadal atresia. In mammals, it has been shown that mercury can cause ataxia, aphagia, tremors, and diminished movement coordination. There are varied neurological and reproductive effects as well (EPA 2009a).

MOLYBDENUM

Molybdenum does not occur as a free metal in the environment, but rather in various oxidation states in minerals. Most molybdenum compounds have low water solubility, but the molybdate ion MoO_2^{-4} is soluble and will form if molybdenum-containing minerals are in contact with oxygen and water. Molybdenum also occurs in minerals containing iron, bismuth, or copper and may be associated with coal or uranium deposits (CCME 1999). Molybdenum is an essential trace element for several enzymes important to animal and plant metabolism. Molybdenum functions as an electron carrier in those enzymes that catalyse the reduction of nitrogen and nitrate.

Molybdenum is used mainly as an alloying element in steel, cast iron, and super alloys and in the electronics industries. Natural sources of molybdenum to the aquatic environment include the weathering of ores from igneous and sedimentary rock and subsequent runoff to streams and lakes. Molybdenum may also enter the aquatic environment through leaching processes near molybdenum mines and burning of fossil fuels (CCME 1999).

Toxicity of Molybdenum to Aquatic Biota: Molybdenum is essential to plants and necessary for plant production, even though it is present in plant tissue at a level much lower (0.5 ppm dry matter basis) than the critical levels for other essential elements.

Acute toxicity values (96-hr LC50s) of 70 and 370 mg/L were reported for fathead minnows (*P. promelas*) exposed to MoO^3 in soft water (20 mg/L) and hard water (400 mg/L), respectively (CCME 1999). Kimball (1978) reported a value of 628 mg/L for the same species. Rainbow trout (*O. mykiss*) exposed to sodium molybdate resulted in a 96-hr LC50 value of 800 mg/L (CCME 1999). For invertebrates, the 24hr, 48hr, and 96hr EC50s (immobilization) for *Tubifex tubifex* were 56, 52, and 29 mg/L, respectively (CCME 1999).

Attachment B-1
General Toxicological Profiles

NICKEL

Nickel combined with other elements occurs naturally in the earth's crust. Nickel is the 24th most abundant element. It is found in all soil, and is also emitted from volcanoes. Nickel is used in a wide variety of applications including metallurgical processes and electrical components, such as batteries (ATSDR 2005; USAF 1990). In the environment, it is primarily found combined with oxygen or sulfur as oxides or sulfides. Nickel concentrations in surface water and groundwater range between 3 µg/L and 10 µg/L (ATSDR 2005). It is considered essential based on reports of nickel deficiency in several animal species (e.g., rats, chicks, cows, and goats). Nickel deficiency is manifested primarily in the liver; effects include abnormal cellular morphology, oxidative metabolism, and increases and decreases in lipid levels. Decreases in growth and hemoglobin concentration and impaired glucose metabolism have also been observed (ATSDR 2005).

Toxicity of Nickel to Aquatic Biota: Nickel is an essential trace element in animals, although the functional importance of nickel has not been clearly demonstrated. Although nickel can exist in several oxidation states, the divalent cation state predominates and is generally considered the most toxic form. As with many metals, the toxicity of nickel increases as hardness decreases. The softer the water, the higher the toxicity of nickel is to aquatic organisms. Fish and invertebrates have approximately the same range of sensitivity. Mollusks and crustaceans are more sensitive than other organisms. Some observed effects of nickel in aquatic environments include tissue damage, genotoxicity, and growth reduction (EPA 2009a).

Nickel does not bioaccumulate to a great extent in animals; however, there is evidence of uptake and accumulation in certain plants (ATSDR 2005).

SELENIUM

A variety of forms of selenium can occur naturally in water and tissues. Selenium in aquatic ecosystems exists in a broad range of oxidation states: ($^{+6}$) in selenates and selenic acid, ($^{+4}$) in selenites and selenous acid, ($^{+0}$) in elemental selenium, and ($^{-2}$) in selenides, hydrogen selenide, and organic selenides. Selenium also shows some tendency to form catenated species like organic diselenides. Within the normal physiological pH range and the reduction potential range permitted by water, only Se, SeO_3^{-2}, $HSeO_3^{-1}$, and SeO_4^{-2} can exist at thermodynamic equilibrium (EPA 2004).

Selenate usually predominates in well-aerated surface waters, especially those with alkaline conditions. In spite of its oxidizing strength, selenate ($SeO4^{-2}$) exhibits considerable kinetic stability in the presence of reducing agents. Competition between sulfate and selenate uptake has been observed in many species: algae, aquatic plants, crustacean, fungi, and wheat. Reduced selenate bioconcentration with increasing sulfate concentration has been demonstrated in Daphnia magna. A significant relationship was shown to exist between acute selenate toxicity to aquatic organisms and ambient sulfate concentrations. Competition with selenate has also been observed for phosphate in green algae, and with chromate and tungstate in anaerobic bacteria (EPA 2004).

Organic selenides in variable concentrations, usually in the form of free and combined selenomethionine and selenocysteine, are also present in natural surface waters. Dissolved organic selenides may be an important source of selenium for phytoplankton cells, because they can account for approximately 80% of the dissolved selenium in open ocean surface waters, and for a significant fraction in many other environments as well. Organoselenium form(s) are much more bioavailable and probably play a very important role in selenium ecotoxic effects (EPA 2004).

Attachment B-1
General Toxicological Profiles

Weathering of rocks and soils may result in low levels of selenium in water, which may be taken up by plants. Volcanic eruptions may also release selenium in air and it commonly enters the air from burning coal or oil. When selenium in fossil fuels is burned, it combines with oxygen and may then react with water to form soluble selenium compounds (ATSDR 2003).

The current understanding of the biogeochemistry of selenium has recently been reviewed by Fan et al. (2002). Their review clearly shows the extreme complexity of selenium biogeochemistry in aquatic environments. Fan et al. describe the selenium biogeochemical cycle as follows: dissolved selenium oxyanions are primarily absorbed by aquatic producers, including microphytes and bacteria, and biotransformed into organoselenium form(s) and selenium element. These, together with other particle-bound selenium sources, constitute the particulate selenium fraction of the water column, and are poorly understood. Once accumulated in the aquatic primary and secondary producers, selenium can be transferred through various aquatic consumers (e.g. zooplankton, insect larvae, larval fish, bivalves) into the top predators, including aquatic birds and piscivorous fish. Selenium can be further chemically transformed through the food chain transfer process (EPA 2004).

Toxicity of Selenium to Aquatic Biota: Selenium undergoes bioconcentration, bioaccumulation, and biomagnification as trophic levels increase. It can enter the food web through both sediments and surface water. Elevated levels cause growth reduction in green algae (Eisler 1985). In other aquatic organisms, the following adverse effects have been observed: loss of equilibrium and other neurological disorders, liver damage, reproductive failure, reduced growth, reduced movement rate, chromosomal aberrations, reduced hemoglobin and increased white blood cell count, and necrosis of the ovaries (EPA 2009a).

Invertebrates are both the most sensitive and the most tolerant freshwater species to selenite with species mean acute values (SMAV) ranging from 440 µg/L for the crustacean, Ceriodaphnia dubia, to 203,000 µg/L for the leech, *Nephelopsis obscura*. The selenite SMAVs for fishes range from 1,783 µg/L for the striped bass, *Morone saxatilis*, to 35,000 µg/L for the common carp, *Cyprinus carpio* (EPA 2004).

Selenate with sulfate adjusted SMAVs range from 593 µg/L for the crustacean, *Daphnia pulicaria*, to 1,515,616 µg/L for the leech, *N. obscura*. The selenate SMAVs for fishes range from 10,305 µg/L for the razorback sucker, *Xyrauchen texanus*, to 226,320 µg/L for channel catfish, *Ictalurus punctatus* (EPA 2004).

EPA (2004) reports the lowest geometric mean chronic value for bluegill of 9.5 micrograms per grams (µg/g) dry weight (dw) whole body based on several studies. The Lemly (1993) study indicates a chronic value for over-wintering juvenile bluegill sunfish of <7.91 µg/g dw and involved an additional natural stress, exposure to a simulated winter low temperature of 4 °C. In this study, juvenile bluegill sunfish exposed to the over-wintering temperature 4 °C appeared to accumulate more selenium in whole-body tissues (7-8 µg selenium/g dw tissue) relative to those exposed at 20 °C (5-6 µg selenium/g dw tissue), but also exhibited increased signs of chronic toxicity (EPA 2004). The final chronic value of 7.91 µg/g dw recommended in the EPA (2004) Draft Update of the Aquatic Life Ambient Water Quality Criteria for Selenium is based on this study (Lemly 1993), in which juvenile bluegill underwent "winter stress syndrome."

Of all the priority and non-priority pollutants, selenium has the narrowest range of what is beneficial for biota and what is detrimental. Selenium is an essential element required as a mineral cofactor in the biosynthesis of glutathione peroxidases. Aquatic and terrestrial organisms require 0.5 micrograms per gram dry weight of selenium in their diet to sustain metabolic processes, whereas concentrations of selenium that are only an order of magnitude greater than the required level have been shown to be toxic

to fish. Selenium has been shown to mitigate the toxic effects of arsenic, cadmium, copper, inorganic and organic mercury, silver, ofloxacin, methyl parathion, and the herbicide paraquat to biota in both aquatic and terrestrial environments. Studies have shown that diet is the primary route of exposure that controls chronic toxicity to fish, the group considered to be the most sensitive to chronic selenium exposure (EPA 2004).

SILICA

Silica, or silicon dioxide, is the most abundant mineral in the Earth's crust and is most commonly found in nature as sand or quartz, as well as in the cell walls of diatoms. Silica is used primarily in the production of window glass, drinking glasses and bottled beverages. The majority of optical fibers for telecommunications are also made from silica. It is a primary raw material for many whiteware ceramics such as earthenware, stoneware and porcelain, as well as industrial Portland cement. Silica is common additive in the production of foods, where it is used primarily as a flow agent in powdered foods, or to absorb water in hygroscopic applications. It is the primary component of diatomaceous earth which has many uses ranging from filtration to insect control.

Toxicity of Silica to Aquatic Biota: No toxicity information is currently available regarding silica and its effects to aquatic biota.

THALLIUM

Thallium is a metallic element that occurs in the earth's crust at a concentration of 0.3 to 0.6 mg/kg. The element is frequently found in sulfur-containing ores and potassium minerals and often forms salts with bromine, chlorine, fluorine, and iodine. Although natural sources of thallium exist, man-made sources predominate in industrial areas. While elemental thallium is insoluble in water, thallium compounds possess a high solubility in water (compounds exhibit solubilities ranging from 220 mg/L to more than 700,000 mg/L), where thallium exists mostly as a monovalent cation in freshwater and a trivalent ion in oxidized freshwater and marine water (USACHPPM 2007; Standen 1967; Weast 1975; Windholz 1976). Thallium adsorbs to sediments and micaceous clays.

Toxicity of Thallium to Aquatic Biota: There are no specific data on the bioaccumulation of thallium or its potential to be transferred from lower trophic levels to higher organisms. Because thallium can be bioconcentrated, it may be that it can also be accumulated in living tissues. Thallium is known to be bioconcentrated by aquatic plants, invertebrates, and fish (Barrows et al. 1978; Zitko and Carson 1975; Zitko et al. 1975).

In aquatic systems, thallium is absorbed primarily from ingestion of soil, water and plant material (EPA 1999b). Toxic effects have been observed in numerous aquatic organisms including daphnia, fathead minnow, and Atlantic salmon. In birds and mammals, thallium is absorbed primarily from ingestion and is distributed to several organs and tissues (skin, liver, muscle) with the highest levels reported in the kidneys. Thallium exposure in mammals causes cardiac, neurologic, reproductive, and dermatological effects. Thallium is taken up by plants and inhibits chlorophyll formation and seed germination (EPA 1999b).

VANADIUM

Vanadium is an element which is widely dispersed in the earth's crust at low concentrations. It is ordinarily recovered from its raw materials in the form of pentoxide, and sometimes as sodium and

ammonium vanadate salts. In the elemental form (fume or dust), it is used to make rust-resistant steel. (WVDEP 2009f). Vanadium may enter aquatic systems through multiple avenues, including release of fly ash and via runoff from naturally vanadium-rich soils and irrigated areas (Rowe et al 2009).

Toxicity of Vanadium to Aquatic Biota: Vanadium is accumulated by biota, sometimes to very high concentrations (Rowe et. al. 2009). The toxicity of vanadium depends on a physic-chemical state, particularly on its valence state and solubility. In the laboratory, dissolved vanadium has been shown to be acutely or chronically toxic to fish and invertebrates (Rowe et al 2009), and ingestion of vanadium contaminated food has also been found to presents risks of bioaccumulation and toxicity (Rowe et al 2009). Despite contamination of some habitats by vanadium, very little is known regarding the potential adverse effects on wildlife that may result from chronic exposure.

ZINC

Zinc makes up less than 1% (approximately 0.002%) of the earth's crust, and is an essential trace element in all living organisms. It occurs in the environment as a sulfide, oxide, or carbonate (Eisler 1993), interacting with a variety of constituents. Zinc is used commercially primarily in galvanized metals and metal alloys, but zinc compounds also have wide applications as chemical intermediates, catalysts, pigments, vulcanization activators and accelerators in the rubber industry, ultraviolet stabilizers, and supplements in animal feeds and fertilizers. Zinc compounds are also used in rayon manufacture, smoke bombs, soldering fluxes, mordants for printing and dyeing, wood preservatives, mildew inhibitors, deodorants, antiseptics, and astringents (ATSDR 2005). In addition, zinc phosphide is used as a rodenticide.

Toxicity of Zinc to Aquatic Biota: In many types of aquatic plants and animals, growth, survival, and reproduction can all be adversely affected by elevated zinc levels. Although it is essential for normal growth and reproduction and is important to central nervous system function, the primary toxic effect of zinc is on zinc-dependent enzymes that regulate the biosynthesis and catabolic rate of ribonucleic acid and DNA.

Zinc in aquatic systems tends to be partitioned into sediment and less frequently dissolved as hydrated zinc ions and organic and inorganic complexes. It is most toxic to aquatic life in conditions of low pH, low alkalinity, low dissolved oxygen, and elevated temperature. Gill epithelium is the primary target site in fish and exposure results in destruction of gill epithelium and tissue hypoxia. Zinc is toxic to plants at elevated levels, causing adverse effects on growth, survival, and reproduction. Elevated zinc levels can cause mortality, pancreatic degradation, reduced growth, and decreased weight gain in birds; and elevated zinc can cause a wide range of problems in mammals including: cardiovascular, developmental, immunological, liver and kidney problems, neurological, hematological (blood problems), pancreatic, and reproductive problems (EPA 2009a). The pancreas and bone are suspected to be the primary targets of zinc toxicity in birds and mammals. Pancreatic effects include cytoplasmic vacuolation, cellular atrophy, and cell death. Zinc preferentially accumulates in bone and induces a softening of bone caused by deficiency of calcium, phosphorus, and other minerals (EPA 2009a).

RADIONUCLIDES

Radionuclides are unstable isotopes of elements (e.g., uranium) that produce ionizing radiation via radioactive decay. Ionizing radiation is radiated energy that is energetic enough to eject one or more orbital electrons from the target atom or molecule (i.e., the radiation ionizes the target). Ionization can produce free radicals, which are chemically unstable atoms or molecules that have an odd number of

electrons (Hinton 1998). These highly reactive products scavenge electrons by breaking chemical bonds, including those in cell membranes and DNA molecules. Reproductive processes and the early stages of development (i.e., gametogenesis through embryonic) are generally the most sensitive to ionizing radiation (i.e., radiosensitive), because many cells are dividing and differentiating. Affects on these processes are likely to be the most limiting endpoint in terms of population maintenance of ecological receptors (IAEA 1992).

POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances. There are more than 100 different PAHs that generally occur as complex mixtures, not as single compounds (ATSDR 1995). A few PAHs are used in medicines and to make dyes, plastics, and pesticides. Others are contained in asphalt used in road construction, and can be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar. They are ubiquitous in the environment, found in the air, water, and soil (ATSDR 1995).

PAHs include unsubstituted compounds as well as those with alkyl, oxygen, or nitrogen substituents. For example, naphthalene is an unsubstituted (or "parent") PAH, and 2-methylnaphthalene is an alkylated PAH. There are two main groups of PAHs: low molecular weight PAHs (LPAHs) and high molecular weight PAHs (HPAHs). The distinction between LPAHs and HPAHs is useful because these groups of PAHs exhibit different degrees of toxicity to wildlife. The LPAHs include acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, and alkylated homologues of these PAHs. The HPAHs include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, perylene, pyrene, and alkylated homologues of these PAHs.

Toxicity of PAHs to Aquatic Biota: PAHs are highly potent carcinogens that can produce tumors in some organisms; but other non-carcinogenic effects are not well understood (Eisler 1987). The effects of PAHs are wide-ranging within an organism and have been found in many types of organisms, including mammals, birds, invertebrates, plants, amphibians, and fish. However, their effects are varied and so generalizations cannot be readily made. Effects on benthic invertebrates include inhibited reproduction, delayed emergence, sediment avoidance, and mortality. Fish exposed to PAH contamination have exhibited fin erosion, liver abnormalities, cataracts, and immune system impairments leading to increased susceptibility to disease (Fabacher et al. 1991; Weeks and Warinner 1984; 1986; O'Conner and Huggett 1988). In addition, although the rate of uptake from the environment is variable among species, bioaccumulation tends to be rapid. In aquatic systems, PAHs generally show increased toxicity with increased molecular weight (Eisler 1987).

POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls (PCBs) are a group of synthetic organic chemicals that can cause a number of different harmful effects. There are no known natural sources of PCBs in the environment. PCBs are either oily liquids or solids and are colorless to light yellow. PCBs enter the environment as mixtures containing a variety of individual chlorinated biphenyl components, known as congeners, as well as impurities. Because they don't burn easily and are good insulating materials, PCBs were used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. The manufacture of PCBs stopped in the United States in August 1977 because there was evidence that PCBs build up in the environment and may cause harmful effects (ATSDR 2000).

Attachment B-1
General Toxicological Profiles

PCBs are mixtures of many individual compounds, termed congeners. All PCB congeners contain two 6-carbon rings, with one chemical bond joining a carbon from each aromatic ring. Chlorine can attach to any of the other 10 carbons, for a total of 209 possible congeners. PCBs within a series of structures having the same chlorine content are known as homologues. In the United States, mixtures of PCB congeners carried the trademark "Aroclor" followed by a four-digit number that indicated the percent chlorine content by weight. Due to differential fate and transport of PCB congeners in the environment, the congener composition of PCBs in environmental media can differ from that of the technical-grade Aroclor that was originally released.

Toxicity of PCBs to Aquatic Biota: There are a number of effects observed in aquatic organisms due to exposure to PCBs (Eisler 1986). Those effects include growth reduction in algae and brook trout; reduced egg survival and reduced fertilization success in flounder, minnows, sea urchins; and complete reproductive failure in brook trout. Carcinogenic effects and biochemical perturbations were observed in trout liver cells and marine fishes; with anemia, hyperglycemia, and altered cholesterol metabolism in brown trout fed diets with 10 ppm PCBs (EPA 1980).

Fish reproduction is the most sensitive endpoint for PCB-related effects (Jarvinen and Ankley 1999). Aroclor 1254 is the most toxic formulation, while the least toxic formulation appears to be Aroclor 1268. Aroclor 1248 exhibits intermediate toxicity, and Clophen A50 (a European PCB formulation) appears to be similar to Aroclor 1254 in toxicity. DeFoe, Vieth et al. (1978) conducted a two-generation study of the effects of Aroclor 1248 on the reproduction of fathead minnows, evaluating larval survival and growth. No adverse effects were observed in fish exposed to 0.1 µg/L Aroclor 1248. Exposure to 0.4 µg/L Aroclor 1248 resulted in a small but significant decrease in larval weight, although larval length was not affected. Larval survival was not affected at any test concentration, up to 3.0 µg/L. The whole-body PCB concentrations in parental fish corresponding to these exposure levels are shown graphically by DeFoe, Veith et al. (1978) and reported numerically as concentration ranges by Jarvinen and Ankley (1999). The range of whole-body concentrations associated with the 0.1 µg/L (no effect) exposure (2.8 to 30.6 mg/kg) overlaps the range of whole-body concentrations associated with the 0.4 µg/L (reduced weight) exposure (11 to 50 mg/kg). These results indicate that whole-body concentrations up to approximately 10 mg/kg Aroclor 1248 are unlikely to adversely affect fish, with the likelihood of minor adverse effects increasing above approximately 30 mg/kg Aroclor 1248. Larval survival remained unaffected when parental whole-body concentrations of Aroclor 1248 ranged from 190 to 360 mg/kg.

PESTICIDES (CHLORDANE)

Chlordane, an organochlorine pesticide, is a man-made chemical that was used as a pesticide in the United States from 1948 to 1988. It is sometimes referred to by the trade names Octachlor® and Velsicol 1068®. Chlordane is not a single chemical, but is a mixture of many related chemicals, of which about 10 are major components. Some of the major components are trans-chlordane, cis-chlordane, beta-chlordene, heptachlor, and trans-nonachlor (ATSDR 1994).

Before 1978, chlordane was used as a pesticide on agricultural crops, lawns, and gardens and as a fumigating agent. Because of concerns over cancer risk, persistence in the environment, and danger to wildlife, the U.S. Environmental Protection Agency (EPA) canceled the use of chlordane on food crops and phased out other above-ground uses. From 1983 until 1988, chlordane's only approved use was to control termites in homes. In 1988, the EPA canceled chlordane's use for controlling termites and all approved use of chlordane in the United States ceased (ATSDR 1994).

In water, chlordane attaches strongly to sediment and particles in the water column. It does not dissolve in water (ATSDR 1994). It is not known whether much breakdown of chlordane occurs in water or in sediment. Chlordane bioaccumulates in bacteria and in fish species (ATSDR 1994); it is highly persistent and lipophilic, accumulating in animal tissues with high fat content.

Toxicity of Chlordane to Aquatic Biota: Chlordane is highly toxic to fresh water invertebrates and fish. Chlordane´s acute toxicity has been reported as moderately toxic to birds and highly toxic to freshwater invertebrates and fish as well as highly toxic to amphibians and reptiles. The 96-hour LC50 for bluegill is 57 to 74.8 µg/L and 42 to 90 µg/L for rainbow trout (Hayes, 1990; Hartley and Kidd, 1983; EPA, 1986). Chlordane is metabolized in animals and the resulting metabolites are also extremely toxic. Other toxic effects of chlordane include decreased survival in birds along with decreased reproduction. Secondary poisoning has been reported in raptors. Increased mortality, growth inhibition and liver cancer have been reported in mice exposed to chlordane (Eisler 1990).

ATTACHMENT B-2

Biota and Toxicity Study Summaries

Attachment B-2
Biota and Toxicity Study Summaries

FISH STUDIES

TVA – Reservoir Fish Assemblage Index (RFAI) Study

The fish community is being assessed using TVA's RFAI methodologies. RFAI sampling locations are CRM 1.5, CRM 4.4, CRM 22.0; ERM 2.5, TRM 531.0, TRM 560.8, and TRM 601.0. These locations were monitored in fall 2009 and will be sampled again in fall 2010. After which, an evaluation of the results will determine if sampling should continue on an annual or an every other year basis.

- To support the continued 316(a) Thermal Variance at KIF, RFAI samples were taken at CRM 1.5 and CRM 4.4 in fall 2001, 2003, 2005, and 2007. These data will provide a baseline for comparison.
- As part of TVA's Valley-wide Reservoir Vital Signs Monitoring Program, RFAI samples are taken at four additional sampling locations on Watts Bar Reservoir: TRM 531.0, TRM 560.8, and TRM 601.0, and CRM 22.0. These locations were sampled in the fall every two years from 1994 to 2008 and will provide baseline data for comparison.
- An additional RFAI sampling location was established at ERM 2.5. There is no historical RFAI data for this location. The initial RFAI samples were collected at ERM 2.5 in fall 2009.

The RFAI methodology collects fish using boat electrofishing and gill netting in a variety of habitat types so that as many species as possible are included and that species are taken in proportion to their true abundance in order to provide a good measure of community diversity, structure, and function.

RFAI sampling locations are nominally located at the stated river miles, but actual sample areas can extend approximately 1.5 miles upstream and/or downstream from the stated river mile. Fish collected are identified to species, counted, and examined for anomalies (such as disease, deformations, or hybridization). All fish will be field identified unless laboratory identification is required for some specimens. During electrofishing, fish observed but not captured are included if positive identification can be made and counts are estimated when high densities of identifiable fish (e.g., gizzard shad) are encountered. Young-of-year fish are counted separately and are excluded from proportional and abundance metrics due to sampling inefficiencies. Field data loggers are used to record all results.

The RFAI uses 12 fish community metrics from four general categories: Species Richness and Composition; Trophic Composition; Abundance; and Fish Health. Individual species can be utilized for more than one metric. Together, these 12 metrics provide a balanced evaluation of fish community integrity.

TVA, ORNL – TDEC-Requested Whole Fish Analysis (Spring 2009)

TDEC requested a collection of crappie for whole fish analysis from four sites (ERM 0.9, ERM 3.0, ERM 8.0, and CRM 1.5). Five black and/or white crappie were collected from each of the four sites. Whole fish composites were made of the five fish from each site and each five fish composite was analyzed for 25 metals, including selenium and mercury.

There were no significant differences in the major metals of concern (i.e., selenium, mercury, and arsenic) among any of these sites.

Attachment B-2
Biota and Toxicity Study Summaries

TVA, ORNL – Fish Health and Bioaccumulation (Winter/Spring and Fall 2009)

The primary objectives of the fish health and bioaccumulation studies conducted in the winter/spring of 2009 was to determine if fly ash exposure was causing short-term, intermediate, and/or long-term health effects on representative (sentinel) fish populations in the vicinity of the spill and at downstream sites. If significant exposure to fly ash-associated metals is occurring to fish in the river systems, then some indication of this would likely be evident from the bioaccumulation and fish health studies conducted during the first two years following the release. The fish health and bioaccumulation study was conducted in the winter/spring of 2009, immediately after the spill, in order to characterize pre-existing and existing conditions relative to bioaccumulation and fish health as a standard for assessing any future effects caused by the ash spill. The study was repeated in fall 2009 in order to evaluate the relationships between levels of metals in fish tissue and various indicators of fish health.

Eight individuals each of adult bluegill, largemouth bass, and channel catfish were collected at each of four sites (ERM 0.9, ERM 2.0, ERM 8.0, and CRM 1.5) by electrofishing and gillnetting. Fish were maintained alive in boat and transported alive to lab for processing. Once in the laboratory, all fish were processed for a suite of health indicators (i.e., blood chemistries, histopathology of organs, bioenergetic indicators, feeding and nutrition, and the overall fish health assessment index). Muscle, liver, and ovary (if available) tissue was obtained from six of the eight individuals of each species for bioaccumulation analysis. Samples were labeled and stored in the freezer. Subsamples of muscle, liver, and ovary were freeze dried in order to obtain percent dry weights.

No patterns or relationships between levels of metals in fish tissue and fish health are obvious at this stage of the study. The spatial downstream gradient of some metals in fish tissue and for some fish health responses indicate that inherent processes or conditions within the river system itself may be, at this stage of the study, the most important factors dictating bioaccumulation of constituents and health of fish compared to any effects due to fly ash exposure.

Studies planned for spring and autumn 2010 will include determining body burdens of 25 metals in muscle, liver, and ovaries (spring only) of four species of fish from six to seven sites (including at least three reference sites). The health status for sunfish and largemouth bass will be evaluated by measuring a suite of biomarkers and bioindicators of health. These biomarkers and indicators of health include:

- Physiological parameters;
- Histopathological responses;
- Bioenergetic status (lipid, etc.); and
- Necropsy investigations including presence/absence of parasites, disease, and developmental anomalies.

By measuring a suite of fish health responses and determining the levels of metals in individual fish, possible causal relations between contaminant exposure and various indicators of fish health can be established. Such studies are not only important in the BERA but also in helping to establish criteria and standards for environmental cleanup and remediation.

TVA, ORNL – Reproductive Study of Female Fish (Spring)

The primary objective of the reproductive study of female fish is to determine if fly ash exposure is causing short-term, intermediate-, and/or long-term reproductive effects on representative fish populations

in the vicinity of the spill and at downstream sites. The reproductive condition of fish representing different trophic levels and home ranges were assessed in spring 2009.

Three species of female fish (bluegill, largemouth bass, and crappie) were collected. Fish were captured in the field, a blood sample taken immediately, and individuals were then transported alive to a fixed laboratory for further processing. Ovaries were removed from each fish, and a variety of reproductive competence parameters were assessed including egg condition, atresia, and fecundity.

Results to date indicate that for largemouth bass egg atresia was more prevalent at ERM 3.0 (spill site). There were no observable differences in reproductive condition for bluegill and crappie among sites. However, these studies are considered to be preliminary because, if the potential exists for fly ash exposure to affect reproductive competence, there would not have been enough time between the spill event and the reproductive season for effects to be manifested.

Studies planned for spring 2010 will include determining body burdens of 25 metals in the ovaries of four species of fish from six to seven sites (including at least three reference sites). Reproductive studies will be conducted on sunfish and largemouth bass, and the health status of these fish will be evaluated by measuring a suite of biomarkers and bioindicators of health.

TVA, ORNL – Whole Forage Fish Analysis on Gizzard Shad

The whole forage fish analysis studies were conducted primarily for the purpose of assessing the role and importance of a main forage fish species (shad) as a mechanism by which metals associated with fly ash are incorporated into the aquatic-terrestrial food chain. Shad are the primary forage of the larger piscovorous fish (i.e., bass) and also piscivorous birds (i.e., great blue herons and ospreys). To assess body burden of fly ash associated metals in shad, three composite samples, with 10 whole shad each, were collected at five sites (ERM 0.9, ERM 3.0, ERM 8.0, CRM 1.5, and CRM 8.0). Each 10 fish composite were analyzed for metals.

Results of the shad collected in spring 2009 indicated little or no significance differences in levels of metals among sites. However, because these samples were collected only five months after the ash spill, there probably was not a sufficient time period for metals to be accumulated and transferred through the aquatic food chain. Composite shad samples were also taken in fall 2009 from seven sites to assess body burdens of metals; however, results from these collections are not yet available.

Additional studies will be conducted in spring 2010 to assess not only body burdens of metals in gizzard shad, but also to assess body burdens of threadfin shad and to evaluate the levels of metal contents in the diets of these prey species.

TVA, ORNL – Reservoir Spring Sport Fish Survey (Spring)

The Spring Sport Fish Survey (SSS) methodology is being used to monitor changes in black bass (largemouth, smallmouth, and spotted bass) populations over time. The SSS sample locations are CRM 1.5 and ERM 2.5. These locations were sampled in spring 2009 and will be sampled again in spring 2010 and 2011. After which, an evaluation of the results will determine if sampling should continue on an annual basis or on a two year monitoring cycle (or every other year basis).

Twelve sample runs are selected for each location based on the various habitat types present. Sample runs consist of thirty minutes of continuous electrofishing at fixed stations (i.e., transect) in the littoral

zone. All black bass collected are weighted, measured, enumerated and visually inspected for general health.

- Sampling at CRM 1.5 includes 10 transects located between CRM 0.0 and CRM 6.0 and two transects located between ERM 0.0 and ERM 1.0. As part of TVA's Valley-wide Reservoir Vital Signs Monitoring Program, this location was monitored annually from 2002 to 2005 and provides baseline data for comparison.
- Sampling at ERM 2.5 includes 12 transects located in the Emory River embayment between ERM 1.0 and ERM 5.0. Sampling was initially conducted at ERM 2.5 in spring 2009. No historical data exist.
- As part of TVA's Valley-wide Reservoir Vital Signs Monitoring Program, annual SSS have been conducted at three additional locations on Watts Bar Reservoir since 2002 (i.e., 2002-2009): Blue Springs, Caney Creek, and Watts Bar Dam.

SSS are used to provide information on growth, recruitment, relative abundance, and health. The spring 2009 results indicate that sport fish are present in numbers and conditions typically observed.

WILDLIFE STUDIES

TVA, UT– Mammal Tissue Concentration Study

Raccoons were evaluated to examine the bioaccumulation of heavy metals and the potentially deleterious health effects that may result from exposure to fly ash. During fall 2009, 10 raccoons were collected from the area around the ash spill and 5 raccoons were collected from an unaffected control area.

Animals were captured in live traps and then sedated. Blood samples were collected for heavy metal analysis, complete blood counts, plasma biochemistry panels, and possible future hormone analysis. Raccoons were then euthanized and had full necropsies performed. Tissue samples were collected for both metal analysis and histopathology. Samples collected for metal analysis included hair, subcutaneous fat, skeletal muscle, liver, kidney, gonad, and brain. Samples collected for histopathology included liver, kidney, gonad, adrenal gland, lung, and brain.

Samples have been submitted for metal analysis and histopathology but results are not yet available. Once available, differences between exposed and control animals will be identified, and samples obtained from live specimens (e.g., hair, blood) will be evaluated to see if they provide accurate measures of heavy metal accumulation in the body.

BIRD STUDIES

TVA – Piscivore and Herbivore Egg Concentration Study

Eggs were sampled from osprey, great blue herons, and Canada geese to test for their exposure to metals in order to establish comparative baselines for future bioaccumulation studies. Sampling locations include various localities in the Emory, Clinch, and Tennessee Rivers. A reference site on the Tennessee River, upstream from its confluence with the Clinch River, was also sampled. These sites were sampled in April 2009, and will be sampled again in 2010. The need for further sampling will be evaluated at the end of 2010. Future samples could be performed annually or bi-annually as needed.

A single egg was removed from each accessible nest. Initially, sample size for all species was low. While this won't change for osprey as their numbers are limited in the project area, samples of heron and

geese eggs will increase in 2010. Clutch size was noted for each nest. Specimens were marked and frozen whole. The content of eggs was sampled without the egg shell.

Initial results show that concentrations of elements are low in piscivorous and herbivorous birds. Only three Canada goose eggs were sampled as they were not a target species initially. However, the combination of elements accumulated by geese was more complex than those observed in osprey and great blue herons. Samples of Canada goose eggs will be increased in 2010.

TVA, Virginia Tech – Insectivorous Bird Tissue Concentration Study

Tree swallows were sampled in 2009 in order to determine their exposure to metals and to establish a comparative baseline for any future studies. Sampling locations include two localities in the Swan Pond Embayment, one at the discharge area of KIF, and reference sites at Melton Hill and Ft. Loudoun Dams. Samples were collected from April to June.

Eggs and nestlings were sampled at new colonies established at the KIF. A single egg and nestling (>14 days old) was removed from each egg clutch. Some nest boxes were used multiple times through the breeding season. Clutch size, hatch success, and nestling success were noted for each clutch. Eggs and nestlings were frozen whole. Egg contents were removed from the egg shell and analyzed. Nestling samples were analyzed using whole body tissues.

Initial results suggest that tree swallows do not yet appear to be experiencing widespread exposure to metals derived from fly ash. Metal concentrations were low in both impacted and reference sites. Notable exceptions were selenium and strontium concentrations in some individuals, including those at reference sites. TVA is evaluating the need for further sampling of tree swallows at the site. Future samples may be greatly expanded in 2010 to include more detailed analysis of bioaccumulation and the potential for reproductive effects in this resource.

REPTILE AND AMPHIBIAN STUDIES

TVA, Virginia Tech, TWRA – Turtle Tissue Concentration Study

Turtles around the spill were sampled in order to determine their exposure to metals and to establish a comparative baseline for any future studies. Sampling locations included sites in the Emory River, Clinch River above its confluence with Emory River, and Clinch River to its confluence with the Tennessee River. Specimens were also collected from a reference site in nearby Knox County. Turtles were sampled during the summer and fall months of 2009.

Adult turtles were sampled using baited traps. All specimens were marked and non-target species were released. A blood sample was taken from all snapping and musk turtles. Snapping turtles from the ash spill were transferred to TWRA for further analysis. Musk turtles were released.

Initial results show that concentrations of elements are low in turtles. Data are currently being analyzed. TVA is evaluating the need for further sampling of turtles at the site. Future samples may greatly expand the 2009 sampling effort to include more detailed analysis of bioaccumulation and the potential for reproductive effects in this resource.

Attachment B-2
Biota and Toxicity Study Summaries

TVA – Amphibian Tissue Concentration Study

Amphibian communities around the spill were sampled in 2009 to determine their exposure to metals and to establish comparative baselines for future bioaccumulation studies. Sampling locations included various localities in the Swan Pond Embayment; three sites directly impacted by the spill were examined. Two reference sites, one further upstream on Swan Pond Creek and one in Knox County, were also sampled. The need for further sampling will be evaluated at the end of 2010.

Breeding aggregations of frogs and toads were located in March 2009. Potential sample sites were identified by driving throughout the project area while listening for vocalizations of breeding frogs and toads. Specific species were identified by their vocalizations. Adult specimens were collected for each species. Specimens were held in holding tanks for four to seven days to allow for complete elimination of waste from intestinal tracts. All specimens were frozen and analyses were performed on whole body tissues.

Initial results show that concentrations of elements are low in amphibians; however, the combination of elements accumulated by amphibians (especially toads) was more complex than those observed in other species (i.e., birds). Future samples could be performed annually or bi-annually as needed. These data will document amphibian response to remediation activities implemented as ash is removed from impacted areas.

INVERTEBRATE STUDIES

TVA, ORNL – Mayfly Larvae Collection and Emerging Adult Mayfly Collection

To assess constituent (i.e., metals) exposures to aquatic invertebrates, the mayfly *Hexagenia bilineata* (adults and nymphs), was chosen as a study specimen because it is a common aquatic invertebrate found throughout the affected watershed. Nymphs of the burrowing mayfly, *H. bilineata*, live in burrows dug in the bottom sediments of the reservoir and feed on organic material. Each year from June through August, they emerge in large numbers as non-feeding adults, and provide an abundant food source to many aquatic and terrestrial predators.

For the initial assessment in summer 2009, five sampling sites were chosen including three sites in the Emory River (ERM 1.0, ERM 2.5, and ERM 6.0) and two sites in the Clinch River (CRM 1.5 and CRM 6.0). An additional sampling site for *H. bilineata* (adults and nymphs) was established at Little Emory River mile 1.0. Composite samples of *H. bilineata* nymphs were collected with a Peterson or Ponar dredge. At each sample location, a line-of-sight transect was established perpendicular to the channel and dredge grab samples collected at no less than five locations dispersed along this transect. A full complement of samples was analyzed without depuration, but a subset of samples was also collected from ERM 1.0 and CRM 1.5 and depurated for 48 hours in a laboratory before analysis. *H. bilineata* adults were collected opportunistically with a sweep net or by hand and sorted by sex and developmental stage (i.e., imago and subimago) before analysis. Results of mayfly collections are currently under review. Continued sampling in 2010 will include additional sampling sites and added analysis (i.e., samples analyzed with and without depuration) to better understand the special extent of contaminant transport downstream of the KIF and provide clarification of the influence of sex and presence of undigested food on estimates of contaminant burdens.

Attachment B-2
Biota and Toxicity Study Summaries

TVA, ORNL – Snail Tissue Concentration Study

To assess constituent (i.e., metals) exposures to aquatic invertebrates, *Pleurocera canaliculatum*, was chosen as a study specimen because it is a common aquatic invertebrate found throughout the affected watershed. *P. canaliculatum*, otherwise known as the silty horn snail, is a relatively large snail that lives in the shallow littoral zone where it feeds on algae and detritus.

For the initial assessment in summer 2009, five sampling sites were chosen including three sites in the Emory River (ERM 1.0, ERM 2.5, and ERM 6.0) and two sites in the Clinch River (CRM 1.5 and CRM 6.0). At each sample location, a line-of-sight transect was established perpendicular to the channel and dredge grab samples collected at no less than five locations dispersed along this transect. Composite samples of snails were collected by hand from shallow rocky or stable wooden structures near the shoreline, and then held for 72 hours in a laboratory to clear their digestive systems (i.e., depuration) before analysis. A full complement of samples was analyzed without depuration, but a subset of samples was also collected from ERM 1.0 and CRM 1.5 and depurated for 48 hr in a laboratory before analysis.

Results of snail collections are currently under review. Continued sampling in 2010 will include additional sampling sites and added analysis (i.e., samples analyzed with and without depuration) to better understand the special extent of contaminant transport downstream of the KIF and provide clarification of the influence of sex and presence of undigested food on estimates of contaminant burdens.

TVA – Assessment of Benthic Macroinvertebrate Community Survey

The benthic macroinvertebrates community is being sampled using TVA's Reservoir Benthic Macroinvertebrate Index sampling methodology. The initial sampling was completed in January 2009, with quantitative collections at 11 locations, including three in the Emory River, six in the Clinch River, and two in the Tennessee River; at least one upstream site served as a reference for each river. Sampling was conducted again in winter 2009/2010 and included the initial 11 sample locations, plus three additional locations in the Emory River (ERM 2.2, ERM 3.0, and ERM 4.1) that were not sampled in January 2009 due to limited access and on-going recovery operations, and one additional far-field location in the Tennessee River (TRM 560.8). A total of 15 locations have been sampled to date. An evaluation of these results will be used to determine future monitoring (i.e., sampling locations and frequency). The monitoring plan will be revised as appropriate.

At each sample location, a line-of-sight transect is established across the width of the reservoir, and one Ponar grab sample collected at 10 equally-spaced locations along this transect. If rocky substrates are encountered, a Peterson dredge may be used. For each sample, water depth and substrate composition is recorded. Care is taken to collect samples only from the permanently wetted bottom portion of the reservoir (i.e., below the elevation of the minimum winter pool level). Each sample is washed on a 589 microgram mesh screen and the remaining content preserved for taxonomic analysis. The matrix from each grab sample (i.e., 10) is processed separately in the lab. Specimens are identified to the genus/species phylogenetic level, given their developmental stage and condition.

Sampling locations (i.e., 15) are ERM 1.0, ERM 2.2, ERM 3.0, ERM 4.1, ERM 5.0, and ERM 6.0; CRM 0.5, CRM 1.5, CRM 3.0, CRM 4.0, CRM 6.0, and CRM 8.7; and TRM 560.8, TRM 566.3, and TRM 573.9.

Results from the January 2009 sampling showed considerable variation among sites within and among the three affected rivers in species composition, density, and species richness. Densities and species richness

among the reference sites and downstream sites in the Emory and Tennessee River sites were very similar, and relatively subtle differences existed in species composition. In the Clinch River, richness and density were generally highest at the two reference sites, although richness at a site immediately downstream of the confluence of the Emory River and one near the mouth of the river was comparable to the reference sites.

TOXICITY STUDIES

TVA initiated multi-phase laboratory sediment and surface water toxicity studies in the spring and summer months of 2009. The objective of the toxicity testing was to determine whether metals associated with fly ash found in site sediment and surface water are harmful to or are bioaccumulated by benthic invertebrates or fish. These toxicity tests can be used to measure interactive toxic effects of complex constituent mixtures in sediment and surface water. The toxic effects endpoints measured survival, growth, and reproduction, and metals bioaccumulation elicited by exposure of benthic and aquatic species to whole ash, elutriates, dredge plume water, and ash stilling pond effluent. Phase I testing was conducted in spring 2009 and Phase II in summer 2009.

Sediment

Multiple 3.1-m Vibracore® samples were collected immediately upstream (Vb.1) and downstream (Vb.2) of dredging on March 17, 2009 composited into two discrete samples, individually homogenized, placed in 19-liter (L) plastic buckets and kept in cold storage (4 ºC) until use. Multiple 3.1-m Vibracore® samples (Vb.3 & Vb.4) were collected and composited on June 11and 12, 2009, homogenized, placed in 19-L plastic buckets and kept in cold storage (4 ºC) until use. June 2009 samples were also treated with resin in an effort to provide a suitable reference control that retains the physical properties of ash without the chemical toxicity. Laboratory control sediment was collected from CRM 189.0. The methods for toxicity test are discussed in more detail in TVA (2009) *Kingston Fossil Plant Fly Ash Recovery Project Sampling Plan for Phase I Dredging Operations*. Various acute and chronic test protocols were used in the sediment toxicity testing, including:

- *Corbicula fluminea* bioaccumulation for sediments
- *Ceriodaphnia dubia* 96-hour survival test with whole ash elutriates
- *Pimephales promelas* 96-hour survival test with whole ash elutriates
- *Lumbriculus variegates* 4-day toxicity test (pre-bioaccumulation)
- Freshwater Juvenile Mussel (*Lampsilis siliquoidea*) 10-day survival for whole ash elutriates
- Freshwater Juvenile Mussel (*L. siliquoidea*) 5-day survival for sediments
- Freshwater Juvenile Mussel (*L. siliquoidea*) 10-day survival for sediments
- *Hyalella azteca* 10-day survival and growth for sediments

Results from the Phase I sampling in March 2009 (ash composite samples VB1 and VB2) indicated no appreciable bioaccumulation of metals in *C. fluminea* exposures (28-day) to whole ash nor any toxic effects in *C. dubia* (96-hour), *P. promelas* (96-hour), or *L. siliquoidea* (10-day) exposures to ash elutriates. *L. variegatus* exposures (4-days) to whole ash showed no effects on survival, but worms did not burrow so bioaccumulation was not assessed. No effects on survival were noted for *L. siliquoidea* (5-day) exposures to whole ash, but exposures (10-day) to one of the whole ash samples did result in significant effects on survival relative to laboratory control sediment. *H. azteca* exposures (10-day) to whole ash samples indicated adverse effects on survival, growth, and biomass.

Attachment B-2
Biota and Toxicity Study Summaries

Results from the untreated Phase II sampling in June 2009 (ash composite samples VB3 and VB4) indicated no appreciable bioaccumulation of metals in *C. fluminea* exposures (28-day) to whole ash. Effects on survival were noted in both of the centrifuged and uncentrifuged elutriate samples for *L. siliquoidea* (10-day) exposures. Effects on survival were noted in one of the centrifuged elutriate samples for *C. dubia* (96-day) exposures. No effects on survival were observed in the uncentrifuged elutriate samples for *C. dubia* (96-hour) exposures. Effects on survival were noted in one of the centrifuged and one of the uncentrifuged elutriate samples for *P. promelas* (96-hour) exposures. Similar results were seen with Ultraviolet-treated elutriate samples. *L. variegatus* exposures (4-day) to whole ash showed no effects on survival, but worms did not burrow so bioaccumulation was not assessed. Effects on survival were noted in one of the whole ash samples for *L. siliquoidea* (5-day) exposures as well as one of the whole ash samples for (10-day) exposures. *H. azteca* exposures (10-day) to both whole ash samples indicated adverse effects on survival, growth, and biomass. Effects on survival were noted in one of the whole ash samples for *L. siliquoidea* exposures (5-day) as well as one of the whole ash samples for exposures (10-day).

Results from the resin-treated Phase II sampling in June 2009 (ash composite samples VB3 and VB4) provided promising but inconclusive results. Elutriates treated with resin to remove metals demonstrated significantly reduced toxicity in several tests. However, tests of bulk sediment treated with resin exhibited less pronounced reductions in toxicity and in at least one test may have been associated with higher toxicity. These results are being evaluated for development of future testing protocols.

Fly ash in Emory River possesses unique physical properties that present unfamiliar challenges to sediment toxicologists. Within a day or two of collecting whole ash and storing in containers, the solids settle out into a very compacted state while porewater separates and surfaces; this same behavior occurs in toxicity test chambers. With each use, the compacted ash and separated porewater must be homogenized to ensure consistent exposures. The key to evaluating ash toxicity appears to lie in the development of a suitable reference control material that has similar properties. To date, TVA has (1) attempted to formulate sediment, but it appears that no naturally-occurring medium exists that approaches the grain size distribution of ash; (2) considered “ash washing” with acids followed by porewater reconstitution, but it is thought that such rigorous manipulations would alter the behavior of ash in the laboratory (e.g., compacting); and (3) treatment with resins to decrease the bioavailable fraction of metals in pore water, which based on preliminary studies, appears to be the best approach coupled with follow-up studies with resin treatment of ash, TVA will focus on experimental approaches to better understand bioavailability of metals in ash.

Surface Water

Emory River dredge plumes were visually located. Hydrolab was used to delineate the most turbid depth, and a peristaltic pump was used to collect aqueous plume sample. Samples were held at 4 ºC until use. Reference control and dilution water were collected from unaffected areas of the Emory River. In addition, 24-hour composite stilling pond effluent samples were collected with an ISCO sampler, and samples were held at 4 ºC until use. The methods for toxicity test are discussed in more detail in TVA (2009) *Kingston Fossil Plant Fly Ash Recovery Project Sampling Plan for Phase I Dredging Operations*. Various acute and chronic test protocols were used in the surface water toxicity testing, including:

- *C. dubia* 7-day survival and reproduction test with Emory River Plume
- *C. dubia* 7-day survival and reproduction test with Outfall 001
- *P. promelas* 7-day survival, growth, and biomass test with Emory River Plume

Attachment B-2
Biota and Toxicity Study Summaries

P. promelas 7-day survival, growth, and biomass test with Outfall 00. No effects (survival, reproduction) were observed in 7-day chronic exposures with *C. dubia* to plume or stilling pond effluent samples collected from April to June 2009. Results with identical exposures to the April and May 2009 samples by *P. promelas* (survival, growth) were invalidated due to confirmed pathogen interference. *P. promelas* chronic tests with ultraviolet-treated plume and stilling pond effluent samples collected in June 2009 resulted in no adverse effects.

Another phase of testing (96-hour *C. dubia* and *P. promelas*) involves weekly (August to September) and bimonthly (October to present) monitoring of dredge plume and stilling pond effluent samples in response to increased dredging rates. Grab samples were collected from observed dredging plumes on the Emory River and 24-hour composite samples were collected from the KIF Stilling Pond Outfall 001 and shipped to Hydrosphere Research laboratory in Alachua, Florida. Unaffected Emory River water (collected at ERM 12.2) was used as reference control and dilution water. The methods for toxicity test are discussed in more detail in TVA (2009) *Kingston Fossil Plant Fly Ash Recovery Project Sampling Plan for Phase I Dredging Operations*. The following surface water toxicity tests were conducted:

- *C. dubia* 96-hour survival test with Emory River Plume
- *P. promelas* 96-hour survival test with Emory River Plume
- *C. dubia* 96-hour survival test with Outfall 001
- *P. promelas* 96-hour survival test with Outfall 001

A total of 50 tests, including one re-test of Outfall 001, were performed over the period. Only one test from a sample collected on October 27, 2009 from Outfall 001 exhibited any toxicity for *C. dubia*. The same sample showed no toxicity for *P. promelas*. On November 5, 2009 another sample from Outfall 001 was collected and exhibited no toxicity for either *C. dubia* or *P. promelas*.

ATTACHMENT B-3

Selection of Representative Species for Food Web Modeling Exposures

Attachment B-3
Selection of Representative Species for Food Web Modeling Exposures

TROPHIC LEVELS AND CATEGORIES OF REPRESENTATIVE ORGANISMS

Site-specific species are selected to represent the important trophic levels in the aquatic food web in order to assess the potential risks for ecological receptors within the river system. Key trophic levels within the food web include primary consumers (herbivores), secondary consumers (omnivores), and top predators (carnivores/piscivores at the top of a food web). Some species can occupy more than one trophic position in a food web. For example, muskrats consume both plants and benthic invertebrates, depending on the time of year and food available. As a result, the muskrat was selected as an indicator species for both aquatic- and riparian-feeding herbivorous mammals as well as aquatic- and riparian-feeding omnivorous mammals.

SELECTION OF INDICATOR SPECIES

Indicator species were chosen to represent a cross-section of feeding guilds for selected assessment endpoints and allow estimation of rates of survival, growth and reproduction for populations or receptors they represent. Indicator species were selected to represent avian and mammalian populations that reside or forage in habitats present on the site. Indicator species selected for each feeding guild are as follows:

- Aquatic- or riparian-feeding herbivorous bird: wood duck (*Aix sponsa*)
- Aquatic- or riparian-feeding omnivorous (insectivorous) bird: mallard (*Anas platyrhynchos*); and killdeer (*Charadrius vociferus*)
- Aquatic- or riparian-feeding piscivorous bird: osprey (*Pandion haliaetus*) and great blue heron (*Ardea herodias*)
- Aquatic- or riparian-feeding herbivorous mammal: muskrat (*Ondatra zibethicus*)
- Aquatic- or riparian-feeding omnivorous mammal: raccoon (*Procyon lotor*)
- Aquatic- or riparian-feeding piscivorous mammal: mink (*Mustela vison*)
- Aerial-feeding insectivorous bird: tree swallow (*Tachycineta bicolor*)
- Aerial-feeding insectivorous mammal: gray bat (*Myotis grisescens*)

Indicator species were not selected to represent reptiles or amphibians that likely use each site, because the available toxicity data are insufficient to support establishing distinct risk-based screening criteria (EPA 2005). A summary of the available effects data for reptiles is discussed below.

Because effects data for reptiles and amphibians are extremely limited (Sparling, et al. 2000), it is necessary to assume that the risk characterizations for other receptors is protective of these species. Most information on reptilian toxicity of metals arises from free ranging specimens. This implies that almost all data are derived from greatly undefined, very likely multi-compound, long-term exposure conditions (Sparling et al. 2000). The literature that is available for reptiles generally consists of reptilian mortality resulting from pesticide applications, reports of residue analyses of various contaminants, and limited information concerning the inhibitory effects of organochlorines on detoxifying enzyme activity (Hall 1980; Sparling et al. 2000). Recent studies have been conducted on the effects of endocrine-disrupting chemicals on alligator populations but provide no data for metals. Albers et al (1986) compared tissue residues of seven metals in snapping turtles from two contaminated sites, one a freshwater habitat and the other a brackish habitat. No toxicity data was available however.

Furthermore, there are several plants, invertebrates, amphibians, reptiles, fish and birds listed as species of conservation concern in Roane County, as evaluated by the TVA Regional Natural Heritage Program (Jacobs 2009). This list of species of concern was consulted during the selection process of the

representative guilds and surrogate species evaluated as measurement endpoints to be further evaluated. As presented in Jacobs (2009), only one bird or mammal, the gray bat (*Myotis grisescens*), was identified as a federally listed endangered species. As a result, the gray bat was selected as a representative species for aerial-feeding insectivorous mammals.

The rationale for selection of each of these species is discussed in the subsections below.

Selection of Aquatic- or Riparian-Feeding Herbivorous Avian Receptor

The wood duck is a medium-sized perching duck that could be present at the site. It is an herbivorous bird that forages on the ground and in the water. Diet consists mostly (99%) of plants, nuts, fruits, and seeds of trees (especially acorns) and shrubs. Breeding habitats include wooded swamps, shallow lakes, marshes, or ponds. Nests are generally built in holes in large trees in forested wetlands or in bird boxes if available. Home ranges vary with season, latitude, and breeding condition.

The wood duck was selected to represent herbivorous birds associated with the site for the following reasons:

- It is a common duck in wetland and river habitats;
- Populations are essentially non-migratory in the site vicinity; and
- Populations are easily monitored.

Selection of Aquatic- or Riparian-Feeding Omnivorous (Insectivorous) Avian Receptor

Two receptors were selected to evaluate omnivorous avian species. These receptors include the mallard and the killdeer, as described below.

The mallard is the most abundant of the United States ducks. It inhabits natural bottomland wetlands, rivers, ponds, lakes, marshes, and flooded fields, foraging on seeds, rootlets, and tubers of aquatic plants, seeds of swamp and river bottom trees, acorns, cultivated grains, insects, mollusks, amphibians, small fishes, and fish eggs. The mallard usually nests on the ground in concealing vegetation, generally within a few kilometers of the water. Migration distances depend on winter temperature, water conditions, and population size (EPA 1993a,b). For the purposes of this evaluation, mallards are assumed to eat primarily insects.

The mallard was selected to represent omnivorous (insectivorous) birds associated with the site for the following reasons:

- It is a common duck in wetland and river habitats;
- It preys on primarily insects, which may accumulate COPECs; and
- It forages both in the water and on the ground during which the intake of COPEC could occur through incidental surface water and sediment ingestion.

The killdeer is a type of plover with commonly found on sandbars, mudflats, fields, and pastures, eating mainly insects. The killdeer usually nests on the ground in small depressions. Migration distances depend on winter temperature, water conditions, and population size (EPA 1993a,b). For the purposes of this evaluation, killdeer are assumed to eat primarily insects.

Attachment B-3
Selection of Representative Species for Food Web Modeling Exposures

The killdeer was selected to represent omnivorous (insectivorous) birds associated with the site for the following reasons:

- It is a common shorebird in wetland and river habitats;
- It preys primarily on insects, which may accumulate COPECs; and
- It forages in the seasonally-exposed (shallow) sediments and mudflats during which the intake of COPEC could occur through incidental surface water and sediment ingestion.

Selection of Aquatic- or Riparian-Feeding Piscivorous Avian Receptor

Two receptors were selected to evaluate piscivorous avian species. These receptors include the osprey and the great blue heron, as described below.

Ospreys inhabit a variety of freshwater and marine areas, including freshwater lakes and rivers, brackish marshes, and lagoons. They prey primarily on fish but may also feed on aquatic organisms such as crustaceans, birds, mammals, amphibians, and reptiles. They may be exposed to COPECs through bioaccumulation in prey that forage in the water and sediment and ingest sediment incidentally through food. Ospreys build their nests on the tops of isolated trees and man-made structures. Breeding colonies are generally close to foraging grounds and nesting sites are often used for more than one year (EPA 1993a,b).

The osprey was selected to represent piscivorous birds associated with the site for the following reasons:

- Osprey have been observed at the Kingston site;
- Osprey prey primarily on fish, which may bioaccumulate COPECs; and
- Osprey is a protected migratory species and is easily monitored.

Great blue heron are the largest member of the heron group that inhabit a variety of freshwater and marine areas, including freshwater lakes and rivers, brackish marshes, and lagoons. They prey on primarily aquatic animals such as fish, crustaceans, birds, mammals, amphibians, and reptiles. They may be exposed to COPECs through bioaccumulation in prey that forage in the water and sediment and ingest sediment incidentally through food. Great blue heron prefer tall trees for nest sites but may also nest on the ground or on rock ledges. Breeding colonies are generally close to foraging grounds and nesting sites are often used for more than one year (EPA 1993a,b).

The great blue heron was selected to represent piscivorous birds associated with the site for the following reasons:

- Great blue heron have been observed at the Kingston site;
- It preys on fish and aquatic mammals, amphibians and reptiles, which may bioaccumulate COPECs; and
- It forages both in the water and on the ground during which the intake of COPEC could occur through incidental surface water and sediment ingestion.

Selection of Aquatic- or Riparian-Feeding Herbivorous Mammalian Receptor

The muskrat is primarily herbivorous, but may also feed on arthropods (i.e., mussels) seasonally. It is found in freshwater streams, lakes, marshes, and ponds. They are solitary animals that are active all year long, building their nests directly in the water systems. Muskrat may breed several times per year, with

litter sizes of three to six young. Muskrat usually forage within 5 to 10 meters (15 to 30 feet) of their nest (EPA 1993a, b).

The muskrat was selected to represent herbivorous mammals associated with the site for the following reasons:

- Muskrat are active year-round, foraging and building their nests in the water systems;
- Muskrat are common prey for hawks, minks, raccoons, owls, red fox, and snapping turtles; and
- Muskrat burrows provide important shelter or places to find food for many vertebrates.

Selection of Aquatic- or Riparian-Feeding Omnivorous Mammalian Receptor

The raccoon is an omnivorous and opportunistic mammal that forages on fruits, nuts, invertebrates, reptiles, amphibians, and fish. This species occupies a wide variety of habitats, including freshwater and saltwater marshes, swamps, floodplain forests, and most any aquatic habitat. Raccoons can make their dens in hollow trees as well as burrows in the ground. Home range data vary, but can be several hundred acres. While diet proportions are determined by location and season, for the purposes of this assessment, raccoon will be assumed to eat primarily invertebrates.

The raccoon was selected to represent omnivorous mammals associated with the site for the following reasons:

- Raccoons have been observed at the Kingston site;
- It preys primarily on invertebrates, which may accumulate COPECs; and
- It uses surface water for both drinking and foraging, which could increase the intake of COPECs through incidental surface water and sediment ingestion.

Selection of Aquatic- or Riparian-Feeding Piscivorous Mammalian Receptor

The mink is a common mammal in North America, and would likely inhabit parts of Tennessee including the Kingston site. Mink are found in a variety of aquatic habitats, including waterways such as rivers, streams, lakes, and ditches, as well as swamps, marshes, and backwater areas. Mink hunt primarily along the shorelines and emergent vegetation, consuming whatever prey is most abundant (EPA 1993a,b). While their diet can include mammals, fish, amphibians, crustaceans, birds, reptiles, and insects, for the purposes of this assessment, mink will be assumed to eat primarily fish.

The mink was selected to represent piscivorous mammals associated with the site for the following reasons:

- Mink are a common piscivorous species associated with rivers, streams, and lakes;
- It preys on fish and aquatic mammals, amphibians and reptiles, which may bioaccumulate COPECs; and
- It forages both in the water and on the ground during which the intake of COPECs could occur through incidental surface water and sediment ingestion.

Selection of Aerial-Feeding Insectivorous Avian Receptor

The tree swallow inhabits streams, lakes, ponds, and marshes, nesting near water in natural tree cavities or abandoned woodpecker holes, less frequently in open woodland away from water, and in bird boxes or in

crevices of buildings. Eggs are typically laid from late April to late June, with clutch sizes of four to six eggs. Tree swallows forage primarily on insects flying in the air over land or water, but are also known to consume ground insects (e.g., beetles) and spiders, and on occasion, some seeds and fruits (NatureServe 2009). For the purposes of this evaluation, tree swallows are assumed to eat primarily emergent aquatic insects (mayflies).

The tree swallow was selected to represent aerial-feeding insectivorous birds associated with the site for the following reasons:

- Tree swallows have been observed on the site;
- Tree swallows are common species in the region and are relatively easy to monitor; and
- It preys on primarily insects, which may accumulate COPECs.

Selection of Aerial-Feeding Insectivorous Mammalian Receptor

The gray bat is listed as a federally endangered species in North America, and could possibly inhabit parts of Tennessee including the Kingston site. Gray bats predominately inhabit caves; however, non-cave roost sites are also used. They are often times found in forested areas along the banks of streams and lakes where they have protection, and where young can feed and take shelter in forest areas near the entrances to cave roosts.

Gray bats hunt primarily along streams, over the water, but rarely are found in the open (NatureServe 2009). Gray bats forage on flying insects, including mayflies and beetles, but their diet can vary with local resources and habitat. For the purposes of this assessment, gray bats will be assumed to eat primarily emergent insects (mayflies).

The gray bat was selected to represent aerial-feeding insectivorous mammals associated with the site for the following reasons:

- Gray bats are a federally listed endangered species and are considered a sensitive receptor for the site;
- Gray bats are thought to be permanent residents in the region; and
- It preys primarily on insects, which may accumulate COPECs.

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ATTACHMENT B-4

Food Web Model Assumptions

Attachment B-4
Food Web Model Assumptions

FOOD WEB MODELING

Ingestion-based food chain modeling is used in the BERA to evaluate bioaccumulative COPECs. The purpose of the food chain modeling is to characterize potential exposures to COPECs via the food chain and to identify potential adverse effects for mammals and birds. The remainder of this section provides general information regarding the components of the model.

WILDLIFE RECEPTORS

Indicator species were chosen to represent a cross-section of feeding guilds for selected assessment endpoints and allow estimation of rates of survival, growth and reproduction for populations or receptors they represent. Indicator species were selected to represent avian and mammalian populations that reside or forage in habitats present on the site. The rationale for the selected indicator species is discussed in Attachment B-3. The selected indicator species for each feeding guild are as follows:

- Aquatic- or riparian-feeding herbivorous bird: wood duck (*Aix sponsa*)
- Aquatic- or riparian-feeding omnivorous (insectivorous) bird: mallard (*Anas platyrhynchos*); and killdeer (*Charadrius vociferus*)
- Aquatic- or riparian-feeding piscivorous bird: osprey (*Pandion haliaetus*) and great blue heron (*Ardea herodias*)
- Aquatic- or riparian-feeding herbivorous mammal: muskrat (*Ondatra zibethicus*)
- Aquatic- or riparian-feeding omnivorous mammal: raccoon (*Procyon lotor*)
- Aquatic- or riparian-feeding piscivorous mammal: mink (*Mustela vison*)
- Aerial-feeding insectivorous bird: tree swallow (*Tachycineta bicolor*)
- Aerial-feeding insectivorous mammal: gray bat (*Myotis grisescens*)

BIOACCUMULATIVE COPECS

Each of the constituents identified as COPECs for direct contact were also evaluated for the potential to bioaccumulate. Food web modeling is used in addition to field-collected data in order to predict potential exposures of constituent concentrations that may build up in higher trophic levels. The list of bioaccumulative constituents presented within the EPA (2000b) *Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment* was used to identify potential bioaccumulative COPECs (Table B-3-2).

INPUT PARAMETERS AND ASSUMPTIONS

The following subsections show the model input parameters, as well as assumptions made for each.

Exposure Point Concentrations for COPECs

To ensure that the estimate of the average (or mean) is conservative and not underestimated, EPA (1989, 1992) recommends using the UCL_{95} as an estimate for the EPC for each exposure area of a site. However, in cases where the data set is small, the maximum detected concentration is considered the appropriate comparative statistic. Both conservative (UCL for maximum: minimum detected) and realistic (average) exposure assumptions will be evaluated. COPEC concentrations in ambient media are measured directly, while COPEC concentrations in biological tissues of lower trophic species may be measured directly or estimated using intake models and used as food items for higher trophic level species.

Attachment B-4
Food Web Model Assumptions

Exposure Media

Exposure media represent the primary media to which specific receptors or categories of receptors may be exposed. These media include submerged sediment, seasonally-exposed sediment, porewater, epibenthic surface water, and water column surface water. Exposure media differ for feeding guilds, and as a result, exposure media will be divided differently for the representative species evaluated within the food web model as follows:

Aquatic- or riparian-feeding herbivorous bird: wood duck

- Surface water
- Shallow sediment (seasonally-exposed)

Aquatic- or riparian-feeding omnivorous (insectivorous) bird: mallard and killdeer

- Surface water
- Shallow sediment (seasonally-exposed)

Aquatic- or riparian-feeding piscivorous bird: osprey and great blue heron

- Surface water
- Shallow sediment (seasonally-exposed) (great blue heron only)

Aquatic- or riparian-feeding herbivorous mammal: muskrat

- Surface water
- Submerged sediment
- Shallow sediment (seasonally-exposed)

Aquatic- or riparian-feeding omnivorous mammal: raccoon and muskrat

- Surface water
- Submerged sediment
- Shallow sediment (seasonally-exposed)

Aquatic- or riparian-feeding piscivorous mammal: mink

- Surface water
- Submerged sediment
- Shallow sediment (seasonally-exposed)

Aerial-feeding insectivorous bird: tree swallow

- Surface water

Aerial-feeding insectivorous mammal: gray bat

- Surface water

Attachment B-4
Food Web Model Assumptions

Spatial and temporal boundaries were used to aggregate the exposure media. The river system consists of the Emory, Clinch, and Tennessee Rivers. Each river was divided into reaches to more adequately characterize potential effects to the established assessment endpoints. The following reaches and reference sites have been established for each river and are used within the food web models (Figure B-4):

- **Emory River** – Reach A (ERM 0.0 - ERM 1.5); Reach B (ERM 1.5 - ERM 3.5); Reach C (ERM 3.5 - ERM 6.0); Reference (above ERM 6.0)

- **Clinch River** – Reach A (CRM 0.0 - CRM 3.0); Reach B (CRM 3.0 - CRM 6.0); Reference (above CRM 4.5)

- **Tennessee River** – Reach A (TRM 566 - TRM 568); Reference (above TRM 568)

Temporal considerations for the site include the pre-release period (prior to December 22, 2008), during the time critical removal period (from December 22, 2008 to completion of dredging associated with the time-critical removal action), and post-time-critical removal period (from the completion of dredging associated with the time-critical removal action to the preparation of the ERA for the river system). For the purposes of food web modeling, post-time-critical removal period data will be used as available and will be supplemented as necessary with data collected during the time-critical removal period.

Bioaccumulation and Bioconcentration Factors

The processes of bioaccumulation and bioconcentration are important to an ERA because they provide a basis of prediction and discussion regarding the potential for constituent uptake into flora and fauna. Constituents in tissues of organisms in the food chain are likely to be ingested by the species which feed on them (i.e., those occupying higher trophic levels); the result of which may be the expression of toxicological effects by the higher trophic level species.

Bioconcentration factors (BCFs) are derived from the ratio of tissue concentrations in an organism to constituent concentrations in surface water. Bioconcentration factors do not consider concentrations from food ingestion. They consider only direct uptake from water, and are used mainly when evaluating bioaccumulation in aquatic plants, aquatic invertebrates, and fish. Bioaccumulation factors (BAFs) are similar to BCFs in that they evaluate uptake of constituent concentrations from surface water; however, BAFs also consider concentrations ingested from food items. As a result, BAFs are typically used when evaluating the uptake of constituents by fish and other aquatic organisms that are exposed to concentrations in surface water, sediment, and prey.

When practical and available, site-specific bioaccumulation and bioconcentration factors are used for the food chain modeling, otherwise these factors are obtained from literature sources such as Sample, et al. 1997; Baes, et al. 1984; Travis and Arms 1988; Belfroid, et al. 1994; Belfroid, et al. 1995; Beyer 1990; Beyer, et al. 1996; and other related literature. If a BAF or BCF obtained from the literature was in dry weight, it was converted to wet weight in the estimated ingestion calculation using the following conversion factors: 0.167 for invertebrates; 0.12 for plants and 0.32 for mammals.

$$\text{BAF (wet weight)} = \text{BAF (dry weight)} * \text{Conversion Factor}$$

Attachment B-4
Food Web Model Assumptions

Home Range

The degree of an organism's exposure is greatly influenced by its home range. An organism with a home range entirely within the affected area will likely have a greater potential exposure than an organism with a home range overlapping only a portion of the affected area. However in some instances, it is possible for organisms with large home ranges to, at times, remain within a smaller area provided that area if that are provides adequate food and cover. In these instances, the home range would not adequately represent the exposure to COPECs. Average home ranges for adult organism are used within the food web model.

Site Foraging Frequency (SFF)

SFF is a term used to describe the ratio of the site area to the average home range for the representative species. A For organisms with foraging areas smaller than the reach (exposure area), the SFF is assumed to be 1 (i.e., 100% of individual's diet comes from within the reach. For organisms with foraging areas greater than the reach, the SFF will be adjusted based on literature values for the foraging/home range of a measurement receptor. For several of the receptors (i.e., osprey mink), the home ranges are larger than the areas evaluated for each river reach. SFFs calculations are represented by a simple ratio where the size of the affected area is divided by the size of the home or foraging range of the receptor. For the purposes of this assessment, the size of the affected area was based on the river reach boundary.

Dietary Fraction

The portion of the total diet made up by each prey item is known as the dietary fraction. The estimates of dietary fraction used in this BERA are based on values found within the literature. When more than one literature source of dietary information is available, the dietary fraction estimates are based on an average of all relevant literature sources or the values most relevant to Eastern Tennessee were used. Some receptors also incidentally ingest ambient media (i.e., submerged sediment). For these receptors, the fraction of ambient media incidentally ingested is also included as part of their diet. For example, great blue heron are assumed to incidentally ingest a substantial amount of sediment while feeding and preening unlike osprey feeding in the same riverine environment, which most likely ingest little or no sediment.

Average Ingestion Rate

Average ingestion rates are determined for representative species from values in the literature. Ingestion rates are presented as both wet weight and dry weight. Ingestion of ambient media (i.e., sediment) is expressed as dry weight, while plant and animal dietary items are expressed in wet weight.

Average Body Weight

Average body weights for representative species are based on adult organism values presented in literature sources. Where more than one source was available, the value used is based on the average of all species-specific adult body weights available or the values most relevant to Eastern Tennessee. For some species, average body weights for males and females can be substantially different. In these instances, an average is calculated for both male and female species.

Attachment B-4
Food Web Model Assumptions

MODEL OUTPUT

Food web ingestion-based exposure calculations will be performed for the identified representative receptor species to characterize potential exposures to constituents via the food web and to identify potential adverse effects for wildlife at the sites. Ingestion modeling is based on species-specific exposure parameters and ingestion intake requirements. Arithmetic mean and UCL_{95} concentrations will be used to evaluate the range of potential ingestion-based exposures within each river reach. The use of mean concentrations is appropriate because birds and mammals are highly mobile and consume prey items containing varying levels of COPECs. The use of UCL_{95} concentrations is intended to represent, in effect, a reasonable maximum exposure estimate. If a data set is too small to calculate the arithmetic mean or UCL_{95}, the maximum concentration will be used for model calculations. The following model will be used to calculate the ingestion-based exposure for each indicator receptor:

$$\text{Ingestion (mg/kg - day)} = \left(\frac{\{(P_{MEDIUM} \times C_{MEDIUM} \times (IR_M)) + ((P_{FOOD1} \times C_{FOOD1}) + (P_{FOOD2} \times C_{FOOD2}) \times (IR_F))\} \times (SUF) \times (ED)}{BW} \right)$$

Where:

P_{MEDIUM}	=	Proportion of the diet comprised of the medium (unitless)
C_{MEDIUM}	=	Concentration of the constituent in the medium (mg/kg)
P_{FOOD1}	=	Proportion of the diet comprised of the first food item (unitless)
C_{FOOD1}	=	Concentration of the constituent in the first food item (mg/kg)
P_{FOOD2}	=	Proportion of the diet comprised of the second food item (unitless)
C_{FOOD2}	=	Concentration of the constituent in the second food item (mg/kg)
IR_F	=	Ingestion rate of food (kg/day)
IR_M	=	Ingestion rate of media (kg/day)
SUF	=	Site use factor (unitless)
ED	=	Exposure duration (unitless)
BW	=	Body weight of the organism (kg)

and:

C_{FOOD1}	=	C_{MEDIUM} x BAF_{FOOD1}
C_{FOOD2}	=	C_{MEDIUM} x BAF_{FOOD2}
BAF_{FOOD1}	=	Bioaccumulation factor for first food item (unitless)
BAF_{FOOD2}	=	Bioaccumulation factor for second food item (unitless)

TOXICITY ASSESSMENT

Modeling studies use constituent-specific TRVs for the purpose of estimating risk. For the most part, TRVs are based on studies using laboratory species because toxicological studies have not been conducted on most wildlife species. TRVs are available from a variety of sources such as EPA (2009b; 2005); Sample, et al. (1996; 1997); Agency for Toxic Substances and Disease Registry, and many constituent-specific scientific sources and publications. Toxicological benchmarks are typically reported as NOAELs and LOAELs. Both NOAELS and LOAELs for each COPEC are used in the food web modeling so that a range of predicted food web impacts can be evaluated. These ecotoxicity values will vary depending on the species, as described below.

Toxicity values must be carefully selected, and may require mathematical adjustment in order to represent the species selected for a site. In order to have a toxicity value representative of specific mammalian wildlife species rather than a mammalian laboratory species, an extrapolation (i.e., a mathematical formula based on differences in body weights) will likely be needed (Sample, et al. 1997). The

extrapolation is necessary because the laboratory mammalian species and wildlife species are of varying sizes.

A generic approach for modeling a constituent-specific reference toxicity value for the purpose of estimating risk to a generic mammalian "wildlife species," is shown below (Sample, et al. 1996):

$$NOAEL_{\text{Wildlife Species}} = NOAEL_{\text{Test Species}} \times \left[\frac{BW_{\text{TestSpecies}}}{BW_{\text{WildlifeSpecies}}} \right]^{\frac{1}{4}}$$

Where:

$NOAEL_{\text{Wildlife Species}}$	=	NOAEL for the wildlife species (i.e., the TRV)
$NOAEL_{\text{Test Species}}$	=	NOAEL for the laboratory test species (i.e., the toxicological benchmark)
$BW_{\text{Test Species}}$	=	Body weight of the laboratory test species
$BW_{\text{Wildlife Species}}$	=	Body weight of the wildlife species

No body size scaling extrapolation was applied to toxicity values obtained from EPA EcoSSL guidance (2005c) since those values are derived using multiple mammal test species.

Toxicity values for birds are not typically extrapolated, regardless of the laboratory test species (Sample, et al., 1996). For example, the NOAEL for a laboratory test bird (e.g., a mallard duck) would be used exactly to represent a NOAEL for the great blue heron.

Appendix C
Groundwater Transport Modeling Methodology

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List of Acronyms

COC	constituent of concern
ft	foot
HELP	Hydrologic Evaluation of Landfill Performance model
KIF	Kingston Fossil Plant
SAP	Sampling and Analysis Plan
TAL	total analyte list
TDS	total dissolved solids
TSS	total suspended solids
VMOD	Visual MODFLOW

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1. BACKGROUND AND PURPOSE

Contiguous ash deposits within the former Dredge Cell, the active Ash Pond, and the Lateral Expansion Area will be closed under the Comprehensive Environment Response, Compensation, and Liability Act as a single Ash Landfill. The Ash Landfill will be backfilled with compacted dry ash, contoured to promote surface runoff, and capped with 2 feet (ft) of clay followed by 1 ft of vegetated topsoil. Depending on the closure alternative adopted, a foundation treatment zone extending to bedrock will be constructed around the perimeter of the Ash Landfill to enhance its seismic stability. Groundwater flow patterns at the Kingston Fossil Plant (KIF) site indicate that groundwater in contact with the ash in the closed Ash Landfill would be transported with shallow groundwater to the Emory River and Swan Pond Embayment. In addition, groundwater in contact with other ash deposits beneath the Stilling Pond and the Ash Processing Area ("Ball Field") is expected to discharge to the Emory River and/or the Intake Channel. Some of the constituents in groundwater migrating through alluvial sediments beneath the KIF site may be subject to natural attenuation by adsorption, ion-exchange, and chemical precipitation. For example, geochemical speciation modeling of ash leachate attenuation by Milligan and Ruane (1980) and Velasco and Bohac (1991) indicate adsorption of arsenic and chromium by clay minerals and free iron oxides present in the alluvial sediments.

The goal of the groundwater transport analysis will be to quantify ash-related constituent concentrations and mass loadings entering the reservoir via groundwater seepage from source areas. These predictions would subsequently be used in evaluating long-term risks to human and aquatic receptors. The constituents of concern (COCs) selected for modeling purposes are arsenic, mercury, chromium, selenium, radium-226, and thorium-228. These constituents are naturally-occurring metals and radionuclides that have been concentrated in the ash through the coal combustion process. These COCs are representative of the primary constituents in ash that have been shown to contribute to potential risk to human or ecological receptors exposed to environmental media within the river system. These COCs will be specifically modeled to predict future mass loadings of these constituents and to represent the fate and transport behavior of other ash-related constituents.

2. MODEL DOMAIN

Groundwater transport modeling of ash-related constituents to adjacent streams under post-closure conditions will encompass the area indicated on Figure C-1. Boundaries of the model domain generally follow natural hydrologic boundaries, including Pine Ridge and the reservoir. These boundaries represent hydrologic divides across which no shallow groundwater flow occurs. Note that model boundaries representing the reservoir are assumed to lie along the approximate centerline of the channel (Figure C-1). Model cells falling within the reservoir, between the shoreline and the model boundary, will be assigned fixed hydraulic heads equal to the reservoir elevation. This will allow prediction of cell-by-cell inflow rates and COC concentrations for groundwater emerging through the reservoir bottom sediments. The western model boundary will follow an assumed groundwater streamline and represents another no-flow boundary condition. The upper boundary of the model (excluding areas of surface water) will be represented by flux boundary conditions to allow for groundwater recharge by precipitation within distinct subregions of the domain. These subregions will include the Ash Landfill, the Ash Processing Area, the elevated area associated with Pine Ridge, and other areas underlain by natural geologic media. No-flow conditions will be assigned to the lower model boundary.

Relevant hydrostratigraphic units represented in the model will include, in descending stratigraphic order: ash deposits, the alluvial clay-silt layer, the alluvial sand layer, residuum layer, Conasauga Shale and Rome Formation bedrock. Spatial variations in thickness of the ash and alluvial layers will be estimated from spatially interpolated lithologic data derived from existing and planned borings (Figure C-2). An arbitrary thickness of 50 to 100 ft will be assigned to bedrock in order to keep the lower model boundary

below the expected penetration depth of ash-related constituents. Small regions of soil fill material associated with the impoundment dikes and the perimeter dike foundation treatment zone may also be represented in the model if their hydraulic properties differ substantially from properties of adjacent alluvial layers. The horizontal and vertical components of hydraulic conductivity and porosity of media represented in the model will be determined from existing and planned measurements, as discussed below and summarized in the Sampling Analysis Plan (SAP).

The model boundaries will be refined once field investigations are completed and data are evaluated. The sensitivity of the model to the location of this boundary will be evaluated during the early stages of flow model development to evaluate potential errors in location of model boundaries. Analyses will focus on positions of the hydrologic divides along Pine Ridge and the no-flow boundary along the southwestern boundary, as these boundaries affect the recharge area and therefore the overall groundwater flow beneath the closed ash landfill. Actual model boundaries will remain fixed as model sensitivity is evaluated to non-zero fluxes across specific boundaries. The magnitude of boundary fluxes will be determined on the basis of long-term average recharge computed for the area between the actual and hypothetically repositioned model boundaries.

The stratigraphy of the ash deposits, alluvium, residuum and bedrock within the groundwater model domain will be characterized using existing information from approximately 175 borings in the Ash Landfill vicinity. A minimum of two additional boreholes will be completed on Pine Ridge, three within the Ash Landfill, and one southwest of the Ash Processing Area (Ball Field) (Figure C-2) to characterize overburden lithology, thickness, and top of bedrock elevation. These boreholes will extend from the surface at least down to the top of bedrock. The boreholes will be converted to either permanent monitoring wells or temporary well points. Porosity, density, and moisture content will be characterized by taking undisturbed samples of residuum and alluvium (both clay-silt and sand facies).

The hydraulic conductivity (or permeability) will be characterized for ash deposits, alluvial clay-silt unit, alluvial sand unit, residuum, and shale and limestone of the Lower Conasauga Shale bedrock. In situ horizontal hydraulic conductivity (K_h) tests will be performed using one or more of the following methods: single- or multiple-well pumping tests, slug tests, or borehole flowmeter tests. The emphasis will be on Kh measurements since horizontal seepage is expected to be the dominant mode of contaminant transport. The following hydraulic conductivity data will be collected.

- Ash deposit permeabilities will come from approximately 47 existing hydraulic conductivity measurements available for samples from the KIF site. No further data will be required.

- Alluvial clay-silt unit permeabilities will come from a mixture of 14 previously published site values (8 for K_h, 6 for K_v), and borehole flow metering results (for K_h) of three newly installed well points/temporary wells (TWP-04, TWP-05, and TWP-06) at sites within the Dredge Cell/Ash Pond in the GW model domain (Figure C-3).

- Alluviual sand unit permeabilities will come from a mixture of 8 previously published site values (5 for K_h, 3 for K_v), and borehole flow meter testing (for K_h) of 4 newly installed temporary well points (TWP-04, TWP-05, TWP-06, and TWP-22) at sites both within the Dredge Cell/Ash Pond in the GW model domain and southwest of the Ash Processing Area adjacent to the GW model domain (Figure C-3).

- Residuum hydraulic conductivity values will come from aquifer testing on existing upgradient well AD1; existing downgradient wells AD2, 6AR, and 22; the new upgradient residuum well (GW-02), a new temporary well point TWP-22 (Figure C-3); aquifer tests (for K_h) will be performed at each well

and one undisturbed soil sample will be collected from the new upgradient well (GW-02) for laboratory analysis of K_v.

– Bedrock hydraulic conductivity values will come from previously published site values (3 for Kh) and planned aquifer testing of five new wells – two new upgradient bedrock wells (GW-01 and GW-03) on Pine Ridge (Figure C-3) by single-well pump testing and three new temporary well points (TWP-24, TWP-25, and TWP-26) (Figure C-3) by aquifer "slug" testing.

3. GROUNDWATER FLOW AND TRANSPORT CODES

The Visual MODFLOW (VMOD) suite of coupled numerical groundwater flow and transport codes (Schlumberger Water Services, http://www.swstechnology.com/) will be used for the analysis of groundwater transport of ash-related constituents to the reservoir. VMOD includes the widely-applied MODFLOW code developed by the U.S. Geological Survey (McDonald and Harbaugh 2000) for simulating three-dimensional saturated groundwater flow. MODFLOW will be used to estimate the three-dimensional groundwater velocity field required for contaminant transport simulations. For transport simulations, one of the multispecies reactive groundwater transport codes supported by VMOD (e.g., PHT3D or RT3D) will be used. In addition, the U.S. Environmental Protection Agency's Hydraulic Evaluation of Landfill Performance (HELP) hydrologic water budget model (Schroeder et al. 1994) will be used for estimating groundwater recharge rates by precipitation over various subregions of the model domain.

4. FLOW MODEL CALIBRATION

The groundwater flow model will be calibrated to current local head field using snapshots of water levels in wells, temporary well points, piezometers, and surface water reference points (Figure C-4). Four new wells and nine new temporary well point installations will be completed for augmenting existing locations. Water level measurement locations will therefore include 4 surface water locations, 60 coal ash locations, 88 alluvium locations, 4 residuum locations, and 14 bedrock locations, as shown on Figure C-4. Two KIF site-wide temporal snapshots of water levels will be conducted: once during the higher precipitation period (February-April) and once during the lower precipitation period (August-October) to encompass the range of expected water levels.

Natural upward seepage is expected from the bedrock aquifer to the alluvial aquifer and ultimately to the river. The direction and magnitude of upward vertical gradients will be confirmed by measuring water levels (hydraulic heads) in five existing paired piezometers and three new paired temporary well points, screened separately in bedrock and alluvial aquifers. Pressure transducers with data recorders are to be installed in each well to allow for continuous measurements for at least one month. The frequency of monitoring thereafter will depend on the initial monitoring results.

The purpose of flow model calibration is to verify that the flow model is capable of reproducing the measured hydraulic head field with reasonable accuracy. Calibration accuracy will be presented in terms of the sum of squared errors and error distribution relative to areas of model sensitivity. The calibration process will allow for adjustments in layer hydraulic conductivities and/or recharge rates within the range of measured values in order to achieve a reasonable match between observed and predicted heads. Calibration will be performed using either parameter optimization methods (e.g., the PEST code developed by Doherty 2004) or manual trial-and-error parameter adjustments, if required adjustments are considered minor.

Calibration will require prior estimation of current groundwater recharge rates of model subregions using the HELP code. HELP estimation of subregion recharge rates for flow model calibration and for later

post-closure simulations will require subregion media thicknesses (between ground surface and water table), unsaturated hydraulic properties of relevant media, and long-term meteorological data. Average thicknesses of media beneath each subregion will be estimated from (1) spatially interpolated lithologic data based on existing and planned borings, and (2) the spatially interpolated water table derived from groundwater level measurements in wells and piezometers. Required unsaturated hydraulic parameters include field capacity, wilting point, and initial moisture content. Field capacity and wilting point values for ash are available from previous KIF studies (e.g., Boggs and Julian 2004). Values for other geologic media will be estimated from the literature for soils having similar grain-size characteristics. Initial moisture content inputs will be estimated from soil test boring measurements available for ash deposits, soil fill, and natural alluvial and residual soils. Historical daily precipitation data recorded at the Tennessee Valley Authority's gauging station 0712, located at the KIF plant, will be used in estimating average recharge rates under current conditions for each model subregion. Corresponding daily temperature and solar radiation data will be internally generated by HELP from site latitude and measured daily rainfall. Meteorological data requirements for estimating subregion recharge rates for post-closure conditions will be handled in a similar manner. Surface boundary flux will be considered as another calibration variable.

5. TRANSPORT SIMULATIONS

Transport simulations will be performed for two hydrologic scenarios using the coupled three-dimensional flow and transport codes. These simulations will be simplified by running a steady-state simulation of the groundwater flow field for each hydrologic scenario. The steady-state representation of the flow field will then be coupled with a transient simulation of reactive contaminant transport. The first hydrologic scenario will simulate worst-case hydrologic conditions, resulting in maximum groundwater flow and contaminant flux toward the reservoir. To produce these conditions, normal winter pool reservoir elevation will be assigned to the reservoir model boundaries, and winter recharge rates will be applied to the upper model boundary. Under the second hydrologic scenario, long-term average surface recharge and reservoir stage conditions will be applied to the flow model to produce average rates of groundwater flow and contaminant flux to the reservoir.

An important aspect of transport model development involves representation of changes in groundwater chemical characteristics, as ash deposits are continually leached by infiltrating precipitation and/or lateral groundwater flow. Mathematical relationships (e.g., an exponential decay function) will be used to describe ash constituent leaching behavior. Leaching functions for each modeled COC will be assigned as concentration boundary conditions in regions of the model occupied by ash. In order to define the leaching functions, sequential batch extractions and/or column leaching tests will be performed on ash samples and ash composite samples. A total of eight ash samples will be collected; six of the ash samples will be collected within the Ash Landfill area; the remaining two ash samples will be collected from the Ash Processing Area (Figure C-5). Results of the leaching tests will be used to quantify COC concentration variations as a function of leaching expressed in pore volumes. Relationships between concentration and leaching pore volumes will be developed for each modeled COC.

Key geochemical parameters, including the solubility-controlling minerals of relevant geologic units, and measures of their adsorption and ion-exchange capacities, are required for groundwater transport model development. Both historical and planned measurements of geochemical parameters will be used to characterize the attenuative capacity of the alluvium and residuum soils. Site-specific geochemical data are currently available for three alluvial clay-silt samples, two alluvial sand samples, and two residual soil samples. Nine additional soil samples will be collected from the Ash Landfill area for laboratory analysis: four samples of alluvial clay-silt and five samples of alluvial sand (Figure C-6). Samples will be analyzed for mineral composition, cation exchange capacity, exchangeable cations, free iron oxide, calcite equivalent, soluble salts, and soil pH.

Regions of the model representing ash deposits, including the Ash Landfill, the Ash Processing Area, and ash deposits beneath the Stilling Pond, may be treated as distinct source areas. Ash was deposited in each of these areas at different times and in some cases by different methods. Differences in ash handling methods and age could result in groundwater in contact with the ash having different chemical characteristics. The need for treating these three areas of ash deposits separately in the model will be determined on the basis of sampling of groundwater in contact with the ash to measure constituent concentrations for the areas. If analytical results for the three areas are markedly different, then relationships would be developed separately for each area. Otherwise, one set of leaching relationships would be developed for the ash.

The aqueous phase constituent concentrations/radioactivities in groundwater in contact with the ash will be characterized by collecting samples from 18 new well points/temporary wells completed in coal ash deposits (Figure C-7). Samples will be filtered in-line and analyzed for total analyte list (TAL) metals, including mercury, radionuclides, major and minor ions, ammonia-N, total suspended solids (TSS) and total dissolved solids (TDS), and field parameters, as described in the SAP.

Initial conditions for the transport model include the aqueous phase concentrations of geochemically-relevant constituents, not only for the groundwater in contact with the ash, but for groundwater initially present in each geologic unit through which the groundwater migrates. Aqueous phase concentrations/radioactivities will therefore be measured in alluvial, residual and bedrock aquifers for use as initial transport model conditions. A minimum of 19 groundwater samples will be collected from existing and new wells and/or temporary well points (Figure C-7); samples will be filtered in-line and analyzed for TAL metals, including mercury, radionuclides, major and minor ions, ammonia-N, TSS and TDS, and field parameters, as described in the SAP.

Simulation of three-dimensional transient transport might prove infeasible due to excessive simulation run times or numerical stability/convergence issues arising from the large overall dimensions of the model, refined gridding required for transport simulations, and the expected duration of contaminant transport to the reservoir. In this case, it would be necessary to reduce transport simulations to a series of two-dimensional vertical profile models. Profile models would follow a limited number of groundwater streamlines representing a range of transport conditions between source areas and the reservoir. Estimates of groundwater contaminant flux rates entering the reservoir would be provided for each profile model. These results, together with groundwater flux rates entering reservoir over the entire discharge boundary (obtained from the three-dimensional flow model), would allow interpolation of the contaminant flux distribution for the entire groundwater discharge boundary.

Predicted concentrations of modeled COCs in groundwater discharging to the reservoir bottom sediments will ultimately be used in evaluating potential impacts to benthic organisms. Similarly, predicted concentrations of modeled COCs in the reservoir, after mixing of groundwater COC mass loadings under low-flow or stagnant conditions, will be used to assess potential aquatic ecosystem and human health impacts. Presentation of the model results will include a description of uncertainties, including the potential error in the flow model and its impact on transport model results.

6. REFERENCES

Boggs, J.M. and H.E. Julian, 2004, *Hydrogeologic Evaluation of Proposed Coal-Combustion By-Product Disposal Area Expansion*, TVA Report No. WR2004-2-36-130.

Doherty, J., 2004, *PEST: Model Independent Parameter Estimation*. Watermark Numerical Computing, Brisbane, Australia.

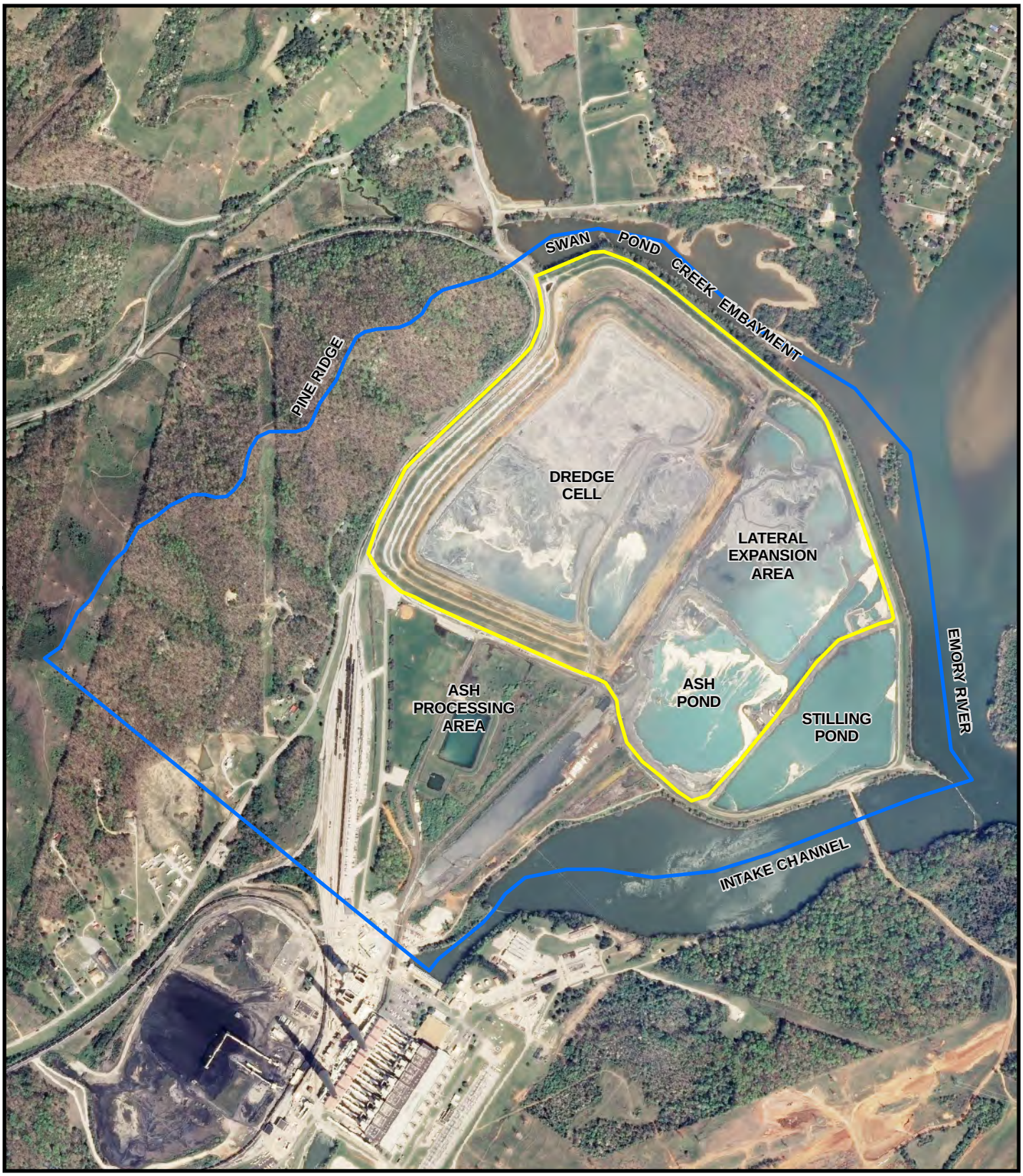
McDonald and Harbaugh, 2000, MODFLOW-2000 Version 1.18.01, Groundwater modeling software available at http://water.usgs.gov/nrp/gwsoftware/modflow2000/modflow2000.html.

Schlumberger Water Services 2010, Visual MODFLOW, Groundwater modeling & environmental software available at http://www.swstechnology.com.

U.S. Environmental Protection Agency 1994, *Hydrologic Evaluation of Landfill Performance Model (HELP)*: Engineering Documentation for Version 3, authored by Schroeder, P. R., T. S Dozier, P. A. Zappi, B. M. McEnroe, J. W. Sjostrom, and R. L. Peyton.

FIGURES

Figure C-1. Groundwater Model Domain



Date of map imagery:
April 17, 2008

Ash Landfill
Groundwater Model Boundary

N

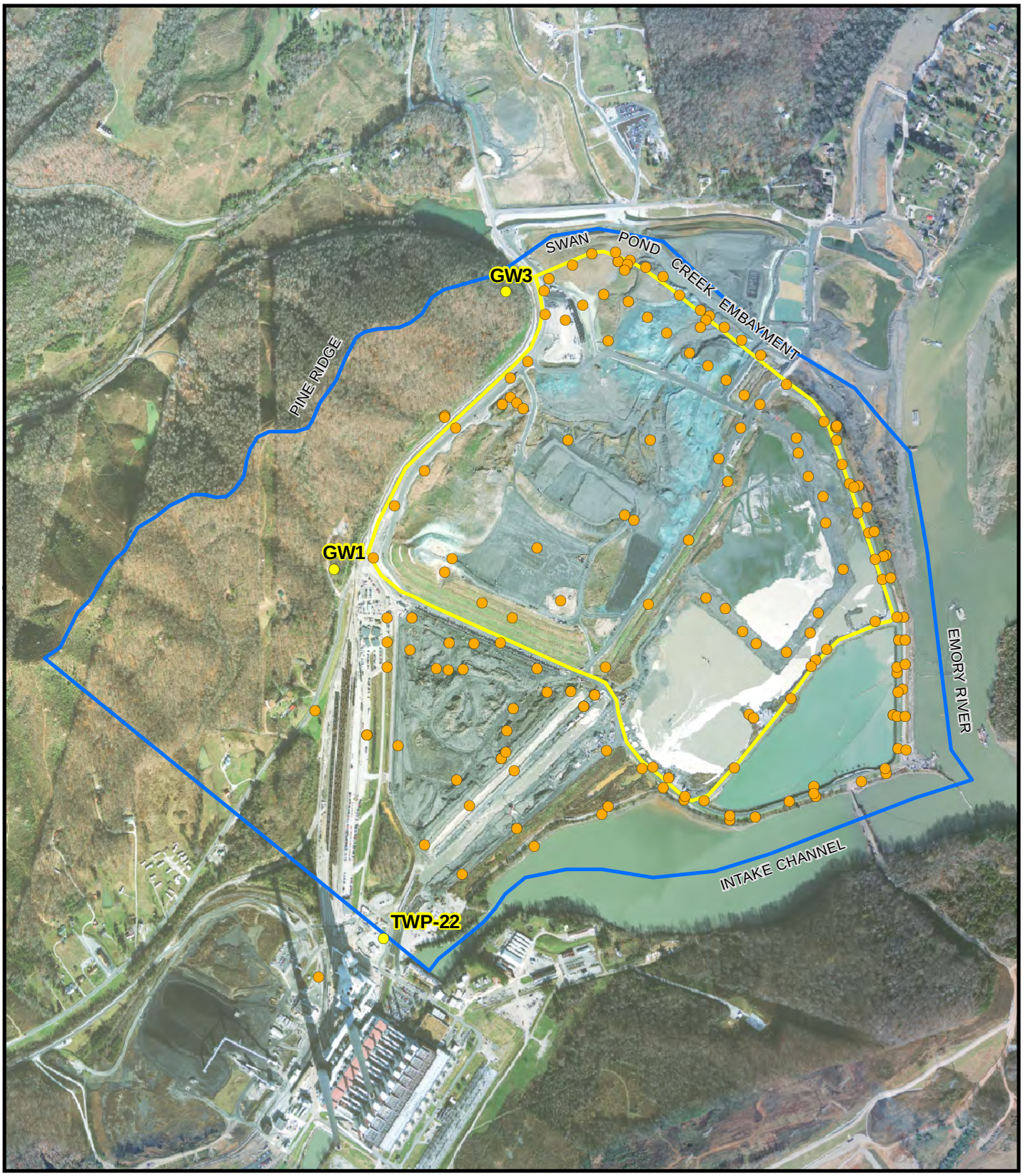
0 500 1,000 1,500 Feet

Map compiled: 01/26/2010

Tennessee Valley Authority
E&T – Environmental Resources
Geographic Information & Engineering

File Name:
GroundWater_Fig1_GeneralModel_20100114_8x11_r1.pdf

Figure C-2. Stratigraphic Boring Locations



Existing Boring Location
Proposed Boring Location *
Ash Landfill
Groundwater Model Boundary

Date of map imagery:
December 1, 2009

N

0 500 1,000 1,500 Feet

* Proposed locations are general guidelines subject to relocation based on factors in the field.

Map compiled: 01/27/2010

Tennessee Valley Authority
E&T – Environmental Resources
Geographic Information & Engineering

File Name:
GroundWater_Fig2_Stratigraphic_Boring_20100114_8x11_r1.pdf

Figure C-3. Hydraulic Conductivity Measurement Locations

- Alluvium (Clay-Silt) Kh
- Alluvium (Clay-Silt) Kv
- Alluvium (Sand) Kh
- Alluvium (Sand) Kv
- Bedrock Kh
- Alluvium Kh (Proposed) *
- Residuum Kh (Proposed) *
- Bedrock Kh (Proposed) *
- Ash Landfill
- Groundwater Model Boundary

Date of map imagery:
December 1, 2009

N

0 500 1,000 1,500 Feet

* Proposed locations are general guidelines and subject to relocation based on factors in the field.

Map compiled: 01/27/2010

Tennessee Valley Authority
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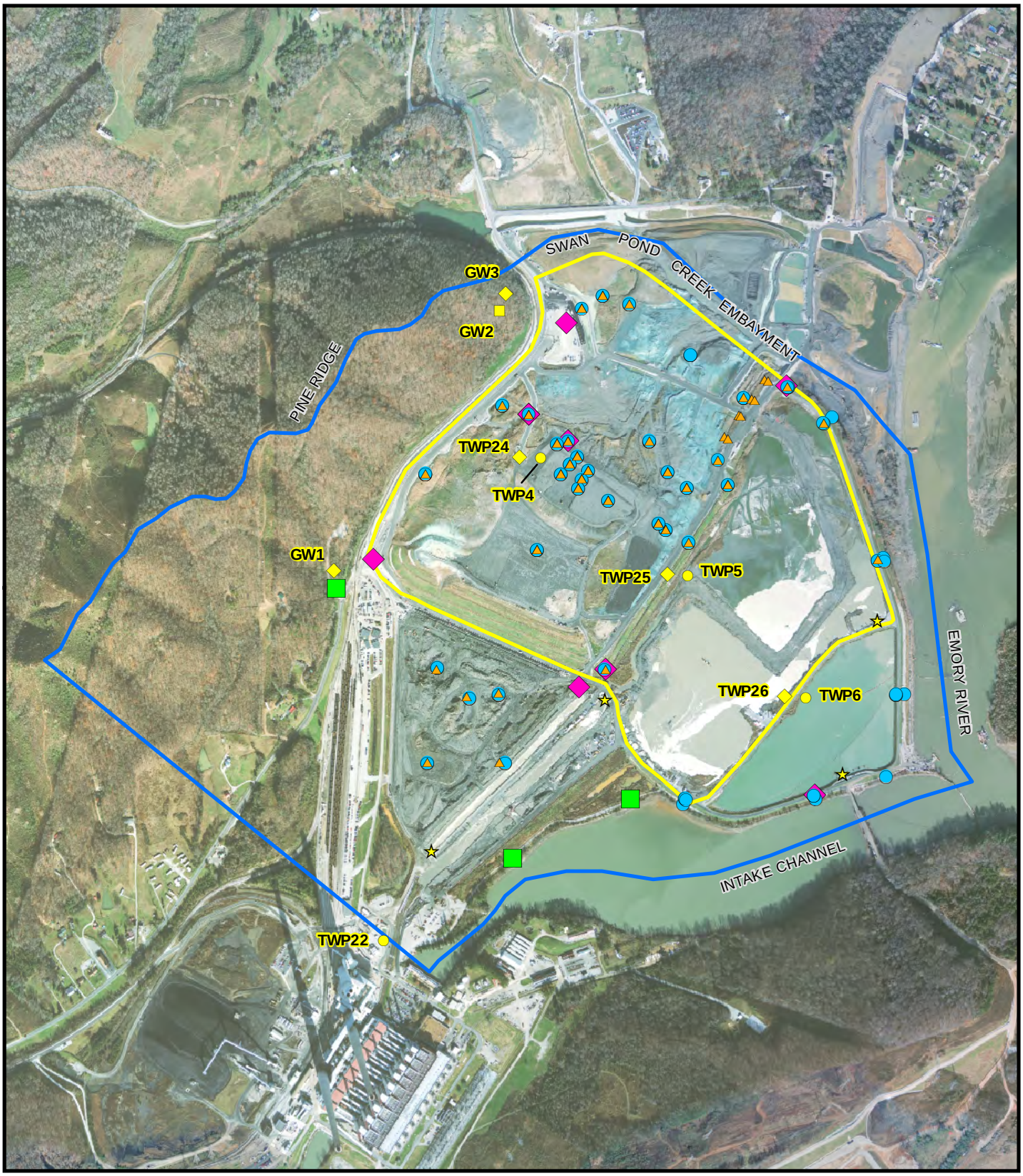
Geographic Information & Engineering

File Name:
GroundWater_Fig3_HydraulicConduct_20100114_8x11_r1.pdf

Figure C-4. Water Level Measurement Locations



Ash
Alluvium
Residuum
Bedrock
Alluvium (Proposed) *
Residuum (Proposed) *
Bedrock (Proposed) *
Surface Water (proposed) *
Closure Site
Groundwater Model Boundary

Date of map imagery:
December 1, 2009

N

0 500 1,000 1,500 Feet

* Proposed locations are general guidelines and subject to location based on factors in the field.

Map compiled: 01/27/2010

Tennessee Valley Authority
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File Name:
GroundWater_Fig4_WaterLevelMeasure_20100114_8x11_r1.pdf

Figure C-5. Column Leaching Test Sample Locations

Date of map imagery:
December 1, 2009

Ash Sample for Leaching Tests (Proposed) *
Ash Landfill
Groundwater Model Boundary

N

0 500 1,000 1,500 Feet

* Proposed locations are general guidelines subject to relocation based on factors in the field.

Map compiled: 01/26/2010

Tennessee Valley Authority
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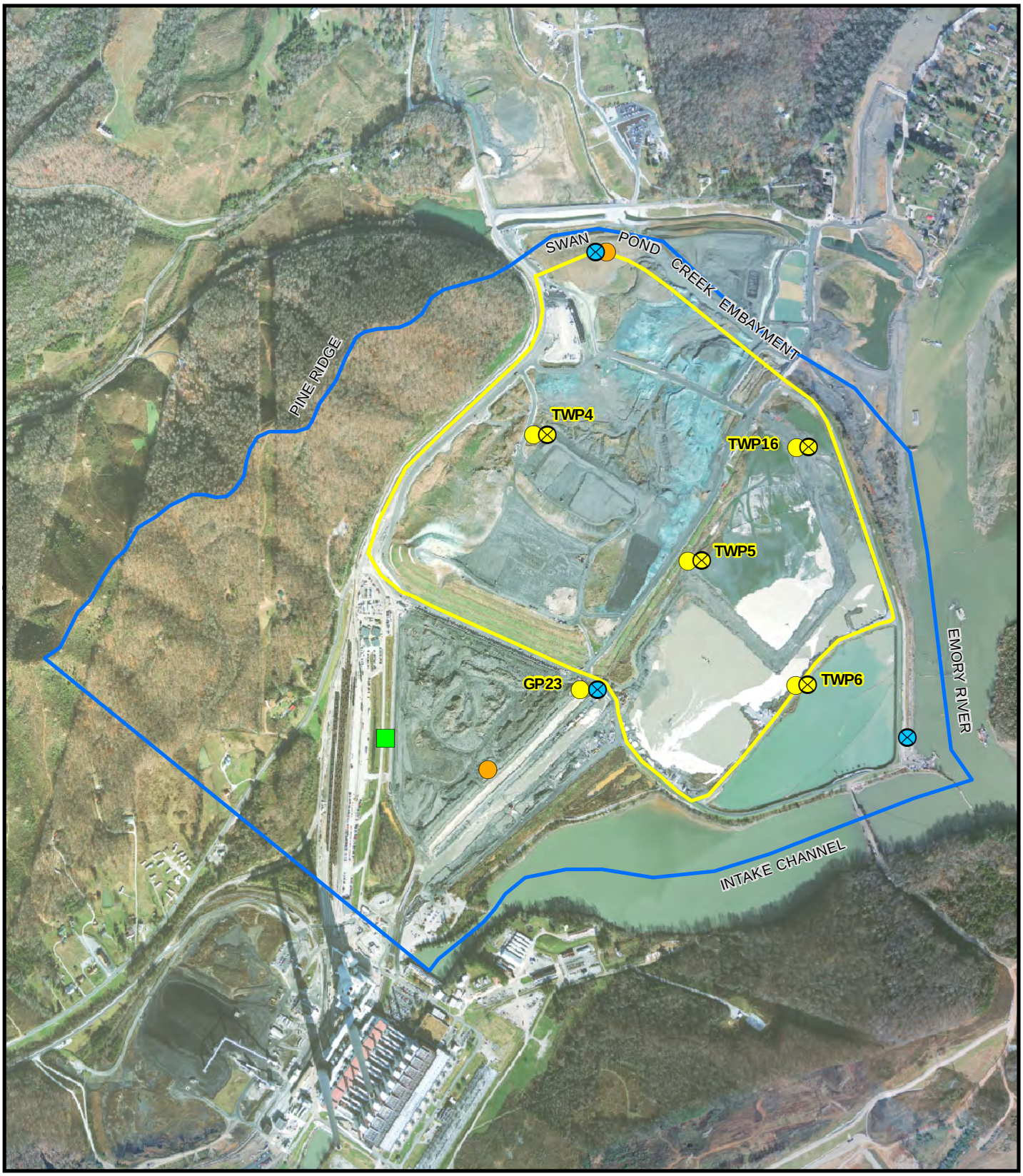
File Name:
GroundWater_Fig5_AshLeachateTesting_20100121_8x11_r1.pdf

Figure C-6. Geochemical Analysis Sample Locations



Alluvium (Cl/Si) Existing
Alluvium (Sand) Existing
Residuum Existing
Alluvium (Cl/Si) Proposed *
Alluvium (Sand) Proposed *
Ash Landfill
Groundwater Model Boundary

Date of map imagery:
December 1, 2009

N

0 500 1,000 1,500 Feet

* Proposed locations are general guidelines subject to relocation based on factors in the field.

Map compiled: 01/27/2010

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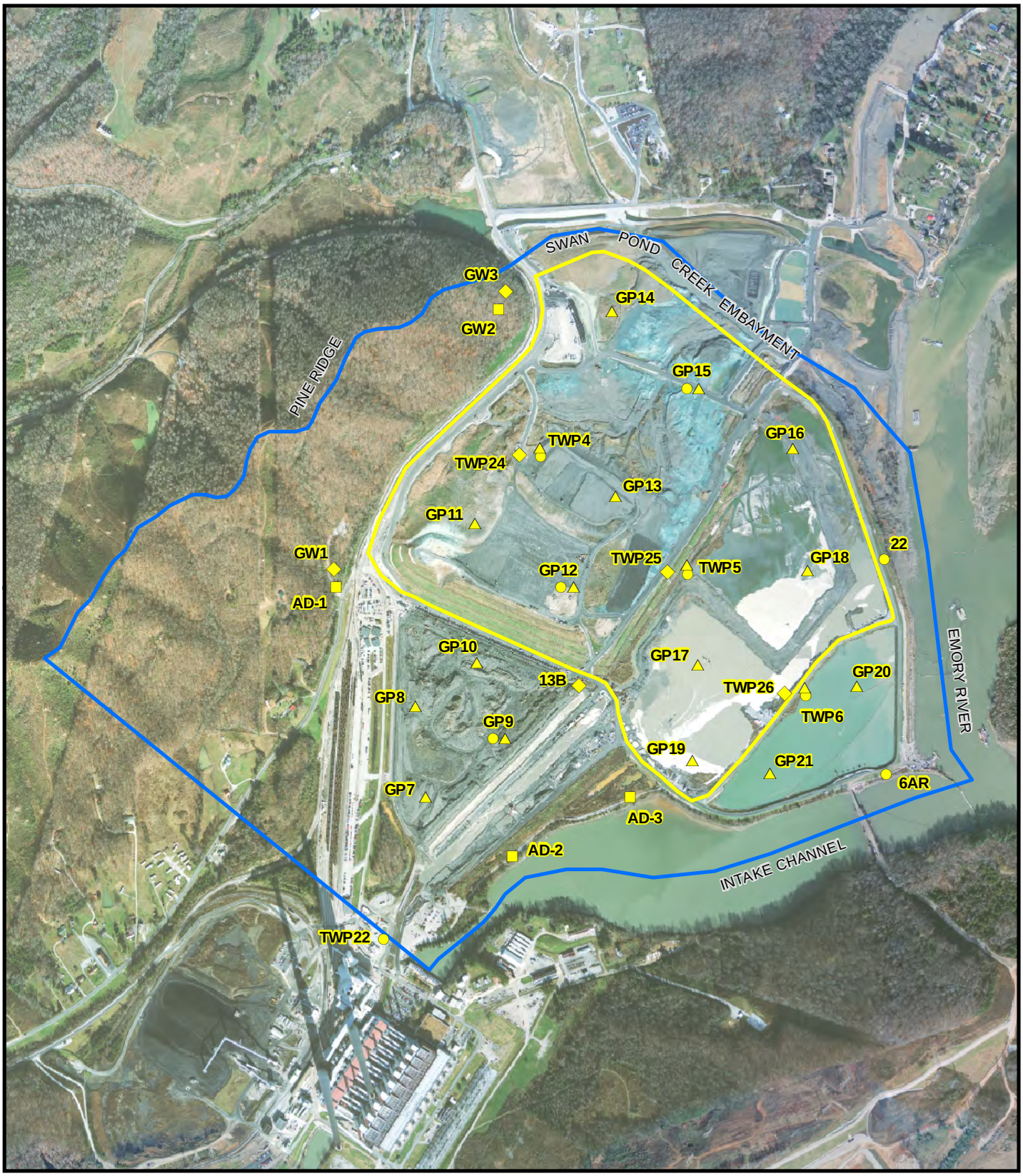
File Name:
GroundWater_Fig6_GeochemicalSampling_20100121_8x11_r1.pdf

Figure C-7. Aqueous Phase Concentration Sample Locations



Ash (Proposed) *
Alluvium (Proposed) *
Residuum (Proposed) *
Bedrock (Proposed) *

Ash Landfill
Groundwater Model Boundary

Date of map imagery:
December 1, 2009

N

0 500 1,000 1,500 Feet

* Proposed locations are general guidelines and subject to relocation based on factors in the field.

Map compiled: 02/10/2010

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File Name:
GroundWater_Fig7_AqueousPhaseConc_20100114_8x11_r1.pdf

Appendix D
Field Sampling Summary

Appendix D
Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Ash Deposit Sampling									
Emory River Reference Reach	10 locations upstream of ERM 6.0, 3 locations upstream of CRM 4.5, 3 locations upstream of TRM 568.0	16 samples	Ash/ Sediment	Vibracore	Visual observations PLM (field lab)	Field Observations None	None	None	**PLM** - 1 x 4-oz. jar
Emory Reach C	ERM 3.5 - ERM 6.0 - 10 1/4 mile transects, samples collected left-center-right in river channel	30 samples							
Emory Reach B (Channel)	ERM 1.5 - ERM 3.5 - 16 dredge grid sections with 2 samples per grid section	32 samples							
Emory Reach B (Non-channel)	ERM 1.5 - ERM 3.5 - 16 1/8 mile sections, samples collected left-right of channel, plus 10 samples targeting larger coves	32 samples							
Intake Channel	5 random locations collected similar to non-channel sections above	5 samples							
Emory Reach A	ERM 0.0 - ERM 1.5 - 12 1/8 mile sections, samples collected left-center-right of channel	36 samples							
Clinch Reach B	CRM 3.0 - CRM 4.5 - 12 1/8 mile sections, samples collected left-center-right of channel	36 samples							
Clinch Reach A	CRM 0.0 - CRM 3.0 - 12 1/8 mile sections, samples collected left-center-right of channel	36 samples							
Tennessee Reach B	TRM 566 - 568 - 8 1/2 mile sections, samples collected left-center-right of channel	12 samples							
Tennessee Reach A	TRM 550 - 566 - 4 sections, every 5 miles; samples collected left-center-right of channel	12 samples							
Small coves	Selected small coves or anomalies	21 samples							
Confirmatory PLM	10% or samples sent to fixed lab for PLM	26 samples			PLM (fixed lab)	EPA-600/M4-82-020	None	None	**PLM** - 1 x 4-oz.

Appendix D
Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Seasonally-Exposed Sediment Sampling									
Emory Reference Reach	Upstream of ERM 6.0 in the Emory River, collected randomly along shoreline	5 samples	Ash/ Sediment	Hand Auger/ Vibracore	Visual observations PLM (field lab) Metals	**PLM** - EPA-600/M4-82-020 **Metals/Hg** - SW-846 6010B/6020/7470A	**PLM** - none **Metals** - 180 days **Hg** - 28 days	**PLM** - none **Metals/Hg** - none	**PLM** - 2 x 4-oz. jars (1 field lab, 1 fixed lab) **Metals/Hg** - 1 x 16-oz. jars **Radionuclides** - 2 x 16-oz. jars
Emory Reach C	ERM 3.5 - ERM 6.0 - 10 locations, 4 per mile alternating left-right bank	10 samples							
Emory Reach B	ERM 1.5 - ERM 3.5 - 16 locations, 8 per mile alternating left-right bank	16 samples							
Intake Channel	2 random locations	2 samples							
Emory Reach A	ERM 0.0 - ERM 1.5 - 12 locations, 8 per mile alternating left-right bank	12 samples							
Clinch Reach B	CRM 3.0 - CRM 4.5 - 12 locations, 8 per mile alternating left-right bank	12 samples							
Clinch Reach A	CRM 0.0 - CRM 3.0 - 12 locations, 4 per mile alternating left-right bank	12 samples							
Radionuclides, Legacy Constituents, and Chemical Speciation Samples	Random selection of 25% of above locations	18 samples			Radionuclides (K-40, RA 226/228, iso-Th, iso-U, Cs-137, Co-60) PAHs (parent & alkylated) PCBs Pesticides Metals speciation (As, Se, Hg, Cr)	**Radionuclides** - 901.1 Gamma Spectroscopy, EPA 903.1 Ra-226, EPA 904 Ra-228, EML HASL-300 Iso Th, Iso U **PAHs** - SW-846 8270 SIM **PCBs** - SW-846 8082 **Pest** - SW-846 8081A **Cr**VI- SW846 3060A/7199 **As, Se, Hg** - Lab SOPs	**Radionuclides** - 180 days **PAHs, PCBs, Pest** - 14 days prep, then 40 days to analysis **CrVI**- 24 hours **As, Se, Hg** - Lab SOP	**Radionuclides** - none **PAHs, PCBs, Pest** - cool <6°C **CrVI** - cool <6°C	**Radionuclides** - 2 x 16-oz. jars **PAHs, PCBs, Pest, Metals** - 2 x 16-oz. jar
Confirmatory PLM	Random selection of 10% of above locations	7 samples			PLM (fixed lab)	EPA-600/M4-82-020	None	None	**PLM** - 1 x 4-oz. jar

Appendix D
Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Submerged Sediment Sampling									
Reference Locations (Emory, Clinch, Tennessee Rivers)	3 locations upstream of ERM 6.0, 3 locations upstream of CRM 4.5, 3 locations upstream of TRM 568.0	9 samples	Ash/ Sediment	Hand Auger/ Vibracore	Visual observations and PLM (included in ash deposit sampling) Metals	**Metals** - SW-846 6010B/6020/7470A	**Metals** - 180 days	**Metals** - none	**Metals** - 1 x 16-oz. jars
Emory Reach C	ERM 3.5 - ERM 6.0 - 10 locations, 4 per mile	10 samples							
Emory Reach B	ERM 1.5 - ERM 3.5 - 16 locations, 8 per mile	16 samples							
Intake Channel	2 random locations	2 samples							
Emory Reach A	ERM 0.0 - ERM 1.5 - 12 locations, 8 per mile	12 samples							
Clinch Reach B	CRM 3.0 - CRM 4.5 - 12 locations, 8 per mile	12 samples							
Clinch Reach A	CRM 0.0 - CRM 3.0 - 12 locations, 4 per mile	12 samples							
Tennessee Reach B	TRM 566 - 568 - 4 locations, 2 per mile	4 samples							
Tennessee Reach A	TRM 550 - 566 - 4 locations, every 5 miles	4 samples							
Radionuclides, Legacy Constituents, and Chemical Speciation Samples	Random selection of 25% of above samples	20 samples			Radionuclides (K-40, Ra-226/228, iso-Th, iso-U, Cs-137, Co-60) PAHs (parent & alkylated) PCBs Pesticides AVS/SEM Metals speciation (As, Se, Hg, Cr) TOC	**Radionuclides** - 901.1 Gamma Spectroscopy, EPA 903.1 Ra-226, EPA 904 Ra-228, EML HASL-300 Iso Th, Iso U **PAHs** - SW-846 8270 SIM **PCBs** - SW-846 8082 **Pest** - SW-846 8081A **AVS/SEM** - EPA-821-R-91-100 (draft) **CrVI** - SW-846 3060A/7199, **As, Se, Hg** - Lab SOP **TOC** - SW-846 9060/Lloyd Kahn/ASTM D2974	**Radionuclides** - 180 days **PAHs, PCBs, Pest** - 14 days prep, then 40 days to analysis **AVS/SEM** - 14 days **CrVI**- 24 hours **As, Se, Hg** - Lab SOP **TOC** - 14 days	**Radionuclides** - none **PAHs, PCBs, Pest** - cool <6°C **AVS/SEM** - cool <6°C **CrVI** - cool <6°C **TOC** - pH <2 HCl, cool <6°C	**Radionuclides** - 2 x 16-oz. jars **PAHs, PCBs, Pest, TOC**- 2 x 16-oz. jar **AVS/SEM** - Lexan liner/4-oz glass (zero headspace) **Metals** - 1 x 8-oz. jar **TOC** - 2 x 40-mL glass vial

Appendix D
Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Submerged Sediment Sampling									
Reference Locations	Upstream Emory River > ERM 6.0	2 samples	Ash/ Sediment	Ponar Sampling Device	PAHs (parent & alkylated) PCBs Pesticides Metals Radionuclides (K-40, Ra-226/228, iso Th, iso U, Cs-137, Co-60) AVS/SEM EPA tox test parameters (e.g, TOC, grain size) Sequentially-extracted metals	**PAHs** - SW-846 8270 SIM **PCBs** - SW-846 8082 **Pest** - SW-846 8081A **Metals** - SW-846 6010B/6020/7470A **Radionuclides** - 901.1 Gamma Spectroscopy, EPA 903.1 Ra-226, EPA 904 Ra-228, EML HASL-300 Iso Th, Iso U **AVS/SEM** - EPA-821-R-91-100 (draft) **TOC** - SW-846 9060/Lloyd Kahn/ASTM D2974 **Grain size** - ASTM D 422 **Sequentially-extracted metals** - Querol et. al. (1999)	**PAHs, PCBs, Pest** - 14 days prep, then 40 days to analysis **Metals** - 180 days **Radionuclides** - 180 days **AVS/SEM** - 14 days **TOC** - 14 days **Grain size** - none	**PAHs, PCBs, Pest** - cool <6°C **Metals** - none **Radionuclides** - none **AVS/SEM** - cool <6°C **TOC** - none **Grain size** - none	**PAHs, PCBs, Pest, Metals, TOC** - 2 x 16-oz. jars **Radionuclides** - 2 x 16-oz. jars **AVS/SEM** - Lexan liner/4-oz glass (zero headspace) **Grain size** - 1 x 16-oz. jar
Emory Reaches A, B, C	ERM 0.0 - 1.5, ERM 1.5 - 3.5, ERM 3.5 - 6.0	8 samples							
Reference Locations	Upstream Clinch River > CRM 4.5	2 samples							
Clinch Reaches A, B	CRM 0.0 - 3.0, ERM 3.0 - 4.5	8 samples			*H. azteca* - 10, 28 day *C. dubia* - 7 day *C. tentans* - 10, 28 day	Inland Testing Manual, EPA 600/R-99/064 (Method 100.1) ASTM E 1706-05 (Annex A2) EPA-821-R-02-013	8 weeks	Cool <6°C	Minimum 6 x 5-gal buckets
Sediment Porewater Sampling									
Reference Locations	Upstream Emory River > ERM 6.0	2 samples	Sediment Porewater	Ponar Sampling Device or Vibracore	Metals (dissolved) DOC Hardness Major ions (chloride, sulfate) Alkalinity DO, pH, ORP, SC	**Metals** - SW-846 6010B/6020/7470A **DOC** - SM 5310B **Hardness** - EPA 200.7/200.8, SM 2340B **Major ions** - EPA 300 **Alkalinity** - SM 2320B **DO, pH, ORP, SC** - direct measurement	**Metals** - 180 days **Hg** - 28 days **DOC** - 28 days **Hardness** - 180 days **Major ions** -28 days **Alkalinity** - 14 days	**Metals/Hg** - filter then pH<2 HNO3 **DOC** - field filter, pH<2 H2SO4, cool <6°C **Hardness** - ph<2 HNO3, cool <6°C **Major ions** - cool <6°C **Alkalinity** - cool <6°C	**Metals/Hg** - 1 x 1-L HDPE **DOC** - 1 x 250-mL glass jar **Hardness** - 1 x 250-mL HDPE **Major ions** - 1 x 250-mL HDPE **Alkalinity** - 1 x 250-mL HDPE
Emory Reaches A, B, C	ERM 0.0 - 1.5, ERM 1.5 - 3.5, ERM 3.5 - 6.0	8 samples							
Reference Locations	Upstream Clinch River > CRM 4.5	2 samples							
Clinch Reaches A, B	CRM 0.0 - 3.0, ERM 3.0 - 4.5	8 samples							

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Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Surface Water Sampling									
Reference Locations (Emory, Clinch, Tennessee Rivers)	ERM 8.0, CRM 6.0, TRM 568.5 (adjust to correlate with reference sediments) - 3 locations x 2 depths x 8 weekly rounds	48 samples	Surface Water	Peristaltic pump	Metals (total/dissolved) TSS/TDS DOC Hardness DO, pH, ORP, SC, temp, turbidity	**Metals** - SW-846 6010B/6020/7470A; EPA 200.7/200.8/245.7 **TSS** - EPA 160.2 **TDS** - EPA 160.1 **DOC** - SM 5310B **Hardness** - EPA 200.7/200.8, SM 2340B **DO, pH, ORP, SC, temp, turbidity** - direct measurement	**Metals** - 180 days **TSS/TDS** - 7 days **DOC** - 28 days **Hardness** - 180 days	**Metals** - pH<2 HNO3 **TSS/TDS** - cool <6°C **DOC** - field filter, pH<2 H2SO4, cool <6°C **Hardness** - pH<2 HNO3 cool <6°C	**Total metals** - 1 x 1-L HDPE **Diss metals** - 1 x 1-L HDPE **TSS/TDS** - 1 x 1-L HDPE **DOC** - 1 x 250-mL glass jar **Hardness** - 1 x 250-ml HDPE
Emory River Locations	ERM 1.0, 2.0, 3.0, 4.0 (adjust to correlate with submerged sediments) 4 locations x 2 depths x 8 weekly rounds	64 samples							
Clinch River Locations	CRM 2.0, 3.5 (adjust to correlate with submerged sediments) 2 locations x 2 depths x 8 weekly rounds	32 samples							
Tennessee River Location	TRM 566 (adjust to correlate with submerged sediments) 1 locations x 2 depths x 8 weekly rounds	16 samples							
Radionuclides, and Chemical Speciation Samples	Random selection of 25% of above locations	40 samples			Radionuclides (K-40, Ra-226/228, iso-Th, iso-U, Cs-137, Co-60) Metals speciation (As, Se, Hg, Cr)	**Radionuclides** - 901.1 Gamma Spectroscopy, EPA 903.1 Ra-226, EPA 904 Ra-228, EML HASL-300 Iso Th, Iso U **Cr VI** - SW846 7199 **As, Se, Hg** - Lab SOP	**Radionuclides** - 180 days **Cr VI**- 28 days **As, Se, Hg** - Lab SOP	**Radionuclides** - none **Cr VI** - pH=9 NaOH, cool <6°C **As, Se, Hg** - Lab SOP	**Radionuclides** - 1 x 2.5-gal. cube **CrVI** - 1 x 500-mL HDPE **As, Se, Hg** - 1 x 1-L HDPE
Reference Bioassay Location (Emory River)	ERM 8.0 (adjust to correlate with reference sediments) - 1 location	1 sample			*C. dubia* - 7 day *P. promelas* - 7 day	Inland Testing Manual, EPA-821-R-02-013 (EPA Method 1000.0 and 1002.0)	36 hours to first use	Cool <6°C	5-gal cubitainers
Emory River Bioassay Locations	ERM 1.0, 2.0, 3.0, 4.0 (adjust to correlate with submerged sediments) 4 locations	4 samples							

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Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Groundwater Sampling and Aquifer Testing									
Water Level Measurements (Feb-Apr)	4 existing SW locations onsite 60 existing well points in ash 82 existing well points in alluvium 2 existing wells in alluvium 4 new well points in alluvium 3 existing wells in residuum 1 new well in residuum 8 existing well points in bedrock 3 new well points in bedrock 1 existing well in bedrock 2 new wells in bedrock	170 tests	Ground-water	Water Level Meter	Water level	Field Measurement	None	None	None
Water Level Measurements (Jul-Sep)		170 tests							
Vertical Gradient Measurements	8 paired well points	16 tests	Ground-water	Pressure tranducers	Hydraulic head	Field Measurement	None	None	None
Soil Porosity/ Density Tests	3 new well boreholes in residuum 3 new well point boreholes in alluvium (sand & clay) 2 boreholes in alluvium (sand & clay)	12 samples	Soil	Shelby Tubes	Dry bulk density Effective porosity Total porosity Moisture content	ASTM D 2937 ASTM D 4404-86 ASTM D 6836 ASTM D 2216	28 days	Sealed ends of sample tube, cool 4°C	Shelby tube
Hydraulic Conductivity Tests	2 new well boreholes in residuum	2 samples	Soil	Shelby Tubes	Vertical hydraulic conductivity	ASTM D 5126-90	None	Sealed ends of sample tube	Shelby tube
In-situ Hydraulic Conductivity Measurements	3 new well points in Dredge/Ash Pond Area -- alluvium (silt/clay and sand)	3 tests	Aquifer	Borehole flow meter test	Horizontal hydraulic conductivity	Field measurement	None	None	None
	AD-1, AD-2, 6AR, 22, TWP-22, and new upgradient residuum well GW-1	6 tests		Aquifer slug test			None	None	None
	3 new well points in Dredge/Ash Pond Area --bedrock	3 tests		Single well aquifer pump test					
	2 new upgradient bedrock wells	2 tests							
Column Leaching Tests	6 samples - ash landfill/stilling pond 2 samples - ash processing area	8 samples	Ash	Split barrel samplers	Column leaching test (As, Hg, Cr, Se, Ra-226, Th-228)	SW-846 Method 1314 (draft) ASTM D4793	None	None	2x16-oz. jars

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Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Groundwater Sampling and Aquifer Testing									
Soil Attenuation Capacity Tests	4 samples of alluvial clay/silt 5 samples of alluvial silty sand	9 samples	Soil	Shelby tube or split barrel sampler w/ liner	Mineral composition Free iron oxide CEC, exchangable cations, calcite equivalent, soluble salts, soil pH	**Mineral composition** - XRD and polarized light microscopy **Free Iron Oxide -** Chao and Zhou (1983) **CEC, exchangable cations, calcite equivalent, soluble salts, soil pH** - ASA 1996, Methods 14,15,16, and 40, or equivalent Lab SOP	28 days	Sealed ends of sample tube, cool <6°C	Shelby tube or split-barrel liner
Constituent Concentrations in Groundwater in Contact with Ash	18 boreholes/Geoprobes in ash	18 samples	Leachate	DPT or low-flow sampling	Metals (diss.) TSS, TDS Anions (chloride, fluoride, sulfate, nitrate-nitrite) Ammonia-N Radionuclides (diss.) (K-40, Ra-226/228, iso-Th, iso-U) Field parameters (pH, ORP, DO, SC, temperature)	**Metals -** SW-846 6010B/6020/7470A ; EPA 200.7/200.8/245.7 **TSS -** EPA 160.2 **TDS -** EPA 160.1 **Anions -** EPA 300 **Ammonia-N** - EPA 350.1 **Radionuclides -** EPA 901.1 Gamma Spec EPA 903.1 Ra-226, EPA 904 Rad-228, EML HASL-300 Iso Th, Iso U	**Metals** - 180 days **TSS/TDS** - 7 days **Anions** - 28 days **Ammonia-N** - 28 days **Radionuclides** - 180 days	**Metals** - pH<2 HNO3 **TSS/TDS/Anions** - cool <6°C **Ammonia** - pH<2 H2SO4, cool <6°C **Radionuclides** - none	**Metals** - 1 x 1-L HDPE **TSS/TDS** - 1 x 1-L HDPE **Anions** - 1 x 1-L HDPE **Ammonia** - 1 x 1-L HDPE **Radionuclides** - 1 x 2.5-gal. cube
Constituent Concentrations in Groundwater	6 existing wells 3 new wells 4 new well points in alluvium 3 new well points in bedrock 3 boreholes/Geoprobes in alluvium	19 samples	Ground-water	DPT or low-flow sampling	Metals (diss.) TSS, TDS Anions (chloride, fluoride, sulfate, nitrate-nitrite) Ammonia-N Radionuclides (diss.) (K-40, Ra-226/228, iso-Th, iso-U) Field parameters (pH, ORP, DO, SC, temperature)	**Metals -** SW-846 6010B/6020/7470A; EPA 200.7/200.8/245.7 **TSS -** EPA 160.2 **TDS -** EPA 160.1 **Anions -** EPA 300 **Ammonia-N** - EPA 350.1 **Radionuclides -** EPA 901.1 Gamma Spec EPA 903.1 Ra-226, EPA 904 Rad-228, EML HASL-300 Iso Th, Iso U	**Metals** - 180 days **TSS/TDS** - 7 days **Anions** - 28 days **Ammonia**-N - 28 days **Radionuclides** - 180 days	**Metals** - pH<2 HNO3 **TSS, TDS, Anions** - cool <6°C **Ammonia** - pH<2 H2SO4, cool <6°C **Radionuclides** - none	**Metals** - 1 x 1-L HDPE **TSS, TDS** - 1 x 1-L HDPE **Anions** - 1 x 1-L HDPE **Ammonia** - 1 x 1-L HDPE **Radionuclides** - 1 x 2.5-gal. cube **TSS, TDS** - 1 x 1-L HDPE

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Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Benthic Invertebrates Sampling									
Reference Locations	Emory River > ERM6.0, Clinch River near CRM 6.0; 3 composite samples per location; each of 3 taxon (snail, larval mayfly, adult mayfly)	18 samples	Benthos non-depurated	Ponar/ Peterson	Metals	**Metals** - SW-846 6010B/6020/7471A	**Metals** - 180 days **Hg** - 28 days	**Metals/Hg** - none	**Metals/Hg** - 1 x 8 - oz. jar (20 g min)
Emory Reaches A, B, C	ERM 1.0, 2.5, 4.0; 3 composite samples per location; each of 3 taxon (snail, larval mayfly, adult mayfly)	27 samples							
Clinch Reaches A, B	CRM 1.5, CRM 3.5; 3 composite samples per location; each of 3 taxon (snail, larval mayfly, adult mayfly)	18 samples							
Reference Locations	Emory River > ERM6.0, Clinch River near CRM 6.0; 3 composite samples per location; each of 2 taxon (snail, larval mayfly)	12 samples	Benthos depurated	Ponar/ Peterson	Metals	**Metals** - SW-846 6010B/6020/7471A	**Metals** - 180 days **Hg** - 28 days	**Metals/Hg** - none	**Metals/Hg** - 1 x 8 - oz. jar (20 g min)
Emory Reaches A, B, C	ERM 1.0, 2.5, 4.0; 3 composite samples per location; each of 2 taxon (snail, larval mayfly)	18 samples							
Clinch Reaches A, B	CRM 1.5, CRM 3.5; 3 composite samples per location; each of 2 taxon (snail, larval mayfly)	12 samples							
Reference Location transects	Emory River near ERM 6.0 Clinch River near CRM 6.0 Tennessee River near TRM 574.0; 10 samples/transect	30 samples	Benthos	Ponar/ Peterson	Biosurvey of Benthic Communities	Laboratory identification and enumeration	N/A	Formalin	pint and/or quart jars
Emory River biosurvey transects	ERM 1.0, 2.0, 3.0, 4.0, and 5.0; 10 samples/transect	50 samples							
Clinch River biosurvey transects	CRM 0.5, 1.5, 3.0, and 4.0; 10 samples/transect	40 samples							
Tennessee River biosurvey transects	TRM 560.8 and 566.5; 10 samples/transect	20 samples							

Appendix D
Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Fish Sampling									
Reference Locations (bass, bluegill, catfish)	Upstream Emory River near ERM 8.0 Upstream Clinch River near CRM 8.0; 3 species per reach; up to 6 replicates	36 samples	Non-Filet Portion of Fish	Electro-shock/ gill net	Metals Speciation (As) % Moisure % Lipids Pest/PCB - 25% of the samples	**Metals** - SW-846 6010B/6020/7471A **% Moisure -** Lab SOP **% Lipids -** Lab SOP **As speciation** - Lab SOP **PCBs** - SW-846 8082 **Pest** - SW-846 8081A	**Metals** - 180 days, **Hg** - 28 days **PCBs, Pest** - 14 days prep, then 40 days to analysis	frozen, dry ice	Plastic bag **Metals** - 20 g min **PCBs, Pest** - 20 g min
Emory Reaches A, B, C (bass, bluegill, catfish)	ERM 1.0, 2.5, 4.5; 3 species per reach; up to 6 replicates	54 samples							
Clinch Reaches A, B (bass, bluegill, catfish)	CRM 1.5, CRM 3.5; 3 species per reach; up to 6 replicates	36 samples							
Reference Locations (bass, bluegill, catfish)	Same as above; filet portion	36 samples	Filet Portion of Fish		Metals Speciation (As) % Moisture % Lipids Pest/PCB - 25% of the samples Radionuclides (K-40, RA 226/228, iso-Th, iso-U, Cs-137, Co-60) (25% of the filet samples)	**Metals** - SW-846 6010B/6020/7470A **% Moisure** - Lab SOP **% Lipids** - Lab SOP **As speciation** - Lab SOP **PCBs** - SW-846 8082 **Pest** - SW-846 8081A **Radionuclides** - 901.1 Gamma Spectroscopy, EPA 903.1 Ra-226, EPA 904 Ra-228, EML HASL-300 Iso Th, Iso U	**Metals** - 180 days **Hg** - 28 days **PCBs, Pest** - 14 days prep, then 40 days to analysis **Radionuclides** - 180 days	frozen, dry ice	Plastic bag **Metals** - 20 g min **PCBs, Pest** - 20 g min **Radionuclides** - 50 g min
Emory Reaches A, B, C (bass, bluegill, catfish)	Same as above; filet portion	54 samples							
Clinch Reaches A, B (bass, bluegill, catfish)	Same as above; filet portion	36 samples							
Reference Locations (gizzard shad, threadfin shad)	Upstream Emory River near ERM 8.0 Upstream Clinch River near CRM 8.0; 3 composite samples per reach; 2 species	12 samples	Whole Body Fish		Metals Speciation (As) % Moisture % Lipids Pest/PCB - 25% of the samples	**Metals** - SW-846 6010B/6020/7471A **% Moisure** - Lab SOP **% Lipids** - Lab SOP **As speciation** - Lab SOP **PCBs** - SW-846 8082 **Pest** - SW-846 8081A	**Metals** - 180 days, **Hg** - 28 days **PCBs, Pest** - 14 days prep, then 40 days to analysis	frozen, dry ice	Plastic bag **Metals** - 20 g min **PCBs, Pest** - 20 g min
Emory Reaches A, B, C (gizzard shad, threadfin shad)	ERM 1.0, 2.5, 4.0; 3 composite samples per reach; 2 species	18 samples							
Clinch Reaches A, B (gizzard shad, threadfin shad)	CRM 1.5, CRM 3.5; 3 composite samples per reach; 2 species	12 samples							
Reference Locations (biosurvey)	Use historical data only	none	Fish		Biosurvey of Fish Community	Field Observations	N/A	N/A	N/A
Emory Reach B (biosurvey)	ERM 1.5-3.5 1 survey per reach	1 survey							
Confluence Emory/Clinch (biosurvey)	Confluence of Emory and Clinch Rivers (ERM 0.0 to 1.0 and CRM 4.0 to 5.0)	1 survey							
Clinch Reaches A (biosurvey)	CRM 0.0-2.0 1 survey per reach	1 survey							

Appendix D
Field Sampling Summary

Sample Task	Sample Point	Approx Sample No	Matrix	Sampling Method/ Equipment	Required Analysis	Analytical Method	Holding Time	Sample Preservation	Containers
Wildlife Sampling									
Reference Locations (swallow)	Melton Hill Dam, Fort Loudon Dam; min. 10 replicates each site	20 samples	Tree Swallow egg/ nestling	Nest Robbing	Metals % Moisture	**Metals** - SW-846 6010B/6020/7471A **Moisture** - Lab SOP	**Metals** - 180 days **Mercury** - 28 days	frozen, dry ice	Plastic bag **Metals** - 20 g min
Emory River (swallow)	Near ERM 2.5 and ERM 3.0; min. 10 replicates each site	20 samples							
Clinch River (swallow)	Near CRM 1.0 and CRM 2.5; min. 10 replicates each site	20 samples							
Tennessee River (swallow)	Near TRM 566.0; min. 10 replicates each site	10 samples							
Reference Locations (heron)	TN River near TRM 569.5; up to 10 replicates each site	10 samples	Heron egg/ nestling						
Emory River (heron)	Near ERM 3.0; up to 10 replicates each site	10 samples							
Clinch River (heron)	Near CRM 2.5; up to 10 replicates each site	10 samples							
Aquatic Vegetation Sampling									
Reference Locations (emergent macrophytes)	Upstream of ERM 6.0, upstream of CRM 4.5, and upstream of TRM 568.0; 3 locations per reach; 2 samples per location (one of each plant type)	18 samples	Macro-phyte	Plant Clippings	Metals % Moisure	**Metals** - SW-846 6010B/6020/7471A **Moisture** - Lab SOP	**Metals** - 180 days **Hg** - 28 days	frozen, dry ice	Plastic bag **Metals** - 20 g min
Emory Reaches A, B, C (emergent macrophytes)	ERM 0.0-1.5, 1.5-3.5, 3.5-6.0; 3 locations per reach; 2 samples per location (one of each plant type)	18 samples							
Clinch Reaches A, B (emergent macrophytes)	CRM 0.0-3.0, 3.0-4.5; 3 locations per reach; 2 samples per location (one of each plant type)	12 samples							
Tennessee Reach B (emergent macrophytes)	TRM 566-568; 3 locations per reach; 2 samples per location (one of each plant type)	6 samples							
Reference Locations (periphyton)	Upstream of ERM 6.0, upstream of CRM 4.5; one location each reach; 3 composite samples per location	6 samples	Peri-phyton	Artificial Substrate	Metals % Moisure	**Metals** - SW-846 6010B/6020/7471A **Moisture** - Lab SOP	**Metals** - 180 days, **Hg** - 28 days	frozen, dry ice	Plastic bag **Metals** - 20 g min
Emory Reaches A, B, C (periphyton)	ERM 1.0, 2.5, 4.0; one location per reach; 3 composite samples per location	9 samples							
Clinch Reaches A, B (periphyton)	CRM 1.5, 3.5; one location per reach; 3 composite samples per location	6 samples							

Appendix E
Quality Assurance Project Plan Addendum

Appendix E
Quality Assurance Project Plan Addendum

The Kingston Ash Recovery Project has developed a comprehensive Quality Assurance Project Plan (QAPP) which governs the collection, analysis, reporting, and use of environmental data associated with the overall project. The QAPP (ESI 2009) has been approved by the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environmental Conservation and is available in the Administrative Record, available at http://www.tva.gov/kingston/admin_record/index.htm. The QAPP was prepared in accordance with EPA's *Guidance for Quality Assurance Project Plans*, EPA QA/G-5 (EPA 2002). The QAPP provides the framework for implementation of the environmental sampling to support both time-critical and non-time-critical removal actions, as needed. The QAPP addresses most of the required elements of a QAPP.

This addendum supplements the QAPP by providing task-specific information for the required elements that are not included in the approved QAPP (e.g., task-specific data quality objectives). Table E-1 provides a "cross-walk" that summarizes the document location where the task-specific QAPP-required elements may be found.

Task-specific sampling procedures are described in Section 5.0 of the River System Sampling and Analysis Plan (SAP). Details are specified in the Standard Operating Procedures (SOPs) listed in Table E-2.

Appendix C to the QAPP presents quality assurance requirements for aqueous matrices. For the SAP, aqueous matrices will include sediment porewater, surface water (mid-depth and epibenthic), and groundwater (both in contact with the ash and within the aquifer system). The following supplementary information is provided for the SAP:

- Sample containers, preservation, and holding times for aqueous samples are listed in Table C-1 in the QAPP. Task-specific sample containers, preservation, and holding times shown in Appendix D of the SAP, and take precedence over the QAPP.

- Analytes, methods, and target reporting limits are listed in Table C-2 in the QAPP. The requirements for dissolved organic carbon (DOC) are the same as for total organic carbon (TOC). The target reporting limits for metals speciation (arsenic, chromium, mercury, and selenium) are the same as for the Target Analyte List (TAL) metals. Target reporting limits are compared to human health and ecological screening values in Table E-3, as a check that the limits are adequate for use in risk assessment screening. Laboratory-specific SOPs will be followed for arsenic, chromium, mercury, and selenium speciation once the laboratory has been selected.

- Precision and accuracy objectives for quality control (QC) samples for aqueous matrices are listed in Table C3 of the QAPP. The requirements for DOC are the same as for TOC. The target reporting limits for metals speciation (arsenic, chromium, mercury, and selenium) are the same as for the TAL metals.

Appendix D to the QAPP presents quality assurance (QA) requirements for solid matrices. For the SAP, solid matrices will include ash deposits, seasonally-exposed sediment, submerged sediment, and geological formation soil. The following supplementary information is provided for the SAP:

- Sample containers, preservation, and holding times for solid samples are listed in Table D-1 in the QAPP. Task-specific sample containers, preservation, and holding times shown in Appendix D of the SAP, and take precedence over the QAPP.

- Analytes, methods, and target reporting limits are listed in Table D-2 in the QAPP. Task-specific analytical methods for solid matrices are shown in Appendix D of the SAP. Target reporting limits are shown in Table E-4 in this QAPP Addendum for those analytes not included in the QAPP. These target reporting limits are compared to human health and ecological screening values in Tables E-5 and E-6, as a check that the limits are adequate for use in risk assessment screening.

- Precision and accuracy objectives for QC samples for aqueous matrices are listed in Table D-3 of the QAPP. Task-specific objectives for solid matrices are shown in Tables E-7 and E-8 of this QAPP Addendum for those analytes not included in the QAPP.

Appendix G to the QAPP presents QA requirements for biological matrices. For the SAP, biological matrices will include benthic invertebrates (snails and mayflies), fish (largemouth bass, bluegill, channel catfish, gizzard shad, and threadfin shad), and birds eggs/hatchlings (tree swallow and heron). The following supplementary information is provided for the SAP:

- Sample containers, preservation, and holding times for solid samples are listed in Table G-1 in the QAPP. Task-specific sample containers, preservation, and holding times are shown in Appendix D of the SAP, and take precedence over the QAPP.

- Analytes, methods, and target reporting limits are listed in Table G-2 in the QAPP. Task-specific analytical methods for solid matrices are shown in Appendix D of the SAP. Target reporting limits are shown in Table E-9 in this QAPP Addendum for those analytes not included in the QAPP. These target reporting limits are compared to human health and ecological screening values in Table E-9, as a check that the limits are adequate for use in risk assessment screening.

- Precision and accuracy objectives for QC samples for aqueous matrices are listed in Table G-3 of the QAPP. Task-specific objectives for solid matrices are shown in Table E-10 of this QAPP Addendum for those analytes not included in the QAPP.

Table E-1. Quality Assurance Project Plan Cross-Walk

QAPP Element	Location in SAP	Location in SOPs
Data Quality Objectives	Appendix A: Data Quality Objectives for Environmental Media	
Sampling Design	Section 2.2: Study Design 2.2.1 Ash Deposits 2.2.2 Seasonally Exposed Sediment 2.2.3 Submerged Sediment 2.2.4 Sediment Porewater 2.2.5 Surface Water 2.2.6 Groundwater 2.2.7 Benthic Invertebrates 2.2.8 Fish 2.2.9 Wildlife	
Sampling Methods	Section 5.1 Field Sampling Procedures 5.1.1 Ash Deposits 5.1.2 Seasonally-Exposed Sediment 5.1.3 Submerged Sediment 5.1.4 Sediment Porewater 5.1.5 Surface Water 5.1.6 Groundwater 5.1.7 Benthic Invertebrates 5.1.8 Fish 5.1.9 Wildlife Appendix D: Field Sampling Summary	Applicable SOPs[1]
Sample Collection	Appendix D: Field Sampling Summary	Applicable SOPs[1]
Data Review and Validation (TVA-KIF-QAPP Section 21.0)	Appendix B: Baseline Ecological Risk Assessment Methodology Appendix C: Groundwater Transport Modeling Methodology	
Assessments and Response Actions (TVA-KIF-QAPP Section 19.0)		

Note:

[1]Applicable SOPs are referenced in the SAP and listed in Table E-2.

Table E-2. Standard Operating Procedures for the River System Sampling and Analysis

SOP Number	SOP Title
TVA-KIF-SOP-01	Surface Water Sampling
TVA-KIF-SOP-02	Groundwater Sampling
TVA-KIF-SOP-04	Soil Sampling for Inorganic Analysis
TVA-KIF-SOP-05	Sediment Sampling
TVA-KIF-SOP-06	Field Documentation
TVA-KIF-SOP-07	Sample Labeling, Packing, and Shipping
TVA-KIF-SOP-08	Decontamination of Equipment
TVA-KIF-SOP-09	Sediment Sampling For AVS/SEM Analysis
TVA-KIF-SOP-11	Field Quality Control Sampling
TVA-KIF-SOP-12	Management of Investigation-Derived Waste
TVA-KIF-SOP-13	Sample Retain Archive and Maintenance
TVA-KIF-SOP-14	Hydrolab Datasonde® Standardization and Field Parameter Measurement
TVA-KIF-SOP-15	Collecting and Processing Heron and Osprey Eggs
TVA-KIF-SOP-18	Management and Implementation of EQuIS-Based Chain-of-Custody
TVA-KIF-SOP-20	Ash Homogenization
TVA-KIF-SOP-29	Mayfly Sampling
TVA-KIF-SOP-30	Snail Sampling
TVA-KIF-SOP-31	Fish Sampling With Gill Nets
TVA-KIF-SOP-32	Fish Sampling With Seines
TVA-KIF-SOP-33	Fish Sampling - Boat-Mounted Electrofishing
TVA-KIF-SOP-35	Benthic Macroinvertebrate Community Sampling
TVA-KIF-SOP-39	Monitoring Well and Piezometer Well Installation and Completion
TVA-KIF-SOP-42	Slug Testing
TVA-KIF-SOP-43	Porewater Collection from Sediment and Ash

Table E-3. Comparison of Screening Levels for Inorganics and Radionuclides with Target Reporting Limits Aqueous Matrices

Analyte	CAS No.	QAPP Target Reporting Limit (ug/L)	Surface Water RBSL (ug/L or pCi/L)	Surface Water Basis	Groundwater RBSL (ug/L or pCi/L)	Groundwater Basis	Surface Water ESL Values (mg/L or pCi/L)	Source
Aluminum	7429-90-5	100	3,700	RBSL	3,700	RBSL	087.0	AWQC
Antimony	7440-36-0	2.0	1.5	RBSL	1.5	RBSL		
Arsenic	7440-38-2	2.0	0.018	AWQC, Consumption of Water and Organism	0.045	RBSL	150.0	AWQC
Barium	7440-39-3	10	730	RBSL	730	RBSL	NA	
Beryllium	7440-41-7	3.0	4	MCL	4	MCL	NA	
Boron	7440-42-8	10	730	RBSL	730	RBSL	NA	
Cadmium	7440-43-9	1.0	1.8	RBSL	1.8	RBSL	002.2	
Chromium	7440-47-3	2.0	100	MCL	100	MCL	011.0	AWQC
Cobalt	7440-48-4	2.0	1.1	RBSL	1.1	RBSL	NA	
Copper	7440-50-8	5.0	150	RBSL	150	RBSL	009.0	AWQC
Iron	7439-89-6	50	300	RBSL	2,600	RBSL	NA	
Lead	7439-92-1	2.0	5	Tennessee MCL	5	MCL	NA	
Manganese	7439-96-5	5.0	50	AWQC, Consumption of Water and Organism	88	RBSL	NA	
Mercury	7439-97-6	0.2	0.05	TWQC, Water and Organisms	0.057	RBSL	000.77	AWQC
Molybdenum	7439-98-7	5.0	18	RBSL	18	RBSL	NA	
Nickel	7440-02-0	5.0	73	RBSL	73	RBSL	052.0	AWQC
Selenium	7782-49-2	2.0	18	RBSL	18	RBSL	005.0	AWQC
Silver	7440-22-4	2.0	18	RBSL	18	RBSL	NA	
Thallium	7440-28-0	2.0	0.24	RBSL	0.24	RBSL	NA	
Vanadium	7440-62-2	4.0	18	RBSL	18	RBSL	NA	
Zinc	7440-66-6	50	7,400	AWQC, Consumption of Water and Organism	11,000	RBSL	120.0	AWQC
Cs-137		1.0	1.57	RBSL	1.57	RBSL	NA	
Co-60		1.0	3.03	RBSL	3.03	RBSL	NA	
K-40		1.0	1.93	RBSL	1.93	RBSL	NA	
Ra-226		1.0	0.000816	RBSL	0.000816	RBSL	NA	
Ra-228		1.0	0.0458	RBSL	0.0458	RBSL	NA	
Th-228		1.0	0.159	RBSL	0.159	RBSL	NA	

Table E-3. Comparison of Screening Levels for Inorganics and Radionuclides with Target Reporting Limits Aqueous Matrices
(continued)

Analyte	CAS No.	QAPP Target Reporting Limit (ug/L)	Surface Water RBSL (ug/L or pCi/L)	Surface Water Basis	Groundwater RBSL (ug/L or pCi/L)	Groundwater Basis	Surface Water ESL Values (mg/L or pCi/L)	Source
Th-232		1.0	0.471	RBSL	0.471	RBSL	NA	
U-234		1.0	0.674	RBSL	0.674	RBSL	NA	
U-235		1.0	0.663	RBSL	0.663	RBSL	NA	
U-238		1.0	0.547	RBSL	0.547	RBSL	NA	

Notes:

AWQC = Ambient Water Quality Criterion
CAS = Chemical Abstract Service
ESL = ecological screening level
mg/L = milligrams per liter
MCL = maximum contaminant level
NA = not available or applicable
pCi/L = picocuries per liter
RBSL = risk-based screening level
TWQC = Tennessee Water Quality Criterion
µg/L = microgram per liter

Table E-4. (QAPP Table D-2) Analytes, Methods, and Target Reporting Limits Solid Matrices

Sample Type(s)	Test Parameter / Physical Parameter	Test Method	Reporting Limit
Cell Ash Soil Bedrock	Bulk Density	ASTM D2937	0.1 pcf
	Effective Porosity	ASTM D4404-86	0.01%
	Total Porosity	ASTM D6836	0.01%
	Moisture Content	ASTM D2216	0.001%
	Vertical Hydraulic Conductivity	ASTM D5126-90	0.1 cm/sec
	Soil pH	ASTM D4972-01	0.1 pH units
	Polarized Light Microscopy	EPA-600/M4-82-020 or equivalent Lab SOP	4%
	Column Leaching	ASTM D4793	QAPP Table C-2
	Free Iron Oxide	Chao and Zhou (1983)	1%
	Cation Exchange Capacity Exchangable Cations Calicte Equivalent Soluble Salts	ASA 1996 Methods 14,15,16, or equivalent Lab SOP	1.0 meq/100 grams

Notes:

ASTM = American Society for Testing Materials
pcf = per cubic foot
cm/sec = centimeters per second
meq = milliequivalent

Table E-5. (QAPP Table D-2) Analytes and Target Reporting Limits Solid Matrices

Sample Type(s)	Test Parameter Method	CASRN	QAPP Reporting Limit (µg/kg)	Sediment Target CRQL[1] (µg/kg)	Sediment RBSL[2]	Sediment Region 4 ESVs (µg/kg)	Sediment Notes
Released Ash Sediment	**Pesticides - SW-846 8081A**						
	aldrin	309-00-2	ND	1.7	29	2	Region III
	alpha-BHC	319-84-6	ND	1.7	77	6	Region III
	alpha-chlordane	5103-71-9	ND	1.7	1,600	0.5	chlordane as basis
	beta-BHC	319-85-7	ND	1.7	270	5	Region III
	delta-BHC	319-86-8	ND	1.7	NA	6,400	Region III
	4,4'-DDD	72-54-8	ND	3.3	2,000	1.22	
	4,4'-DDE	72-55-9	ND	3.3	1,400	2.07	
	4,4'-DDT	50-29-3	ND	3.3	1,700	1.19	
	dieldrin	60-57-1	ND	3.3	30	0.02	
	endosulfan I	115-29-7	ND	1.7	370,000	2.9	Region III
	endosulfan II	33213-65-9	ND	3.3	370,000	14	Region III
	endosulfan sulfate	1031-07-8	ND	3.3	370,000	5.4	Region III
	endrin	72-20-8	ND	3.3	18,000	0.02	
	endrin aldehyde	7421-93-4	ND	3.3	18,000	0.02	endrin as basis
	endrin ketone	53494-70-5	ND	3.3	18,000	0.02	endrin as basis
	gamma-BHC (lindane)	58-89-9	ND	1.7	520	0.32	
	gamma-chlordane	5103-74-2	ND	1.7	1,600	0.5	chlordane as basis
	heptachlor	76-44-8	ND	1.7	110	68	Region III
	heptachlor epoxide	1024-57-3	ND	1.7	53	2.47	Region III
	methoxychlor	72-43-5	ND	17.0	310,000	18.7	Region III
	toxaphene	8001-35-2	ND	170.0	440	0.1	Region III
	Polychlorinated Biphenyls - SW-846 8082						
	aroclor-1016	12674-11-2	ND	33.0	3,900	NA	
	aroclor-1221	11104-28-2	ND	33.0	140	NA	
	aroclor-1232	11141-16-5	ND	33.0	140	NA	
	aroclor-1242	53469-21-9	ND	33.0	220	NA	
	aroclor-1248	12672-29-6	ND	33.0	220	NA	
	aroclor-1254	11097-69-1	ND	33.0	220	NA	
	aroclor-1260	11096-82-5	ND	33.0	220	NA	
	aroclor-1262	37324-23-5	ND	33.0	220	NA	
	aroclor-1268	11100-14-4	ND	33.0	220	NA	
	PCBs (total)		ND		220	21.6	

Table E-5. (QAPP Table D-2) Analytes and Target Reporting Limits Solid Matrices
(continued)

Sample Type(s)	Test Parameter Method	CASRN	QAPP Reporting Limit (µg/kg)	Sediment Target CRQL[1] (µg/kg)	Sediment RBSL[2]	Sediment Region 4 ESVs (µg/kg)	Sediment Notes
Released Ash Sediment	**Polynuclear Aromatic Hydrocarbons - SW-846 8270 SIM**						
	acenaphthene	83-32-9	67	3.3	3,400,000	6.71	
	acenaphthylene	208-96-8	67	3.3	NA	5.87	
	anthracene	120-12-7	67	3.3	17,000,000	46.9	
	benzo(a)anthracene	56-55-3	67	3.3	150	74.8	
	benzo(a)pyrene	50-32-8	67	3.3	15	88.8	
	benzo(b)fluoranthene	205-99-2	67	3.3	150	27.2	Region III
	benzo(e)pyrene	192-97-2	67	3.3	NA		
	benzo(g,h,i)perylene	191-24-2	67	3.3	NA	170	Region III
	benzo(k)fluoranthene	207-08-9	67	3.3	1,500	240	Region III
	chrysene	218-01-9	67	3.3	15,000	108	
	dibenzo(a,h)anthracene	53-70-3	67	3.3	15	6.22	
	fluoranthene	206-44-0	67	3.3	2,300,000	113	
	fluorene	86-73-7	67	3.3	2,300,000	21.2	
	indeno(1,2,3-cd)pyrene	193-39-5	67	3.3	150	17	Region III
	2-methylnaphthalene	91-57-6	67	3.3	310,000	34.6	naphthalene as basis
	naphthalene	91-20-3	67	3.3	3,600	34.6	
	phenanthrene	85-01-8	67	3.3	NA	86.7	
	pyrene	129-00-0	67	3.3	1,700,000	153	

Table E-5. (QAPP Table D-2) Analytes and Target Reporting Limits Solid Matrices
(continued)

Sample Type(s)	Test Parameter	CASRN	QAPP Reporting Limit (µg/kg)	Soil RL[3] (µg/L)	Soil MDL[3] (µg/kg)	Soil CRQL[1] (µg/kg)
Released Ash Sediment	**Alkylated Polynuclear Aromatic Hydrocarbons- SW-846 8270 SIM**					
	C1-Chrysenes	NA	ND	10	5.0	3.3
	C1-Fluoranthenes/Pyrenes	NA	ND	10	5.0	3.3
	C1-Fluorenes	NA	ND	10	5.0	3.3
	C1-Naphthalenes	NA	ND	10	5.0	3.3
	C1-Phenanthrenes/Anthracenes	NA	ND	10	5.0	3.3
	C2-Chrysenes	NA	ND	10	5.0	3.3
	C2-Fluorenes	NA	ND	10	5.0	3.3
	C2-Naphthalenes	NA	ND	10	5.0	3.3
	C2-Phenanthrenes/Anthracenes	NA	ND	10	5.0	3.3
	C3-Chrysenes	NA	ND	10	5.0	3.3
	C3-Fluorenes	NA	ND	10	5.0	3.3
	C3-Naphthalenes	NA	ND	10	5.0	3.3
	C3-Phenanthrenes/Anthracenes	NA	ND	10	5.0	3.3
	C4-Chrysenes	NA	ND	10	5.0	3.3
	C4-Naphthalenes	NA	ND	10	5.0	3.3
	C4-Phenanthrenes/Anthracenes	NA	ND	10	5.0	3.3

Notes:

[1] CRQLs are from EPA's Contract Laboratory Program and are provided for reference until an analytical laboratory is selected. Project specific quantitation limits will be selected consistent with or as close as possible to the applicable screening levels.

[2] EPA 2009 Mid-Atlantic Risk Assessment website http://www.epa.gov/reg3hscd/risk/human/rb-concentration_Table/Generic_Tables/index.htm

[3] Lab reporting limits and method detection limits from Pace Analytical Laboratories.

CASRN = Chemical Abstract Registry Number
CRQL = Contract Required Quantitation Limit
ESV = ecological screening value
MDL = method detection limit
ND = not determined

Table E-6. Comparison of Screening Levels for Inorganics and Radionuclides with Target Reporting Limits Solid Matrices

Analyte	CAS No.	QAPP Target Reporting Limit (mg/kg)	Sediment RBSL (mg/kg or pCi/g)	Sediment RBSL (mg/kg or pCi/g)	Sediment ESLs (mg/kg)	Source
Aluminum	7429-90-5	40	7,700	7,700	NA	
Antimony	7440-36-0	6.0	3.1	3.1	12	R4
Arsenic	7440-38-2	2.0	0.39	0.39	7.24	R4
Barium	7440-39-3	1.0	1,500	1,500	NA	
Beryllium	7440-41-7	1.0	16	16	NA	
Boron	7440-42-8	20	1,600	1,600	NA	
Cadmium	7440-43-9	0.5	7	7	1	R4
Chromium	7440-47-3	1.5	280	280	52.3	R4
Cobalt	7440-48-4	5.0	2.3	2.3	NA	
Copper	7440-50-8	2.5	310	310	18.7	R4
Iron	7439-89-6	20	5,500	5,500	NA	
Lead	7439-92-1	1.5	400	400	30.2	R4
Manganese	7439-96-5	1.5	180	180	NA	
Mercury	7439-97-6	.02	4.3	4.3	0.13	R4
Molybdenum	7439-98-7	4.0	39	39	NA	
Nickel	7440-02-0	4.0	150	150	15.9	R4
Selenium	7782-49-2	1.5	39	39	NA	
Silver	7440-22-4	3.0	39	39	2	R4
Thallium	7440-28-0	3.5	0.51	0.51	NA	
Vanadium	7440-62-2	2.5	39	39	NA	
Zinc	7440-66-6	6.0	2,300	2,300	124	R4
Cs-137		1.0	3.88	3.88	NA	
Co-60		1.0	0.0361	0.0361	NA	
K-40		1.0	0.108	0.108	NA	
Ra-226		1.0	0.0124	0.0124	NA	
Ra-228		1.0	0.0677	0.0677	NA	
Th-228		1.0	0.154	0.154	NA	
Th-232		1.0	3.1	3.1	NA	
U-234		1.0	4.01	4.01	NA	
U-235		1.0	0.195	0.195	NA	
U-238		1.0	0.742	0.742	NA	

Table E-7. (QAPP Table D-3) Summary of Precision and Accuracy Objectives for Quality Control Samples, Groundwater Modeling Input Parameters

Compound	Test Method	LCS Accuracy (% Recovery)	MS/MSD Accuracy (% Recovery)	LCS/LCSD Precision (RPD)	MS/MSD Precision (% Recovery)	Laboratory Duplicate Precision (RPD)	Field Duplicate Precision[1]
Bulk Density	ASTM D2937	NA	NA	NA	NA	NA	RPD <10% difference < the RL
Effective Porosity	ASTM D4404-86	NA	NA	NA	NA	NA	RPD <10% difference < the RL
Total Porosity	ASTM D6836	NA	NA	NA	NA	NA	RPD <10% difference < the RL
Moisture Content	ASTM D2216	NA	NA	NA	NA	NA	RPD <10% difference < the RL
Vertical Hydraulic Conductivity	ASTM D5126-90	NA	NA	NA	NA	NA	None (No Field Duplicates)
Soil pH	ASTM D4972-01	NA	NA	NA	NA	NA	RPD <20% difference < the RL
Polarized Light Microscopy	EPA-600/M4-82-020 or equivalent Lab SOP	NA	NA	NA	NA	+/- 4%	+/- 4%
Column Leaching	ASTM D4793	NA	NA	NA	NA	20	None (No Field Duplicates)
Free Iron Oxide	Chao and Zhou (1983)	NA	NA	NA	NA	20	RPD <20% difference < the RL
Cation Exchange Capacity Exchangable Cations Calicte Equivalent Soluble Salts	ASA 1996, Methods 14,15,16, or equivalent Lab SOP	NA	NA	NA	NA	20	RPD <20% difference < the RL

Notes:

[1] When both field duplicate results are > 5 times the RL, the RPD must be < 35%. When at least one result is <5 times the RL, the difference must be <2 times the RL.

LCS = laboratory control sample
LCSD = laboratory control sample duplicate
RL = reporting limit
RPD = relative percent difference

Table E-8. (QAPP Table D-3) Summary of Precision and Accuracy Objectives for Quality Control Samples Solid Matrices

Compound	CASRN	Surrogate Compound Recoveries/Chemical Yield (%)	LCS Accuracy (% Recovery)	MS/MSD Accuracy (% Recovery)	LCS/LCSD Precision (RPD)	MS/MSD Precision (% Recovery)	Laboratory Duplicate Precision (RPD)	Field Duplicate Precision[1]
Polynuclear Aromatic Hydrocarbons	83-32-9	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35% difference < the RL
Alkylated Polynuclear Aromatic Hydrocarbons	208-96-8	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35% difference < the RL
Pesticides	309-00-2	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35%difference < the RL
Polychlorinated Biphenyls	11104-28-2	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35% difference < the RL

Note:

[1] When both field duplicate results are > 5 times the RL, the RPD must be < 35%. When at least one result is < 5 times the RL, the difference must be <2 times the RL.

Table E-9. Comparison of Screening Levels for Inorganics and Radionuclides with Target Reporting Limits, Biological (Fish Fillet) Matrices

Analyte	CAS No.	QAPP Target Reporting Limit (mg/kg)	Fish RBSL[1] (mg/kg or pCi/g)
Aluminum	7429-90-5	25	135
Antimony	7440-36-0	0.1	0.0541
Arsenic	7440-38-2	0.1	0.0021
Barium	7440-39-3	0.1	27
Beryllium	7440-41-7	0.1	0.27
Boron	7440-42-8	0.5	27
Cadmium	7440-43-9	0.1	0.135
Chromium	7440-47-3	0.1	203
Cobalt	7440-48-4	.01	0.0406
Copper	7440-50-8	0.5	5.41
Iron	7439-89-6	25	94.6
Lead	7439-92-1	.01	NA
Manganese	7439-96-5	0.5	18.9
Mercury	7439-97-6	0.02	0.0135
Molybdenum	7439-98-7	1.0	0.676
Nickel	7440-02-0	0.1	2.7
Selenium	7782-49-2	0.2	0.676
Silver	7440-22-4	0.05	0.676
Thallium	7440-28-0	0.1	0.00876
Vanadium	7440-62-2	0.2	0.681
Zinc	7440-66-6	2.0	40.6
Cs-137		ND	0.0472
Co-60		ND	0.0791
K-40		ND	0.0514
Ra-226		ND	0.00342
Ra-228		ND	0.00123
Th-228		ND	0.00418
Th-232		ND	0.0133
U-234		ND	0.0185
U-235		ND	0.0181
U-238		ND	0.0146

Note:

[1] ORNL 2010. http://rais.ornl.gov/cgi_bin/prg/prg_search?select=chem

Table E-10. (QAPP Table G-3) Summary of Precision and Accuracy Objectives for Quality Control Samples, Biological Samples

Compound	CASRN	Surrogate Compound Recoveries/Chemical Yield (%)	LCS Accuracy (% Recovery)	MS/MSD Accuracy (% Recovery)	LCS/LCSD Precision (RPD)	MS/MSD Precision (% Recovery)	Laboratory Duplicate Precision (RPD)	Field Duplicate Precision[1]
Polynuclear Aromatic Hydrocarbons	83-32-9	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35% difference < the RL
Alkylated Polynuclear Aromatic Hydrocarbons	208-96-8	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35% difference < the RL
Pesticides	309-00-2	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35% difference < the RL
Polychlorinated Biphenyls	11104-28-2	50 - 130	80 - 120	75 - 125	35	35	35	RPD <35% difference < the RL

Note:

[1] When both field duplicate results are > 5 times the RL, the RPD must be < 35%. When at least one result is < 5 times the RL, the difference must be <2 times the RL.

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