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May 10, 2018

Mr. Michael Liberati
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VIA ELECTRONIC MAIL

Re: Revised Final AOC 4 Long-Term Monitoring Plan
Former DuPont Waynesboro Plant, Area of Concern 4
South River and a Segment of the South Fork of the Shenandoah River, Virginia
Waynesboro, Virginia
EPA ID# VAD003114832

Dear Mr. Liberati:

This letter acknowledges the receipt and review of the Revised Final AOC 4 Long-Term Monitoring (LTM) Plan dated April 2018, submitted to the Virginia Department of Environmental Quality, Office of Remediation Programs (Department) by AECOM on behalf of the E.I du Pont de Nemours and Company (DuPont).

The Department approves the revised LTM Plan as submitted.

If you have any questions, you may contact me at 703-583-3825 or by email at Kurt.Kochan@deq.virginia.gov.

Sincerely,

Kurt W. Kochan
Corrective Action Project Manager
Office of Remediation Programs

cc: DuPont Waynesboro Correspondence File
Brett Fisher, Calvin Jordan, VDEQ-CO
Ceil Mancini, Josh Collins, AECOM

Final AOC 4 Long-Term Monitoring Plan

South River and a Segment of the South Fork of the Shenandoah River, Virginia

Submitted on behalf of:
E.I. du Pont de Nemours and Company

Submitted by:
AECOM
625 West Ridge Pike, Suite E-100
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Project Number: 60559681
Date: February 2015 (submitted as URS Corporation, which is now AECOM)
Revised: April 2018

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Acronym List

Acronym	Explanation
%MeHg	Percent of THg present as MeHg
°C	Degrees Celsius
AOC	Area of Concern
BASS	Bioaccumulation and Aquatic System Simulator
BMA	Bank Management Area
CSM	Conceptual Site Model
DOC	Dissolved Organic Carbon
DuPont	E.I. du Pont de Nemours and Company
dw	Dry weight
Ecological Study	Ecological Study of the South River
EPA	U.S. Environmental Protection Agency
FDA	Food and Drug Administration
FGCM	Fine-grained channel margin
FMeHg	Filtered methylmercury
FTHg	Filtered total mercury
GIS	Geographic Information System
GPS	Global Positioning System
HRAD	Hg (mercury)-release age deposit
IHg	Inorganic mercury
IM	Interim Measures
LTM	Long-term monitoring
LTM Plan	Long-Term Monitoring Plan
LiDAR	Light Detection and Ranging
LWD	Large, woody debris
MDL	Method Detection Limit
MeHg	Methylmercury
mg/kg	Milligram per kilogram
mm	Millimeter
ng/g	Nanograms per gram
NRDC	Natural Resources Defense Council
QA/QC	Quality assurance / quality control
QAPP	Quality Assurance Project Plan
RA	Release Assessment
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RRM	Relative River Mile
SFS	South Fork Shenandoah
SOP	Standard Operating Procedure
SQT	Sediment Quality Triad
SRST	South River Science Team
STM Plan	Short-Term Monitoring Plan
THg	Total mercury
TL	Total length
TOC	Total organic carbon
TSS	Total suspended solids
URS	URS Corporation
VDEQ	Virginia Department of Environmental Quality

Acronym	Explanation
VDGIF	Virginia Department of Game and Inland Fisheries
VDH	Virginia Department of Health
ww	Wet weight
YOY	Young-of-year

1.0 Introduction

The Area of Concern (AOC 4) Long-term Monitoring (LTM) is being performed in an enhanced adaptive management Framework. The original LTM Plan was issued in February 2015. LTM data collected since that time have been evaluated in terms of their uniqueness, and usefulness in remedial decision-making. Based on the evaluation summarized in the LTM Program Assessment and Recommended Modifications Memorandum (AECOM, 2018a), the Work Plan has been revised to reflect modifications proposed by the South River Science Team (SRST) and approved by the Virginia Department of Environmental Quality (VDEQ).

1.1 Background

On behalf of E.I. du Pont de Nemours and Company (DuPont), AECOM has prepared this LTM Plan as part of a remedial strategy designed to address mercury in the South River Watershed, as a result of a release of mercury from the former DuPont facility to the South River in Waynesboro, Virginia (site). Remedial actions are being conducted by DuPont in accordance with the requirements set forth in the site's U.S. Environmental Protection Agency (EPA)-issued Resource Conservation and Recovery Act (RCRA) Corrective Action Permit (Final Hazardous Waste Permit for Corrective Action-Renewal EPA ID No. VAD003114832, issued on September 24, 2009; amended on February 4, 2014). The South River and a portion of the South Fork of the Shenandoah River (SFS) are collectively referred to in the amended permit as the Area of Concern 4 (AOC 4) (see Figure 1-1).

Owing to its size, linear nature, and spatial variability, the remedial strategy requires that the river system be divided into manageable segments, and that remediation occur in an upstream-to-downstream fashion, with components of each segment (e.g., banks, in-channel bed sediments, and floodplains) addressed in an appropriate sequence. Following completion of source controls at the former Waynesboro facility, the first segment of the South River to be addressed includes bank soils and in-channel sediments located within the first two river miles immediately adjacent to, and downstream of, the former site. The design for this segment is described in the approved Interim Measures (IM) Work Plan (Anchor QEA et al., 2015).

The IM is designed to work within an adaptive management framework by defining success criteria, contingency actions, and decision analysis options. This first segment includes eroding bank deposits that may transport legacy mercury into the downstream channel and floodplain areas of the South River. The length of this initial upstream aquatic segment was determined based on reach characteristics, as well as implementability, safety, and adaptive management considerations, targeting an initial interim measures construction period of approximately 3 to 5 years. These actions include a series of bank stabilization activities including enhanced vegetative management, structural stabilization, isolated soil removal and monitored natural recovery of in-stream sediments.

A Short-Term Monitoring Plan (STM Plan) was also developed, as described in Section 2.6 and is currently being implemented. In contrast to the LTM Plan, the STM Plan is designed to measure improvements over relatively rapid timeframes and small spatial scales. The short-term monitoring program is focused on the South River at or near those areas where remedies are being implemented, the LTM Plan is designed to cover a longer timeframe and a much larger area. The STM Plan also includes routine

inspections of remediated areas to monitor the continued integrity and performance of the remedies and their functioning relative to the Bank Management Areas (BMAs).

Data collected as part of both the LTM and STM programs integrate with existing historical data sets collected as part of the Ecological Study of the South River (Ecological Study; URS 2012), as well as the VDEQ 100-Year Monitoring Program for the South River and South Fork Shenandoah River. The monitoring program recognizes the important information that has been assembled by these groups over the past several decades, and will continue to be collected as part of the STM and LTM programs. As the LTM continues to be implemented, there will be communication with those involved with the existing monitoring efforts to efficiently share data, and provide input to the adaptive management process.

1.2 Purpose

The primary purpose of this monitoring plan is to describe an approach within a flexible framework to evaluate the effectiveness of the remedial actions based on the short- and long-term remedial action objectives (RAOs) described in Section 2.2 of this LTM Plan. The plan has been designed to be consistent with the EPA Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation (2004). RAOs constitute a framework for developing protective, implementable, and effective remedial alternatives. The RAOs were defined, and remedial approaches evaluated and selected for Relative River Mile (RRM) 0 to RRM 2.0 of AOC 4, in the Remediation Proposal submitted to the Natural Resources Defense Council (NRDC) in accordance with a consent decree between DuPont, the NRDC, and the Virginia Chapter of the Sierra Club (Anchor QEA and URS, 2013).

1.3 Mercury in the South River and South Fork Shenandoah River

1.3.1 Former DuPont Waynesboro Facility

The site is currently owned and operated by A&AT LLC (a wholly owned subsidiary of INVISTA S.a.r.l.) and is located on approximately 177 acres of flat lying land along the South River in the southeastern corner of Waynesboro, Virginia. From 1929 to 1950, the site used mercury compounds (e.g., mercuric sulfate) in the production of acetate flake and yarn. Mercury from the process wastes was recovered at an on-site retort facility. During that period, mercury releases occurred associated with the acetation process and were subsequently remediated in accordance with applicable waste management practices of the time. In addition to localized soil and groundwater impacts, the storm sewers draining these areas were found to be impacted by the former mercury operations and are currently the primary transport mechanism for mercury loading from the site to the South River. Beginning in 1998, DuPont began a Release Assessment (RA) and RCRA Facility Investigation (RFI) at the site. However, some mercury presently remains in soil and/or groundwater in isolated areas associated with historical operations, and mercury continues to be discharged to the river via the site outfalls. Interim measures were completed in 2010 and again in 2014 to control off-site mercury migration through the site outfall. Final remedial actions are underway at the plant, which include free mercury source area removals, capping, sewer cleaning and institutional controls. The first phase was completed in March 2018 and the second and last phase is expected to be complete by the end of 2018.

1.3.2 River Channel

The South River has unique geophysical, chemical, and biological features that facilitate the mechanisms allowing legacy inorganic mercury (IHg) to continue to enter the South River. Once released from the site, IHg was transported by surface water to sediment and floodplain soils. Sediment is stored in the gravel matrix of the stream channel and along the channel margins in deposits. Mercury was transported through the river channel and has been detected in soil throughout the 100-year floodplain, but the primary mechanism for mercury transport is bank erosion from river banks.

Once IHg enters the South River, a small portion of it is methylated in sediment. Mercury methylation is the biological mechanism whereby IHg is converted to methylmercury (MeHg), which efficiently enters the aquatic food web and is bioaccumulated in river biota and biomagnified through trophic transfer. In addition, the former DuPont Waynesboro facility continues to act as a point source of IHg to the river system.

1.3.3 Floodplain

As described above, mercury was transported by the river channel and was deposited on riverbanks and throughout the 100-year floodplain. Spatial distribution of mercury in floodplain soils within AOC 4 is dynamic and influenced by factors such as distance from the former site, floodplain inundation frequency, land-use, and stream geomorphology. Although legacy mercury is present in the floodplain, a tributary loading study conducted during storm events in the Ecological Study show that the floodplain (excluding South River bank soils) is not a significant source of total mercury (THg) and MeHg to the South River (URS, 2012).

1.4 Scope

Components of the LTM Plan are provided in the following sections:

- Section 2 provides the monitoring strategy, objectives, hypotheses, and the basis for decision-making. This section also summarizes the STM Plan.
- Section 3 presents pre-remediation characteristics of media being monitored, monitoring activities, and sample analysis.
- Section 4 provides an overview of the reporting deliverables anticipated for the monitoring program.
- Section 5 includes information regarding the Quality Assurance Project Plan (QAPP).
- Section 6 lists references utilized in the development of this plan.

2.0 Remedial Strategy

The primary focus of the IM is the reduction of mercury transport from RRM 0 through RRM 2.0 riverbanks. This section describes the objectives, hypotheses to be tested and general approach to be followed in the LTM Plan, and also provides a description of the STM Plan.

2.1 Monitoring Program Objectives

Remedial Action Objectives constitute a framework for developing protective, implementable, and effective remediation alternatives. Additionally, RAOs provide a basis for evaluating different remediation alternatives by describing what the remedial measures are intended to accomplish and helping to focus alternative development and evaluation. The remedial alternative evaluation process evaluates the feasibility, implementability, and sustainability of remedial alternatives, while assessing the extent to which remedies are expected to achieve the RAOs. RAOs should reflect objectives that are achievable through remediation (EPA, 2005). Short- and long-term AOC 4 RAOs are media-specific and consist of the following:

- General response objectives that identify the exposure pathway to be addressed in order to assess potential risks to human health and the environment.
- Performance objectives that identify specific media targets intended to fulfill the general response objective.
- Measurable metrics that consist of quantitative criteria, which establish whether performance objectives have been met.

A combination of some or all of these objectives is developed as part of the remedy.

Short-term RAOs are expected to be met following remedial measure construction. Long-term RAOs may require additional time to respond before they are attained. Preliminary RAOs described in the Remediation Proposal (Anchor QEA and URS, 2013) will be subject to refinement during remediation planning, as well as follow-on adaptive management. It is also likely that some or all of these RAOs will apply to other river segments during subsequent phases of remediation. Initial elements of the short- and long-term RAOs, subject to regulatory agency review and comment, include the following:

- Short-Term RAOs:
  - General response objectives: Reduce IHg transport and exposure and improve bank habitat functions within the upper two miles of the South River.
  - Performance objectives: Conduct and/or maintain bank remediation actions within upper two miles of the South River to achieve sustainable reductions in mercury concentrations and improve bank habitat functions within this reach.
  - Measurable metrics: Bank erosion rates, measured using detailed topographic surveys; establishment of bank vegetation; and mercury concentrations in physical media and biological tissues.

- Long-Term RAOs:
  - General response objectives: Reduce MeHg exposure and improve habitat conditions throughout the South River and SFS River.
  - Performance objectives: Conduct and/or maintain remediation actions that sustain reductions in tissue MeHg concentrations and improve water quality and habitat functions throughout the South River and SFS River.
  - Measurable metrics: Mercury concentrations in biological tissues and physical media, and bank and in-channel habitat metrics (see Section 3 and Table 2-2).

2.2 Long-Term Monitoring Plan Objectives

Once the RAOs have been established, the specific monitoring objectives are defined. The overall goal of the monitoring effort is to provide data to assess the efficacy of the remedy in addressing both migration and potential exposure pathways. Specific objectives of the data collection effort are to provide data to monitor the following:

- Human and ecological exposure to mercury
- System responses to remediation
- Integrity of the remediation action

Monitoring data will also provide input to the adaptive management framework and relative risk model to evaluate whether any aspect of the remedial action, monitoring strategy, corrective action design, or conceptual site model (CSM) needs to be revisited. The LTM Plan addresses changes in the South River and SFS River over longer timeframes and larger spatial scales compared to the short-term monitoring that will be focused primarily in the South River at or near those areas where BMA remedies are being implemented. Similar to the STM Plan, chemical and biological results from the LTM Plan will feed into the relative risk model and the adaptive management approach. In this way, both the short- and long-term information will be used as input to management decisions regarding the efficacy of remediation actions, the need to alter approaches or evaluate new or improved technologies, or to maintain and/or repair areas as necessary.

Most importantly, the monitoring information will help estimate changes in the potential exposures to humans and ecological receptors that result from changes in mercury loading to the South River and SFS River. It is expected that once remedial actions have been implemented, the mercury loading to the South River and SFS River should decline over time and be accompanied by a concomitant reduction in potential mercury exposures and potential risks to humans and ecological receptors. Throughout the implementation and monitoring of this LTM Plan, there will be open and frequent outreach and communication with local communities, physicians and health clinics, and relevant public health groups.

2.3 Hypotheses

The main working hypothesis is that reducing or eliminating the transport of mercury to the South River in a stepwise manner, beginning with source controls at the former DuPont facility, will result in improvements in and downstream of the river reach where remediation has occurred. It is expected that as corrective actions are implemented, mercury loading to the South River and SFS River should decline over time and be

accompanied by a corresponding reduction in potential mercury exposures and potential risks to humans and ecological receptors. Some terrestrial ecological receptors in the South River and SFS River may be exposed to mercury via consumption of aquatic invertebrates and fish. Therefore, it is expected that reducing mercury loading to the South River and SFS River will also reduce exposure of terrestrial organisms to mercury.

2.4 Sampling Design

The LTM Plan was designed through careful evaluation of the large body of scientific research conducted from 2000 to 2011 as part of the Ecological Study of the South River and a Segment of the South Fork Shenandoah River (URS, 2012). A summary of studies assessing various aspects of mercury nature and extent, population dynamics, and physical processes of the South River is provided in the Ecological Study Data Matrix (see Appendix B). Monitoring program sampling locations were selected to be consistent with existing datasets, including the Ecological Study and the VDEQ 100-Year Monitoring Program. Additionally, larger sampling reaches were selected for certain media such as fish, as opposed to discrete locations, based upon consultation with Virginia Department of Game and Inland Fisheries (VDGIF). These sampling reaches were selected to minimize the impact to local biological communities at a given location from repeated sampling.

The sample sizes selected in this LTM Plan were based on statistical evaluations of data collected in the South River during the Ecological Study or by the South River Science Team (SRST). The analyses were performed by the Project Statistician, Dr. John Green of DuPont. The results of the power analysis and the data analysis techniques that will be employed for the monitoring plan are described in more detail in Section 4 and protocol SRDA-1 (see Appendix A).

2.5 Basis for Decisions

The data collected as part of the monitoring programs for AOC 4 will be used to evaluate the effectiveness of potential remedial alternatives and progress in achieving the RAOs described in the Remediation Proposal (Anchor QEA and URS, 2013). Data collected under the monitoring programs will be evaluated in the context of the historical data collected on AOC 4 and managed in a master database. The tools used to measure the effectiveness of the potential remedial alternatives include the Enhanced Adaptive Management Framework and the Relative Risk Model. These tools are described below, and can be reviewed in more detail in the Ecological Study (URS, 2012) and the Remediation Proposal (Anchor QEA and URS, 2013).

2.5.1 South River Database

Baseline LTM data (pre-remediation; 2014 to 2016) were initially evaluated in the context of the historical data collected in AOC 4 (AECOM, 2017). These data are managed in a master database developed as part of the Ecological Study (URS, 2012). The database incorporates analytical and other performance data generated during this project with geographic information systems (GIS) data, including current and historical aerial photography, geomorphology studies, land-use and habitat delineations, and hydrological data. The historical data analyses were presented in detail in the Ecological Study (URS, 2012) and form the basis of the historical database that were used to evaluate the baseline LTM data (AECOM, 2017). Post-remediation LTM reports will be

developed every three years beginning with the completion of the 2019 effort, to document the ecosystem response to remediation.

For the monitoring phase of the program, analytical data generated from this monitoring plan will be incorporated into the database via electronic data deliverables. This data warehouse will be maintained on a DuPont server that provides for a high level of data backup and security. Procedures will be developed to make the database accessible to interested scientists, the public, the regulatory agencies, and others as requested.

The integration of monitoring data with historical data and the decision tools described above is a key step in evaluating remedial effectiveness and potential attainment of RAOs. Figure 2-1 provides a schematic of how the understandings generated from the model will be entered into the adaptive management process and used to update the regional risk in the relative risk model. The first step of data integration was the evaluation of data in the context of the long-term data and historical AOC 4 data (AECOM, 2017). Data collected as part of LTM Plan is specifically designed to provide a baseline against which changes in short-term data can be interpreted. Long-term monitoring data may also be used to establish the potential effects of climactic conditions, which could influence performance monitoring data.

2.5.2 Enhanced Adaptive Management Framework

Consistent with the approach of the remediation, the LTM Plan will also incorporate an adaptive management framework. Adaptive management is a structured and iterative decision-making process that improves management decisions and reduces uncertainty over time as the outcomes of earlier decisions are monitored and lessons learned are incorporated (see Figure 2-2).

Adaptive management promotes flexible decision-making in the face of uncertainty. Careful monitoring of the outcome of implemented actions advances understanding and helps adjust future remedy decisions as part of an iterative learning process. If there are changes made to the remedial effort based on the adaptive management strategy, these changes will also be reflected by changes to the LTM Plan. Adaptive management also recognizes the importance of natural variability in ecological systems and variability in measures of effectiveness of remediation.

Adaptive management requires the following:

- A decision framework that can be updated with new information
- Specific objectives of the remediation defined
- An understanding of the processes and drivers that impact those objectives
- A range of monitoring alternatives
- Monitoring of key performance metrics

Adaptive management is particularly well suited to the AOC 4 remediation and monitoring strategy, in part because remedial measures will be implemented sequentially over the next five to ten years or more, providing an opportunity to effectively integrate lessons learned as data are collected. It will facilitate testing and monitoring remediation actions, particularly where there is a need to assess effectiveness prior to undertaking additional actions. Where actions do not result in measureable improvements, changes in remedial technologies or applications may be required; these changes will be reflected in changes to the LTM Plan.

2.5.3 Relative Risk Model

In an ecological system such as AOC 4 and the South River ecosystem, there are a variety of potential physical, chemical and biological environmental stressors that may pose potential risks to ecological receptors, in addition to mercury. Relative risk models are a tool to understand the interaction of multiple stressors, and their potential impacts on assessment endpoints (i.e., the characteristic of the system that society values and is trying to protect, such as protection of community diversity). For example, chemical stressors and habitat degradation, both of which may be improved by the proposed remediation, can affect the assessment endpoint of avian reproduction. The relative risk model for the South River and a segment of the SFS River provides a framework for assessment of all known stressors in the system (Landis et al., 2015).

Chemical and biological results from the LTM Plan will feed into the model and be evaluated using probability distributions for ecosystem responses. The findings of this exercise will be entered into the adaptive management framework to inform management decisions regarding the efficacy of remediation actions, the need to alter approaches or evaluate new or improved technologies, or to maintain and/or repair areas as necessary. For example, if data collected show no change in macroinvertebrate mercury tissue concentrations after several years of monitoring, either the remedy or monitoring strategy may be considered for modification.

2.6 Short-Term Monitoring

In addition to the LTM Plan, the STM Plan is an important component of the overall monitoring strategy for the AOC 4 remediation. As described in Section 1.0, specific details of the STM Plan were provided in the *AOC 4 Phase 1 Interim Measures Design, Implementation and Monitoring Work Plan* (Anchor QEA et al., 2015). A brief summary of the key components included in the STM Plan is provided below.

The STM Plan is designed to measure improvements over relatively brief timeframes (e.g., two to ten years) and small spatial scales (e.g., adjacent to a particular bank management area). Pre-remedy baseline sampling will begin once BMAs have been finalized. The first post-remedy monitoring will be conducted six months after construction activities have been completed.

The STM Plan is designed to work within the adaptive management framework by defining success criteria, contingency actions, and decision analysis options. It provides a framework to assess the influence of a specific remedial action alternative. The scope of short-term monitoring will be expanded once potential downstream and floodplain areas to be remediated are identified.

The STM Plan for the IM provides an array of monitoring tools to measure the system responses to specific remediation alternatives implemented between RRMs 0 and 2 (see Table 2-1). Because the remedial options that best meet the general response objectives for RRMs 0 to 2 are enhanced vegetative stabilization and structural stabilization, the short-term monitoring is focused on the performance of bank stabilization. The general response objectives are:

- Reduce mercury transport and exposure
- Improve bank habitat functions between RRMs 0 and 2 of the South River

The primary focus of remediation in the short-term is the reduction of mercury transport associated with riverbanks between RRMs 0 and 2. Bank erosion is the most important

transport pathway for THg from riverbanks, so several measurable metrics and success criteria are included in the short-term monitoring effort [e.g., light detection and ranging (LiDAR)] to confirm that bank erosion rates decline and banks maintain their stability in response to remediation actions.

Although bank erosion is the primary mercury transport pathway from riverbanks, other transport pathways from riverbanks are also possible. The short-term monitoring program includes other measureable metrics to capture changes in transport or exposure pathways such as the following:

- THg and MeHg concentrations in surface sediment, which may reflect particle migration from upstream areas of the river
- THg and MeHg concentrations in near-bank pore water
- THg and MeHg concentrations in biological tissue

3.0 Monitoring

The LTM Plan was developed to attain the long-term RAOs for the planned remediation described in Section 2.0. As described, RAOs constitute a framework for developing protective, implementable, and effective remediation alternatives. AOC 4 long-term RAOs are intended to reduce MeHg exposure and improve water quality and habitat conditions throughout the South River and SFS River. Measurable metrics to assess these objectives include the measurement of mercury concentrations in biological tissues and physical media, and bank and in-channel habitat metrics.

The monitoring activities described below will be conducted prior to the implementation of interim measures activities to establish pre-remediation baseline conditions. Following remediation they will be conducted in accordance with the schedule set forth in Table 2-2.

In the following sections, media are arranged based on the monitoring element specified in Table 2-2, as follows:

- Human exposure:
  - Adult fish
- Aquatic ecological exposure:
  - Young-of-year (YOY) fish
  - Sediment
  - Benthic invertebrates (i.e., transplanted Asiatic clams and mayflies)
- Terrestrial ecological exposure:
  - Songbirds (i.e., Carolina wren)
  - Spiders
- Water and habitat quality:
  - Water quality
  - Benthic invertebrate community
  - Substrate grain size

In most sections, historical characterization is provided followed by monitoring activities and sample analyses. Data evaluation is discussed in Section 4.0.

3.1 Soil

The characterization of mercury concentrations in floodplain and bank soils is provided below to describe the current conditions of mercury in soil. Due to the long residence time of sediment stored on the South River floodplain (approximately 4,800 years; Pizzuto, 2012), soil THg concentrations are not expected to change over years or decades. In addition, soil sampling is currently included as part of the VDEQ 100-year Monitoring Program. As a result, no additional monitoring is proposed for mercury in floodplain soils.

3.1.1 Historical Characterization of Mercury in Soil

Mercury concentrations have been documented in soils from the South River floodplain and river banks. Comprehensive sampling of the South River floodplain soils was performed in 2008 to evaluate THg concentration distributions as a function of river mile, floodplain inundation frequency, and land use. The results of the sampling were detailed in the Ecological Study (URS, 2012) and are summarized as follows:

- THg concentrations in floodplain soil samples decrease with distance from the river and distance downstream.
- THg concentrations were highest in the two- and five-year (flood recurrence interval) floodplains.
- The highest THg concentrations tended to be in forested areas.
- THg concentrations in floodplain wetland samples were similar to surrounding floodplain soils.

Bank deposits include soils and sediments that have been deposited on the riverbank that vary in mercury concentration and historical mercury-release age deposits (HRADs), which include areas with high mercury concentrations relative to floodplain soils or background soils. A large dataset has been developed for the South River, detailing mercury concentrations in eroding bank soils. A total of 310 riverbank surficial soil transects have been sampled from RRMs 0.1 to 23.5. The vertically averaged THg concentrations in the riverbank surficial soil samples range from approximately 0.08 to 270 milligrams per kilogram (mg/kg). Additionally, 245 riverbank soil cores were sampled from RRMs 0.1 to 23.5 to inform the IM remedial design.

Forty-seven of these deposits have been delineated between RRMs 0.1 and 23.9, but the majority (39, or 83%) of HRADs are located between RRMs 0 and 11.6, with a higher density of HRADs between RRMs 3 and 4 (six deposits), RRMs 5 and 6 (five deposits), and RRMs 8 and 9 (10 deposits). The concentrations of THg vary spatially within and between HRADs. For example, an HRAD sampled at RRM 8.1 contained THg concentrations ranging between approximately 0.3 mg/kg, and 270 mg/kg.

3.1.2 Monitoring Activities

Floodplain soils and bank soils will not be monitored routinely as part of the LTM Plan. Floodplain soils are monitored as part of the 100-year monitoring plan administered by VDEQ. Since THg concentrations in floodplain soils are not expected to change on decadal time scales, the 100-year monitoring plan frequency is adequate to characterize floodplain soils in future conditions. The stability of river banks will be monitored as part of the STM Plan (see Table 2-1), but post-remediation monitoring of mercury concentrations in remediated river bank soils will not be conducted.

3.2 Human Exposure

Humans may be exposed to mercury in AOC 4 primarily through ingesting aquatic and semi-aquatic food items; this primarily occurs through the consumption of fish tissue. Fish consumption represents the primary potential human exposure pathway in the South River and SFS River. This potential exposure pathway has been effectively managed through fish tissue consumption bans and advisories issued by Virginia Department of Health (VDH) and VDEQ. A consumption ban on eating fish from the SR and SFS was put in place in 1977 because mercury in some fish exceeded the Food and

Drug Administration (FDA) action limit of 0.5 mg/kg. In 1979, an increase in the FDA action limit from 0.5 mg/kg to 1.0 mg/kg in mercury in edible fish tissue resulted in a decrease in the length of river affected by the consumption ban by 40 miles. In 1980, the VDH changed the consumption ban to a consumption advisory, recommending that children and pregnant women eat no fish from these waters and that others eat no more than one meal per week. The consumption advisory was modified again in 2001 to reflect new guidance from the U.S. National Academy of Sciences on an acceptable daily intake of mercury (VDH, 2001). The fish consumption advisory of 2001 was modified in 2011. The current consumption advisory is as follows:

- South River: No fish other than trout should be eaten from these waters. Stocked trout have been tested and are safe to eat.
- SFS River: No more than two meals (½ pound each or the size of your hand) of fish per month should be eaten from these waters. Women who are pregnant or may become pregnant, nursing mothers, and young children should not eat fish from these waters.

With the guidance of the VDH, VDGIF, and VDEQ, fish consumption advisories in English and Spanish are posted on billboards and other durable platforms throughout the South River, including all public access points along the river. The billboards are located in areas such as Constitution Park and Basic Park in Waynesboro, Grottoes Town Park, Grand Caverns, and Crimora Park. English and Spanish brochures entitled *Should I Eat the Fish I Catch* are also available at the billboards. These brochures have been distributed to physicians and health clinics in the area for the past five years and are used in conjunction with the published fish consumption advisories. The maintenance of signage along all access points of the South River, annual contact with local physicians and health clinics, as well as outreach to the Hispanic and other minority communities will be continued.

The current consumption advisory is reviewed periodically by VDH to confirm that it is based on the most current toxicological data for IHg and MeHg. Creel studies have been undertaken three times since 2005, and will be conducted every three to four years in the future to understand what populations are catching fish and their awareness of the consumption advisory.

The SRST has also been working with local health clinics and private physicians to determine how well the fish consumption advisories have reached communities; those results have been used by VDH to determine whether additional actions are needed to improve or enhance education on mercury with local groups. In addition, clinics and physicians are educated about mercury in fish and have been asked to report any signs and symptoms that could be associated with eating fish contaminated with mercury. VDH has made routine contacts with local physicians and health clinics over the past seven years and, to date, has not reported any signs or symptoms that might stem from potential exposure to mercury.

As a result of these and other outreach activities, the SRST has found that changing demographics of the area residents and fishing behavior required specific outreach activities aimed at immigrant populations. The SRST, working through James Madison University, developed and implemented a community outreach program in 2010. This program is called *Promotores de Salud* and is composed of local residents that have been trained to specifically meet this educational need in the Hispanic community. The program has been in place for several years and has graduated more than a dozen "*Promotores*." *Promotores* are members of the local community who educate fellow

residents in the watershed regarding fish consumption. The benefits go well beyond communication of fishing precautions. The *Promotores de Salud* program provides educational materials on mercury and promotes improvements to the general health, nutrition, and well-being of the local Hispanic community. Recently, other non-English speaking groups, including Russian and Arabic speaking populations, have been identified and incorporated into the *Promotores de Salud* program. As part of LTM Plan, DuPont plans to continue the *Promotores* outreach activities, as well as related outreach and monitoring of potential human exposures by working closely with VDH and other relevant groups.

While the SRST, VDH, and VDEQ continue to maintain a focus on fish consumption to confirm that these exposures remain below advisory levels, DuPont and the SRST continues to review and evaluate other potential dietary exposures to human receptors. In this section, the specific monitoring element to assess human exposure will be described, including adult largemouth and smallmouth bass. Each subsection provides a baseline characterization of mercury in the medium, monitoring activities and sample analysis. Sampling locations are presented in Figure 3-1.

3.2.1 Fish

Historical Characterization of Mercury in Fish Tissue

As part of the Ecological Study (URS, 2012), largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*) were sampled for mercury tissue analysis using biopsy plugs. Fish were collected by electro-fishing all likely habitats at each study site in the spring and summer of 2009, 2010, and 2011. Study sites included RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5. Three size classes of bass were sampled: 130 to 174 millimeter (mm) total length (TL), 175–250 mm TL, and > 250 mm TL. These size classes represented bass approximately age-1 plus, age-2 to age-3, and age-4 or older, respectively. Results indicated that mean length-normalized THg in smallmouth bass generally increased with distance down river although THg in fish tissue at sample locations RRM 3.5 and RRM 23.5 were similar. Mean length-normalized THg concentrations in smallmouth bass ranged from 0.73 (+/- 0.63) mg/kg wet weight (ww) (RRM 0.1) to 2.94 (+/- 0.99) mg/kg ww (RRM 11.8) (see Figure 3-2). Largemouth bass exhibited a similar trend in THg concentrations. Mean length-normalized THg concentrations ranged from 1.09 (+/- 0.83) mg/kg ww (RRM 0.1) to 2.95 (+/- 0.87) mg/kg ww at (RRM 11.8) (see Figure 3-2).

Integration with 100-Year Monitoring Program

The LTM Plan fish tissue sampling program has been designed to augment and integrate with existing and future datasets that are part of the VDEQ 100-Year Monitoring Program. Sampling locations are consistent both with established VDEQ sampling sites and target species (smallmouth and largemouth bass). During years when VDEQ is scheduled to collect fish tissue, sampling efforts will be combined in an effort to minimize the potential harm to the resident bass population.

Monitoring Activities: Adult Bass

Adult, edible-sized (i.e., > 7 inches) largemouth and smallmouth bass will be sampled to monitor trends in human exposure to mercury through consumption of adult fish. Fish will be collected by electro-fishing all likely habitats at a study site. Ten individual fish samples of each species will be collected at each sample location in the fall; bass will be monitored once annually at the four locations on the South River and two locations on

the South Fork Shenandoah River (RRM 26 and RRM 48), whereas the remaining four downstream locations will be monitored once every five years to correspond with the VDEQ 100-year monitoring program (see Table 2-2 and Figure 3-1). Concentrations of THg in biopsy plugs will be measured in order to obtain mercury data in a non-lethal manner. Additionally, total length and weight data will be collected. Complete details of adult bass tissue sampling procedures are provided in protocol SRBF-1 (see Appendix A). Data quality objectives are provided in Table 3-1.

Monitoring Activities: Creel Survey

As part of the on-going community outreach efforts being conducted on the South River, creel surveys documenting recreational fishing activities have been conducted in conjunction with VDGIF. These surveys serve to provide valuable information on recreational fishing use of the South River and angler/public awareness of the consumption bans/advisories that are in place. Additionally, they serve as a means to inform users of the river that may not be aware of the current advisories. Creel studies will be conducted every 3 to 4 years following similar methods used in previous surveys.

Sample Analysis

Fish tissue samples will be submitted to the certified analytical laboratory frozen and packed on dry ice. Fish tissue samples will be prepared, digested, and analyzed for THg in accordance with EPA Method 1631. An analytical sample matrix summarizing sample size, analytical methods, sample volumes, and associated method detection limits (MDLs) is presented as part of the QAPP (AECOM, 2018b).

3.3 Aquatic Ecological Exposure

In this section, specific monitoring elements to assess aquatic ecological exposure will be described, including YOY bass, sediment, and benthic invertebrates. A baseline characterization of mercury is also provided for sediment and benthic invertebrates. Data evaluation is addressed in Section 4.0 of this document.

3.3.1 Young-of-Year (YOY) Bass

Monitoring Activities

YOY bass sampling will be conducted to document potential declines in exposure due to remediation. In addition, YOY fish will be collected to monitor YOY exposure to mercury in water and dietary items and exposure of ecological receptors (e.g., piscivorous birds) to mercury in YOY fish. YOY fish are an ideal monitoring element to track long-term changes in mercury exposure due to the relatively short exposures that they experience and their site fidelity or small home range. YOY fish have been successfully used to track short-term (i.e., annual) changes in mercury exposure in several studies. For example, mercury loaded to an experimental lake via atmospheric deposition was detectable in YOY fish within two months (Harris et al., 2007); YOY fish are an important component of many regional mercury-monitoring plans (e.g., Slotton, 2008). In addition to the rapid responses to mercury loading, YOY fish are more spatially restricted (Minns, 1995) because they are subject to more intense predation and associate with protective cover (e.g., large woody debris; LWD).

A single event is warranted in the case of YOY fish in order to generate data that reflects a relatively short exposure period. YOY fish can be collected after only a few months of mercury exposure, whereas adult fish reflect several years of exposure.

YOY smallmouth bass will be collected as a representative YOY fish species. This is because smallmouth bass growth is relatively well understood and sampling can target fish that are only a few months old. The Bioaccumulation and Aquatic System Simulator (BASS) model (version 2.7) was developed for Smallmouth bass in the South River that accurately predicts fish growth and mercury bioaccumulation (URS, 2012). Smallmouth bass ranging from approximately 60 to 130 mm total length will be collected in the fall of each year; this is the length predicted by the BASS model for age zero or YOY fish. Fish will be collected by electro-fishing all likely habitats at each of the six sample locations listed in Table 2-2. Per sample location, THg in ten whole fish samples will be measured once annually in the fall. Complete details of YOY fish tissue sampling procedures are provided in protocol SRBF-1 (see Appendix A). Data quality objectives are provided in Table 3-2.

3.3.2 Sediment

Historical Characterization of Mercury in Sediment

The substrate of the South River consists primarily of a coarse gravel/cobble river bed with very little fine sediment present. As suspended sediment is carried downstream, sediment is deposited in quiescent areas near the banks, including downstream of LWD accumulations (riparian trees that have fallen into the river) and bank obstructions such as living trees. Fine-grained sediment deposits tend to occur where the river slope is lower than about 0.0025 (Skalak and Pizzuto, 2010) and in near-bank areas that are immediately adjacent to the river bank.

A portion of the fine-grained sediment deposits were mapped by Pizzuto (2012), and were termed fine-grained channel margin (FGCM) deposits. Total mercury concentrations are highly variable in FGCM deposits, ranging from approximately 0.1 to 880 mg/kg (URS, 2012). Higher THg concentrations in FGCM deposits are found at depth, buried below fine sediment with more moderate concentrations in the range of tens of mg/kg. The concentrations of IHg in interstitial sediment increase rapidly between RRMs 0 and 12 reaching a maximum of around 20 mg/kg (see Figure 3-3). Beyond this point, concentrations decline, reflecting the decreased inputs of IHg from river banks and other sources.

Limited fine-grained sediment also occurs as interstitial sediment that is interspersed within the coarser substrates of the stream bed or channel area of the river. The areal extent of fine-grained sediment deposits is much smaller than the coarse-grained stream bed. Concentrations of IHg in interstitial sediment have been relatively consistent over the period of the Ecological Study (URS, 2012). Areas with higher MeHg concentrations in interstitial sediment are more ubiquitously distributed from RRM 0 to the confluence with the North River. MeHg concentrations are somewhat temperature dependent; the highest concentrations have been detected when surface water temperatures exceed approximately 12 degrees Celsius (°C). The percent of THg present as MeHg (%MeHg), which has been used in other systems to identify areas of methylation (e.g., Gilmour et al., 1998), is similarly temperature dependent. The %MeHg data also suggest that methylation occurs in the interstitial sediment at all stations between RRM 0 and RRM 25.

Monitoring Activities

Interstitial sediment will be collected to monitor exposure of invertebrates to sediment MeHg and assess rates of potential natural recovery of sediment. Samples will be collected once annually in the spring at five locations in the South River and two

locations on the SFS River (see Table 2-2 and Figure 3-1). Samples will be co-located with invertebrate sample collection locations (see Section 3.3). Three samples will be collected at each sampling location from coarse-grained substrate beds following procedures outlined in SRSE-01 (see Appendix A). All samples will be analyzed for THg and MeHg.

Sample Analysis

Sediment samples to be analyzed for MeHg will be submitted to the certified analytical laboratory frozen and packed on dry ice. Sediment samples to be analyzed for THg will be submitted to the laboratory packed on wet ice. Sediment samples will be analyzed for THg and MeHg in accordance with EPA Methods 1631 and 1630, respectively. An analytical sample matrix summarizing sample size, analytical methods, sample volumes, and associated MDLs is presented as part of the QAPP (AECOM, 2018b). Data quality objectives are provided in Table 3-3.

3.3.3 Benthic Invertebrates

Historical Characterization

Asiatic clams. The Asiatic clam (*Corbicula fluminea*) plays an important role in the aquatic and terrestrial food webs of the South River. *Corbicula* is widely abundant, is consumed by a variety of fish and wildlife species [e.g., crayfish (*Astracoidea*), muskrat (*Ondatra zibethicus*), raccoon (*Procyon lotor*), waterfowl, and white sucker (*Catostomas commersonii*)] and has been the subject of several studies in the South River (Covich et al., 1981; Perry and Uhler, 1981; McMahon, 1991; Bowles, 2003; Murphy 2004; Tumer, 2006; Neufeld, 2010). The characteristics of *Corbicula* also make it a good candidate for evaluating localized mercury bioavailability and uptake.

In 2009, uptake of IHg and MeHg was evaluated in transplanted *Corbicula* at South River study sites RRM 0.1, RRM 3.5, RRM 8.5, and RRM 23.5. *Corbicula* were collected from reference areas on the Middle River and transplanted to each study site using co-located deployment techniques (i.e., caging and seeding) previously established by SRST members (Neufeld, 2010). *Corbicula* were deployed in two different zones of the stream, hydraulic storage zone (near-bank) and hydraulic transport zone (mid-channel). To assess the accumulation of mercury by *Corbicula* over time, samples were collected after one, three, and five weeks of exposure. Results indicated that MeHg concentrations in transplanted *Corbicula* increased with distance downstream [RRM 0.1, mean MeHg 11.8 nanograms per gram (ng/g) ww; RRM 23.5, mean MeHg 61.9 ng/g ww] (see Figure 3-4). IHg concentrations in transplanted *Corbicula* increased from RRM 0.1 to RRM 3.5, and then decreased with distance downstream (RRM 0.1, mean IHg 18.9 ng/g ww; RRM 3.5, mean IHg 65.7 ng/g ww; RRM 23.5, mean IHg 41.3 ng/g ww) (see Figure 3-4).

Mayflies. In 2006, flathead mayflies (Order Ephemeroptera, family Heptageniidae) were collected as part of the invertebrate tissue monitoring for the Ecological Study (URS, 2012) due to their relatively high and spatially variable THg concentrations and their importance in the diets of several fish and bird species in the study area. Samples were collected from 12 South River sample locations in the spring, summer, winter, and fall, where organisms were available. Ecological Study results indicated that THg and MeHg concentrations in flathead mayfly nymphs increased with distance downstream from RRM 0 (see Figure 3-5) Methylmercury concentrations in flathead mayfly nymph tissue were also substantially higher in the spring compared to the other season sampled,

which was consistent among study locations. Flathead mayfly nymphs have since been collected for THg and MeHg tissue analysis for a number of additional ecological investigations of the South River.

Monitoring Activities

Asiatic Clam. Aqueous uptake of THg and MeHg by *Corbicula* will be monitored bi-annually in the spring and fall at each of the seven locations listed in Table 2-2. Similarly sized *Corbicula* will be collected from reference areas in the Middle River and deployed in cages at each location. Per location, three cages will be deployed in the hydraulic transport zone of the stream (mid-channel). Transplanted *Corbicula* will be harvested from the cages after a five-week deployment period. Three composite samples, comprised of 10 individuals (n = 10) each, will be collected from each location per sample event. *Corbicula* shell width and weight will be measured to account for any potential differences or trends. The organisms will be depurated for a period of 24 hours to allow for clearance of gut contents prior to shipping to a certified laboratory where composite samples will be homogenized and analyzed for THg and MeHg. Complete details of Asiatic clam tissue sampling procedures are provided in protocol SRBI-1 (see Appendix A). Data quality objectives are provided in Table 3-4.

Mayfly. Flathead mayflies (Order Ephemeroptera, family Heptageniidae) will be collected to monitor THg concentrations in invertebrate tissue at each of the seven locations listed in Table 2-2. Three samples will be collected from stream substrates at each sample location annually in the late spring/summer. Cobbles will be removed from the river and rinsed in a sorting tray for invertebrate collection. A sample size of three benthic invertebrate samples has been selected to allow for comparisons between sample locations, sample months, and between pre- and post- remedial measures. Each invertebrate replicate sample will be a composite of 10 individual (n = 10) flathead mayflies. The organisms will be depurated for a period of 24 hours to allow for clearance of gut contents prior to shipping to a certified laboratory for THg analysis. Complete details of mayfly sampling procedures are provided in protocol SRBI-2 (see Appendix A). Data quality objectives are provided in Table 3-4.

Sample Analysis

Asiatic Clam. Asiatic clam tissue samples will be submitted to the certified analytical laboratory frozen and packed on dry ice. Samples will be prepared, digested, and analyzed for THg and MeHg in accordance with EPA Methods 1631 and 1630, respectively. An analytical sample matrix summarizing sample size, analytical methods, sample volumes, and associated MDLs is presented as part of the QAPP (AECOM, 2018b).

Mayfly. Mayfly tissue samples will be submitted to the certified analytical laboratory frozen and packed on dry ice. Samples will be prepared, digested, and analyzed for THg in accordance with EPA Method 1631. An analytical sample matrix summarizing sample size, analytical methods, sample volumes, and associated MDLs is presented as part of the QAPP (AECOM, 2018b).

3.4 Terrestrial Ecological Exposure

In this section, specific monitoring elements to assess terrestrial ecological exposure will be described, including passerine birds and terrestrial invertebrates, specifically wolf

spiders. A baseline characterization of mercury, description of monitoring activities and sample analysis is provided for each monitoring element.

3.4.1 Passerine Birds

Historical Characterization of Mercury in Carolina Wren

Several studies have been conducted to evaluate the potential accumulation of mercury in songbirds in habitat adjacent to South River and South Fork Shenandoah River. These studies found that terrestrial Carolina wrens (*Thryothorus ludovicianus*) that occupy the terrestrial floodplain adjacent to South River had mercury in their blood and feathers at concentrations that were elevated above reference (Cristol et al., 2008; Jackson and Evers, 2011). Jackson and Evers (2011) evaluated THg concentration in blood samples from 117 Carolina wrens collected adjacent to the South River and at reference sites in 2009 and 2010. Mean (+/- SD) THg concentrations for Carolina wrens from the South River were 2.62 (±1.22) mg/kg (2009) and 1.87 (±0.69) mg/kg (2010), compared to 0.35 (+/-0.19) mg/kg (2009) and 0.20 (+/- 0.10) mg/kg (2010) at reference sites. The Carolina wren is a year-round resident bird that is widely distributed in the watershed, making it suitable for long-term monitoring.

Monitoring Activities

Mercury exposure in Carolina wren will be monitored at nine study locations (two reference and seven study sites) within the AOC 4 study area (see Table 2-2 and Figure 3-1). The goal is to collect blood samples from three to eight individuals at each study site on a triennial basis, in the summer months (June-July). Birds will be collected using nylon mist nets; when a bird strikes the net, it drops into a pocket where it is retrieved by an experienced handler. Nets will be positioned in suitable, shaded habitats, or in areas without direct sun exposure, and will be checked every 15 to 20 minutes while active. Nets will be closed during unfavorable conditions, such as weather or predation, or if proper monitoring is not possible.

The area where the net is deployed will be monitored from a distance. If a bird is detected, it will be removed immediately and processed. If there are multiple target species collected in the net, individual birds will be removed immediately and placed into small holding bags or buckets in a cool shady location. Captured birds will be processed as quickly as possible and will not be left in the bags for longer than 15 minutes. Special care will be taken to avoid harming captured birds. Several tools will be on hand to remove entangled birds from the net, including a small crotchet hook and small clippers. Following retrieval from the net, the bird will be evaluated and blood will be sampled under the procedures detailed in protocol SRAT-1 (see Appendix A). Data quality objectives are provided in Table 3-5.

Sample Analysis

Avian blood samples will be submitted to the certified analytical laboratory frozen and packed on dry ice. Blood samples will be digested as tissue samples and analyzed for THg in accordance with EPA Method 1631. Previous work has established that 90-100% of mercury in bird blood is present as MeHg (Rimmer et al., 2005). An analytical sample matrix summarizing sample size, analytical methods, sample volumes, and associated MDLs is presented as part of the QAPP (AECOM, 2018b).

3.4.2 Terrestrial Invertebrates

Historical Characterization of Mercury in Spiders

Spiders are an important food item for songbirds and may be an important potential link in the transfer of MeHg between the aquatic and terrestrial components of the South River (Cristol et al., 2008). Spiders accumulate mercury by feeding on a variety of invertebrates, including emergent aquatic insects, over wide foraging areas in the terrestrial environment (Howie, 2010). Sampling the diet of terrestrial songbirds, Cristol et al. (2008) found that the THg concentration in spiders was 1.24 ± 1.47 mg/kg dry weight which was higher than that in lepidopterans (0.38 ± 2.08 mg/kg) and orthopterans (0.31 ± 1.22 ppm).

Monitoring Activities

Wolf spiders (family *Lycosidae*) will be sampled to evaluate potential trophic transfer of mercury from the aquatic to the terrestrial food chain. Five wolf spiders will be collected and analyzed individually from nine study sites (two reference and seven study sites) within AOC 4 in the spring or summer (see Table 2-2 and Figure 3-1). Spiders will be collected by active capture (sweep netting) and passive dry pitfall trapping techniques. Once collected, spiders will be immediately euthanized on dry ice prior to processing. Length (combined cephalothorax/abdomen length) and weight (grams) data will be collected prior to being rinsed and placed into laboratory supplied bottleware. Samples will be analyzed for THg. Detailed procedures for spider tissue sampling are provided in protocol SRBS-1 (see Appendix A). Data quality objectives are provided in Table 3-6.

Sample Analysis

Spider samples will be submitted to a Virginia-certified analytical laboratory frozen and packed on dry ice. Samples will be digested and analyzed for THg in accordance with EPA Method 1631. An analytical sample matrix summarizing sample size, analytical methods, sample volumes, and associated MDLs is presented as part of the QAPP (AECOM, 2018b).

3.5 Water and Habitat Quality

In this section, specific monitoring elements to surface water and habitat quality will be described. A baseline characterization of mercury, description of monitoring activities and sample analysis is provided for surface water.

3.5.1 Surface Water Quality

Surface water samples will be collected in AOC 4 to monitor long-term changes in mercury species, ancillary parameters and nutrients in response to remediation. Surface water sampling integrates existing routine monitoring programs conducted by DuPont and VDEQ, and builds on a long-term (1999-present) database. In addition, surface water sampling is useful in identifying the effect of climate and interannual variability on mercury methylation in the South River, providing an important context for other data (e.g., mercury concentrations in fish tissue).

Historical Surface Water Conditions

Under baseline flow (i.e., non-storm) conditions as defined in the Ecological Study (URS, 2012), the concentration of IHg in particles of surface water increases immediately downstream of the historical outfall at RRM 0 and rises rapidly, reaching a maximum at

RRM 5.2. Particulate IHg concentrations remain somewhat constant (approximately 25 mg/kg) until they decline at approximately RRM 12 (see Figure 3-6) This suggests that particulate IHg is being diluted by low mercury concentration particles in the reach between RRMs 12 and 25. Dissolved (filter-passing) IHg concentrations in South River surface water increase with distance downstream from RRM 0, to approximately RRM 12.

The areas with the highest surface water MeHg concentrations tend to be more widely dispersed, likely due to the widespread methylating capacity of sediment in the South River (Yu et al., 2011). In general, surface water MeHg concentrations are highest between RRMs 10 and 12. MeHg exhibits strong seasonality, increasing in concentration when surface water temperatures reach approximately 12 °C; concentrations do not necessarily increase with temperature throughout the late summer (URS, 2012). Under baseline conditions, positive incremental mass loadings of THg and MeHg are constrained to approximately the first 10 to 12 river miles downstream of the site.

The South River has been identified as impaired for benthic habitat quality between RRM 0 and the confluence between the South River and Stull Run, at approximately RRM 14 (VDEQ, 2009). The most probable stressors causing the impairment are loadings of sediment and phosphorus from point and non-point sources to surface water. The benthic impairment is driven by several factors, including low bank stability, high substrate embeddedness, poor riparian and bank vegetation, and suboptimal riffle stability habitat scores. South River monitoring stations had total phosphorous concentrations that exceed VDEQs 'Threatened Waters' (VDEQ, 2009).

Monitoring Activities

Samples are currently collected on an approximately monthly basis through coordination between VDEQ and DuPont; this will continue throughout the LTM program. Baseline surface water samples will be collected from bridges along the South River (see Figure 3-1) and at locations in the SFS River. The sample locations are listed in Table 3-1. Water samples will be collected using either a diaphragm or submersible pump following the methods outlined in sampling protocol SRSW-1 (see Appendix A). Samples will be collected from 0.3 meters below the water surface of the thalweg. Water samples will be analyzed for THg, MeHg, filtered total mercury (FTHg), filtered methylmercury (FMeHg), total organic carbon (TOC), dissolved organic carbon (DOC), total suspended solids (TSS), and various nutrients, including phosphorous. Select additional parameters may be added to the monitoring program to compliment the data already collected by the VDEQ Surface Water Monitoring Program to describe other potential stressors in surface water (e.g., nutrients). Sample aliquots will be filtered using a 0.45 µm filter submitted for analyses of FTHg, FMeHg, and DOC. Two replicate samples will be collected at each location for filtered and unfiltered THg and MeHg as well as TSS. Data quality objectives are provided in Table 3-7.

Sample Analysis

Surface water samples will be submitted to the certified analytical laboratory packed on wet ice. Samples will be analyzed for THg/FTHg, MeHg/FMeHg, TSS, TOC/DOC, phosphorous, chloride/sulfate, nitrogen, alkalinity, and calcium/magnesium/potassium/sodium, in accordance with EPA Methods 1631, 1630, 2540 D-1997, 5310 C-2000, 365.1, 300, 353.2, 2320 B-1997, and 6010B, respectively. An analytical sample matrix summarizing sample size, analytical methods, sample volumes, and associated MDLs is presented as part of the QAPP (AECOM, 2018b).

3.5.2 Benthic Invertebrate Sampling

Historical Conditions

Benthic macroinvertebrate communities have been investigated as part of the Ecological Study (URS, 2012). As part of this study benthic invertebrate communities were sampled quarterly in riffle and pool habitats at South River sample locations from March 2006 to February 2007. Sample locations included RRM 0.6, RRM 5.2, RRM 11.8, RRM 14.6, RRM 19.0, RRM 22.4, and SFS-01. Phase I results indicated that benthic community structure and composition varies spatially and temporally in the South River.

Two benthic macroinvertebrate community investigations were conducted as part of the Phase II Ecological Study. A sediment quality triad (SQT) investigation was conducted in May 2010 to evaluate potential sediment-associated impacts to benthic macroinvertebrate communities in the South River. As part of the SQT investigation, benthic community samples were collected from Phase II sample locations RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5, as well as a reference location on the South River (SR-01) and Middle River (MR-01). Results of the SQT investigation indicated that benthic macroinvertebrate community structure did not differ significantly between SQT study sites and pooled reference areas; however, relative abundance of sensitive taxa, Ephemeroptera and Trichoptera, were lowest at sample locations RRM 3.5 and 11.8, respectively.

In 2011, a benthic colonization study was implemented, based on procedures outlined by Klemm et al. (1990) and Clements et al. (1989), to assess potential stressor impacts on benthic macroinvertebrate colonization dynamics in the South River. Benthic community structure and colonization dynamics were assessed through the use of substrate-filled benthic colonization trays deployed for a six-week period from May to June 2011 and sampled at two-week intervals. Locations for the colonization study included four South River sampling locations RRM 0.1, RRM 3.5, and RRM 11.8, and reference area SR-01, as well as a reference area on the Middle River, MR-01. Results of the benthic colonization study indicated that the relative composition of functional feeding groups and major invertebrate class/orders were dynamic over the six-week colonization period; however, at the end of six-week colonization, the relative composition of functional feeding groups and major class/orders was not substantially different between study sites and pooled reference areas.

Benthic community data were compiled from these three investigations to produce general linear models to characterize spatial and temporal variation in macroinvertebrates and canonical discriminant analyses on physicochemical and macroinvertebrate data. Results suggested that effects of mercury on macroinvertebrate communities in the South River were minimal and likely confounded by natural variation in physicochemical variables, such as grain size, organic carbon content and other abiotic variables.

Monitoring Activities

As part of the LTM program, benthic macroinvertebrate communities will be sampled according to the Rapid Bioassessment Protocol (Barbour et al., 1999). Six replicate samples will be collected at each of the seven locations listed in Table 3-8 on a triennial basis in the spring and fall. Samples will be collected along a gradient from toe of pool, transitional, and head of riffle habitats at the left, middle, and right points of the wetted stream channel using a Surber sampler. Material collected will be transferred to an appropriately labeled sample container and preserved with 70 percent ethanol.

Preserved samples will be submitted to a benthic laboratory for taxonomic analysis. Complete details of benthic community sampling procedures are provided in protocol SRBI-3 (see Appendix A). Benthic community data are not intended to provide a measure of ecological exposure, so samples will not be analyzed for mercury species. Data quality objectives are provided in Table 3-8.

Sample Analysis

In the laboratory, benthic community samples will be subsampled using a random 300-organism sub-count in accordance with Barbour et al. (1999), which was developed using a 200-organism subcount but allows for the selection of any sub-count. Organisms included in the sub-count will be identified to the lowest taxonomic level practical, typically genus or species. Quality control on sorting procedures will be checked by re-sorting 20 percent of each sample to ensure 90 percent sorting efficiency. The accuracy of taxonomic identification will be evaluated by the re-identification of 10 percent of the samples by an experienced taxonomist to ensure 90 percent similarity. The results of QA/QC procedures for sorting efficiency and taxonomic analyses will be provided with the final data deliverable from the taxonomic laboratory.

Sample Analysis

Benthic macroinvertebrate community data will be analyzed using multi-metric and multivariate procedures to allow for comparisons between sample locations, sample months, and between pre- and post- remedial measures. Multi-metric evaluations will be consistent with frameworks established in Barbour et al. (1999). Specific community metrics that will be evaluated to characterize the benthic macroinvertebrate communities may include, but are not limited to, the following:

- Total abundance
- Taxa richness
- Percent Ephemeroptera
- Percent Ephemeroptera, Plecoptera, and Trichoptera
- Shannon’s diversity index
- Percent dominant taxa
- Percent tolerant individuals
- Modified Hilsenhoff biotic index
- Bray-Curtis dissimilarity coefficient
- Virginia Non-coastal Stream Condition Index (SCI)

Because of the significant influence of substrate characteristics on benthic habitat and the macroinvertebrates that colonize these habitats, along with the likelihood that substrate will respond to proposed habitat improvements, the LTM Plan will include quantitative substrate analysis. Traditional rapid bioassessment protocols for substrate and other habitat characteristics (e.g., Barbour et al., 1999) may lack sufficient detail to provide meaningful data. Substrate will be quantitatively characterized following the pebble count protocol described by Wolman (1954) and used to understand the percentage of the substrate that is less than 2 mm in diameter. A subset of these samples will be analyzed using a series of sieves to quantify grain size (e.g., 2, 4, 8, 16, 32, 64, 128, and 256 mm sieves). Because it is unlikely that substrate composition will

change seasonally or annually unless it is responding to local restoration treatments, substrate characterization should not require the temporal frequency proposed for the benthic communities.

4.0 Data Evaluation and Reporting

The 2017 Baseline LTM Report documented the first three years of monitoring data collected for AOC 4 from 2014 to 2016, prior to completion of the first IM (AECOM, 2017). Post-IM LTM reports will be provided every three years beginning with the 2019 event, to document the ecosystem response to remediation.

The LTM Plan was designed to have adequate statistical power to have a probability of at least 75% of finding a significant downward trend in mercury concentrations within three to five years. Three different trend tests were considered:

- Williams test
- Jonckheere-Terpstra
- Simple linear regression

The sample sizes proposed for the LTM Plan were determined following a power analysis described in the Remediation Proposal (Anchor QEA and URS, 2013). These tests will be employed following collection of three years of post-remediation data. Interim data analysis will focus on relationships between the data and the baseline conditions for each monitoring element.

The monitoring plan is designed to operate within a hypothesis-testing framework. Monitoring data will be collected to describe the effect of remediation on mercury transport pathways or routes of human or ecological exposure. As the monitoring program proceeds, results will be analyzed and reviewed with the appropriate regulatory agencies to determine to what degree, if any, the transport pathways or exposure routes are changing. Data sets that do not change, or that provide ambiguous results, may be collected at a reduced frequency, replaced by collection of data from an alternate medium, modified, or eliminated from the plan in the context of the adaptive management strategy. Conversely, additional sampling events/media may be required based upon unexpected results from the current monitoring program.

As part of the reporting process, results from human exposure monitoring efforts will be shared and discussed with the VDH and other relevant regulatory agencies to evaluate the need for additional outreach to local communities and whether additional consumption advisories are warranted.

5.0 Quality Assurance Project Plan

A programmatic QAPP incorporating the current policies, project organization, functional activities, analytical protocols, and quality assurance/quality control (QA/QC) measures intended to achieve the project data quality objectives will be in place for all investigations within AOC 4, including the LTM Plan (AECOM, 2018b). It is also intended to meet the requirements for conducting work in accordance with QA/QC field protocols for collecting environmental measurement data.

6.0 References

AECOM. 2018a. LTM Program Assessment and Recommended Modifications Memorandum, Former DuPont Waynesboro Site, Area of Concern 4. Issued March 23, 2018.

AECOM. 2018b. RCRA Quality Assurance Project Plan (QAPP). Former DuPont Waynesboro Site, Area of Concern 4. May 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

Anchor QEA and URS. 2013. Remediation Proposal – South River and a Segment of the South Fork Shenandoah River, Virginia. Final report prepared by Anchor QEA, 2013.

Anchor QEA, URS, and E.I. du Pont de Nemours and Company. 2015. Final Interim Measures Design, Implementation and Monitoring Work Plan. Phase I – South River Area of Concern 4. 471 pp.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. USEPA 841-B-99-002. USEPA Office of Water, Washington, D.C.

Bowles, M.W. 2003. Biomonitoring of Mercury in the South River Using Asiatic Clam, *Corbicula fluminea*. Undergraduate Thesis. James Madison University, Harrisonburg, Virginia.

Clements, W.H., J.H. Van Hassel, D.S. Cherry, and J. Cairns, Jr. 1989. Colonization, variability, and the application of substratum-filled trays for biomonitoring benthic communities. Hydrobiologia 173:45-53.

Covich, A.P.; L.L. Dye; and J.S. Mattice. 1981. “Crayfish Predation on *Corbicula* Under Laboratory Conditions.” American Midland Naturalist 105(1):181-188.

Cristol, D.A., R.L. Brasso, A.M. Condon, R.E. Fovargue, S.L. Friedman, K.K. Hallinger, A.P. Monroe, A.E. White. 2008. The movement of aquatic mercury through terrestrial food webs. Science. 320: 335.

EPA. 2004. Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation. OSWER 9355.4-28. U.S. Environmental Protection Agency, Washington, D.C. January, 2004.

EPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. EPA-540-R-05-012. OSWER 9355.0-85. U.S. Environmental Protection Agency, Washington, D.C. December 2005.

Gilmour, C. C., G.C. Riedel, M.C. Ederington, J.T. Bell, G.A. Gill, and M.C.Stordal. 1998. Methylmercury concentrations and production rates across a trophic gradient in the northern Everglades. Biogeochemistry. 40(2-3), 327–345.

Harris, R.C., J.W.M. Rudd, M. Amyot, C.L. Babiarz, K.G. Beaty, P.J. Blanchfield, R.A. Bodaly, B.A. Branfireun, C.C. Gilmour, J.A. Graydon, A. Heyes, H. Hintelmann, J.P. Hurley, C.A. Kelly, D.P. Krabbenhoft, S.E. Lindberg, R.P. Mason, M.J. Paterson, C.L. Podemski, A. Robinson, K.A. Sandilands, G.R. Southworth, V.L. St. Louis, and M.T. Tate, 2007. Whole-ecosystem study shows rapid fish-mercury response to changes in mercury deposition. PNAS 104(42): 16586-16591.

Howie, M.G. 2010. The lateral extent and spatial variation of mercury exposure in birds and their prey near a polluted river. Masters Thesis. College of William & Mary, Williamsburg, VA.

Jackson, A.K. D.C. Evers, M.A. Etterson, A.M. Condon, S.B. Folsom, J. Detweiler, J. Schmerfeld, D.A. Cristol. 2011. Mercury exposure affects the reproductive success of a free-living terrestrial songbird, the Carolina Wren (Thryothorus ludovicianus). The Auk. 128(4): 759-769.

Klemm, D.J., P.A. Lewis, F. Fulk, and J.M. Lazorchak. 1990. Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.. USEPA 600-4-90-030.

Landis, W.G., K.K. Ayre, A.F. Johns, H.M. Summers, J. Stinson, M.J. Harris, C.E. Herring, A.J Markiewicz. 2015. The multiple stressor ecological risk assessment for the mercury-containing South River and Upper Shenandoah River using the Bayesian Network-Relative Risk Model. Integrated Environmental Assessment and Management 13(1): 85-99.

McMahon, R.F. 1991. “Mollusca: Bivalvia.” in J.H. Thorp and A.P. Covich (eds.), Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc., San Diego, California. p. 315-399.

Minns, C.K. 1995. Allometry of home range size in lake and river fishes. Canadian Journal of Fisheries and Aquatic Sciences 52(7): 1499–1508.

Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Masters Thesis. Virginia Tech, Blacksburg, Virginia.

Murphy, G.W. T.J. Newcomb, D.J. Orth, and S.J. Reeser. 2005. “Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia.” Proceedings of the Southeastern Association of Fish and Wildlife Agencies 31:587-596.

Neufeld, D.S.G. 2010. Mercury accumulation in caged *Corbicula*: rate of uptake and seasonal variation. Environmental monitoring and assessment. 168: 385-396.

Perry, M.C. and F.M. Uhler. 1981. “Asiatic clam (*Corbicula manilensis*) and Other Foods Used by Waterfowl in the James River, Virginia.” Estuaries 4(3):229-233.

Pizzuto, J.P. 2012. Geomorphic Processes and Inorganic Mercury: Studies of the South River, Virginia, 2004-2012. University of Delaware. May 9.

Rimmer, C.C., K.P. McFarland, D.C.Evers, E.K. Miller, Y. Aubry, D. Busby, R.J.Taylor. 2005. Mercury concentrations in Bicknell’s thrush and other insectivorous passerines in montane forests of northeastern North America. Ecotoxicology 14:223–240.

Skalak, K.J. and J.P. Pizzuto. 2010. The distribution and residence time of suspended sediment stored within the channel margins of a gravel-bed bedrock river. *Earth Surf. Proc. Land*. 35(4): 435–446.

Slotton, D. 2008. The UC Davis Biosentinel Mercury Program: Using Small Fish to Monitor Fine-scale Patterns of Methylmercury Contamination in the Watershed Fact Sheet. The Fish Mercury Project. San Francisco Estuary Institute Contribution No. 552.

Tumer, T.A. 2006. The Mercury Uptake and Bioaccumulation by Resident Muskrats of the South River, Virginia. Masters thesis. James Madison University, Harrisonburg, Virginia.

URS, 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.

VDEQ. 2009. Bacteria and Benthic Total Maximum Daily Load for South River. Prepared by Engineering Concepts, Inc. July 2009.

VDGIF. 2014. Nongame Fish, Reptile, Amphibian and Aquatic Invertebrate Regulations. http://www.dgif.virginia.gov/fishing/regulations/nongame.asp

VDH (Virginia Department of Health). 2001. Virginia Department of Health Expands Fish Advisory for Mercury. Virginia Department of Health, Richmond, VA. 2p.

Wolman, M.G. 1954. A method of sampling coarse river bed material. Trans. Am. Geophys. Union 35, 951– 956.

Yu, R., J. Flanders, E.E. Mack, R.R. Turner, M. Bilal Mirza, and T. Barkay. 2011. Contribution of Coexisting Sulfate and Iron Reducing Bacteria to Methylmercury Production in Freshwater River Sediments. Environmental Science Technology 46(5): 2684–2691.

Tables

Table 2-1
Short-Term Monitoring Scope Summary
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

Short-Term Remedial Action Objectives				Monitoring Plan Designs			Adaptive Management Outcomes	
General Objective	**Performance Objective**	**Measurable Metric**	**Preliminary Success Criteria**	**General Station Locations**	**Monitoring Frequency**	**Analytical Parameters**	**Contingency Actions**	**Decision Analysis**
Reduce Mercury Transport and Exposure	Increase in Bank Stability	Topography	Reduced Annual Erosion Rate	Maintenance of consistent bank angle	Annually for First 3 Years; Post-storm	Average Annual Erosion Rate	Structural and/or Vegetative Stabilization	Refine Effectiveness Estimates
		Vegetation	>80% Cover; <10% Invasives	Vegetation Plots at Each BMA	Annually for First 3 Years; Post-storm	Cover and Species Composition	Additional Vegetation Enhancement	Refine Effectiveness Estimates
		Design and Implementation	Landowner Approvals and Permits	BMA Properties	NA	NA	NA	Refine Implementation Estimates
	Reduce Mercury Loading from Bank	Surface Sediment	>75% Mercury Concentration Reduction	Transects Spaced 100-200' at each BMA	Twice Annually for First 3 Years	IHg and MeHg Concentrations	NA	Refine Effectiveness Estimates
		Pore Water	>75% Mercury Concentration Reduction	Transects Spaced 100-200' at each BMA	Twice Annually for First 3 Years	IHg and MeHg Concentrations	NA	Refine Effectiveness Estimates
		Periphyton	>75% Mercury Concentration Reduction	Downstream of Representative BMAs (Nearshore)	Twice Annually for First 3 Years	IHg and MeHg Concentrations	NA	Refine Effectiveness Estimates
		Asiatic Clam Sampling	>75% Mercury Concentration Reduction	Downstream of Representative BMAs (Nearshore)	Twice Annually for First 3 Years	IHg and MeHg Concentrations	NA	Refine Effectiveness Estimates
	Reduce In-Channel Mercury Exposure	Periphyton	>50% Mercury Concentration Reduction	Downstream of Representative BMAs (Channel)	Annually for First 10 Years	IHg and MeHg Concentrations	NA	Refine CSM
		Asiatic Clam Sampling	>50% Mercury Concentration Reduction	Downstream of Representative BMAs (Channel)	Annually for First 10 Years	IHg and MeHg Concentrations	NA	Refine CSM
Maintain or Improve Riparian and Aquatic Habitat	Improve Bank Vegetation	Vegetation	>80% Cover; <10% Invasives	Vegetation Plots at Each BMA	Annually for First 3 Years	Cover and Species Composition	Additional Vegetation Enhancement	Refine Effectiveness Estimates
	Improve In-Stream Habitat	Rapid Bioassessment Protocols	Visual Stream Classification	Downstream of Representative BMAs	Quarterly for the First Year and Semi Annually (Q1/Q3) for years 2-10	Rapid Bioassessment Protocol Scores	NA	Refine Effectiveness Estimates

Notes:
NA, Not applicable
IHg - Inorganic Mercury
MeHg - MethylMercury
CSM - Conceptual Site Model
BMA - Bank Management Area

Table 2-2
Long-Term Monitoring Scope Summary
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

Monitoring Element	Objective	Measurements	Proposed Sampling Frequency	Samples per Location	Locations
Monitor Potential Human Exposure					
Largemouth Bass Smallmouth Bass	● Monitor trends in human exposure to MeHg in adult fish	● THg in biopsy plugs ● Total length, weight	● Annually (Fall): SR Locations + RRM 26 and RRM 48; ● Every 5 years (Fall): All locations	10 bass (SMB and LMB)	**South River:** RRM -2.7* RRM 0.1 to 2.3 RRM 5.2 to 11.8 RRM 16 to 23.5 **SFS:** Island Ford (RRM 26) Shenandoah, VA boat ramp (RRM 48) Newport Landing (RRM 63) Hamburg, VA near Rt. 211 bridge (RRM 72) Bentonville Landing near Rt. 613 bridge (RRM 106) **Shenandoah River:** Rt. 17/50 bridge (RRM 143)
Community Outreach	● Monitor trends in human exposure to mercury, including adherence to the fish consumption advisory	● Outreach to non-English-speaking communities (e.g., the Promotores de Salud program and outreach to other non-English language groups) ● Physician and clinic newsletters ● Angler surveys	● Annual outreach to non-English speaking groups, local physicians, and health clinics ● Once every 3 years for the angler survey	NA	Focused on Waynesboro, but also including the downstream locales of Dooms, Crimora and Grottoes. Also dependent on locations of local/state health clinics.
Monitor Ecological Exposure					
Aquatic					
YOY Fish	● Monitor exposure of YOY fish to Hg in water and dietary items ● Monitor exposure of ecological receptors (e.g., piscivorous birds) to Hg in YOY fish ● Document potential declines in exposure due to remediation	● THg in whole fish	Once annually (Fall)	10	RRM -2.7* RRM 0.1 to 2.3 RRM 5.2 to 11.8 RRM 16 to 23.5 SFS near Lynwood, VA (RRM 26) SFS near Shenandoah, VA (RRM 48)
Sediment	● Monitor exposure of invertebrates to sediment MeHg ● Monitor natural recovery of sediment	● THg and MeHg in sediment collected from coarse grained beds	Once annually (Spring)	3	RRM -2.7* RRM 0.1 RRM 3.5 RRM 11.8 RRM 23.5 SFS near Lynwood, VA (RRM 26) SFS near Shenandoah, VA (RRM 48)
Benthic Invertebrates	● Monitor exposure to invertivorous ecological receptors (e.g., YOY fish) ● Monitor responses to decreasing mercury loads	● THg in Mayfly tissue	Once annually (Spring)	3	
Asiatic Clam Tissue	● Provide a data set for comparison with short-term monitoring elements	● THg, MeHg in Asiatic clam tissue	Twice annually (Spring and Fall)	3	
Terrestrial					
Adult Carolina Wren	● Monitor songbird exposure to MeHg	● THg in blood ● Weight	Once triennially (Spring/Summer)	3-8 individuals	**South River (Reference):** Waynesboro Nursery (RRM -6.2)* Ridgeview Park (RRM -1.2)* **South River:** RRM 0.1 to 2.3 RRM 9 (Pond Pilot area) Grottoes City Park (RRM 22) **SFS:** Power Dam (RRM 31) Shuller's Island (RRM 50) Long Bend Farm (RRM 66) Bealer's Ferry (RRM 85)
Wolf Spiders (family Lycosidae)	● Monitor exposure of terrestrial ecological receptors to Hg in spiders ● Monitor Hg transfer between aqueous and terrestrial compartment of the South River	● THg in spiders ● Size	Once annually (Spring/Summer)	5 individuals	
Water Quality and Habitat Quality Monitoring					
Water Quality**	● Monitor trends in water quality ● Provide information on inter-annual ● Continue to describe behavior of mercury species in South River	● Surface water: THg, FTHg, MeHg, FMeHg, TSS, TOC, DOC, phosphorous, chloride, sulfate, nitrogen, alkalinity, calcium, magnesium, potassium, sodium, and water quality parameters (temperature, pH, DO, conductivity)	Monthly**	1 to 2**	**South River:** RRM -2.7* RRM 0.2 RRM 2.3 RRM 5.2 RRM 9.9 RRM 16.5 RRM 23.5 **SFS:** Lynnwood, Rt 708 (RRM 26) Shenandoah, below dam (RRM 48) Rt. 663 (RRM 94)
Benthic Invertebrate Community	● Monitor improvements to benthic community and benthic habitat	● Benthic community (300 count subsampling)	Triennial (Spring and Fall)	6	RRM -2.7* RRM 0.1 RRM 3.5 RRM 11.8 RRM 23.5 Middle River*
		● Substrate condition	Once annually (Fall)	--	

Notes:
DO: dissolved oxygen; DOC: dissolved organic carbon; MeHg: methylmercury; RRM: relative river mile; SFS: South Fork Shenandoah River; T: temperature; THg: total mercury; TOC: total organic carbon; TSS: total suspended solids; YOY: Young-of-Year; LMB: Largemouth bass; SMB: Smallmouth bass
* Reference area
** Sampling conducted in concert with VADEQ routine monitoring; as a result, some parameters are analyzed on a different frequency or for different numbers of replicates
NA, Not applicable

Table 3-1
Data Quality Objectives for Adult Bass Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	The consumption of fish tissue by people is one of the main sources of potential mercury exposure in the South River and South Fork Shenandoah River.
STEP 2: Identify the goals of the study	The fish tissue monitoring program has the following two primary objectives: • Identify trends in potential human exposure to mercury. • Assess variability in total mercury concentrations in adult bass based on seasonality and sex.
STEP 3: Identify the information inputs	Existing Data • A number of studies have evaluated mercury concentrations in fish tissue from the South River and South Fork Shenandoah River including data sets collected by VADEQ and other members of the South River Science team. The following studies have provided data/input that was considered when designing the current study: VADEQ (multiple datasets); Murphy 2004; URS 2012. Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017). New Data To Be Collected • Fish tissue samples (plugs) will be collected from 10, edible-sized largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*) at each study location. Samples will be analyzed for total mercury as described below.

Table 3-1
Data Quality Objectives for Adult Bass Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4: Define the boundaries of the study</td><td>
Geographic Area
Smallmouth and Largemouth bass tissue samples will be collected at 13 stations on the South River, South Fork Shenandoah River and Shenandoah River. The stations include:
<table>
<tr><th>Station ID</th><th>Description</th></tr>
<tr><td>SR-2.7</td><td>Existing SR-01 located at Lyndhurst Ave. to Ridgeview Park</td></tr>
<tr><td>SR0.1</td><td>Constitution Park/Waynesboro Reach</td></tr>
<tr><td>SR11.8</td><td>Dooms to Crimora Reach</td></tr>
<tr><td>SR23.5</td><td>Harriston to Port Republic Reach</td></tr>
<tr><td>SF26.6</td><td>South Fork Shenandoah @ Lynwood</td></tr>
<tr><td>SF48</td><td>SFS @ Shenandoah (above dam)</td></tr>
<tr><td>SF63</td><td>Newport Landing</td></tr>
<tr><td>SF72</td><td>Hamburg, VA near Rt. 211 Bridge</td></tr>
<tr><td>SF106</td><td>Bentonville Landing, near Rt. 613 Bridge</td></tr>
<tr><td>SH143</td><td>Rt. 17/50 Bridge</td></tr>
</table>
Note: Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.

Timeframe
Sampling and analysis will occur annually in the fall for South River sites, SF26.6 and SF48.
Sampling and analysis will occur once every five years in the fall for all sites, coinciding with the VDEQ 100-Year monitoring program.
Sample Type
Tissue biopsy plugs (3-3.5 mm) will be collected in the field from each fish.
</td></tr>
<tr><td>STEP 5: Develop the analytical approach</td><td>Plug samples will be analyzed for total mercury (EPA 1631). Additionally, percent solids analysis (SM 2540 G-1997) will be performed on representative tissue plug samples per species.</td></tr>
</table>

Table 3-1
Data Quality Objectives for Adult Bass Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 6: Specify performance or acceptance criteria</td><td>Field quality control sampling (field duplicates) will not be collected for biological samples. Laboratory duplicate samples will be analyzed from separate aliquots of the same parent sample after homogenization of the sample media.

Acceptance criteria for laboratory quality assurance samples and reporting limits are provided below.
<table>
<tr><th>Analyte</th><th>Laboratory Precision % RPD (LCSD)</th><th>Laboratory Accuracy % Recovery (LCS)</th><th>Laboratory Precision % RPD (MSD or Lab DUP)</th><th>Laboratory Accuracy % Recovery (MS)</th><th>Laboratory Reporting Limit (MDL)</th><th>Laboratory Reporting Limit (RL)</th><th>Project Reporting Limit (RL)</th></tr>
<tr><td>Total Mercury</td><td>30</td><td>75 - 125</td><td>30</td><td>70 - 130</td><td>0.12 ng/g</td><td>0.40 ng/g</td><td>0.40 ng/g</td></tr>
<tr><td>% Total Solids / % Dry Weight</td><td>N/A</td><td>N/A</td><td>15%</td><td>N/A</td><td>0.10%</td><td>0.1 ng/g</td><td>0.1 ng/g</td></tr>
</table>
Notes:
N/A - Not analyzed; LCS and LCSD will not be run for % solids analysis</td></tr>
<tr><td>STEP 7: Develop the detailed plan for obtaining data</td><td>Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018).</td></tr>
</table>

References:

AECOM, 2018. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Masters Thesis. Virginia Tech, Blacksburg, Virginia.

URS, 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.

Table 3-2
Data Quality Objectives for Young-of-Year Bass Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	The consumption of fish by ecological receptors in the South River and South Fork Shenandoah Rivers is an important mercury exposure pathway. Among small sized fish (i.e. <130 millimeters) from the South River, juvenile smallmouth bass (*Micropterus dolomieu*) have been demonstrated to have the highest mercury concentrations due to dietary preferences (Murphy, 2004).
STEP 2: Identify the goals of the study	The fish tissue monitoring program has the following three primary objectives: • Monitor exposure of Young-of-Year (YOY) fish to mercury in water and dietary items. • Monitor exposure of ecological receptors (e.g., piscivorous birds) to mercury in YOY fish. • Document potential declines in mercury exposure due to remediation.
STEP 3: Identify the information inputs	Existing Data • To date there have been limited studies evaluating mercury concentrations in YOY bass from the South River or the South Fork Shenandoah River. Murphy (2004) characterized mercury concentrations in prey items (including juvenile smallmouth bass) within the South River and South Fork Shenandoah Rivers. • Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017). New Data to Be Collected • Ten YOY smallmouth bass will be collected at each monitoring location. Fish will be analyzed as whole-fish samples for total mercury and percent solids as described below.

Table 3-2
Data Quality Objectives for Young-of-Year Bass Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4: Define the boundaries of the study</td><td>
Geographic Area
Smallmouth bass samples will be collected at six stations on the South River, South Fork Shenandoah River and Shenandoah River. The stations include:
<table>
<tr><th>Station ID</th><th>Description</th></tr>
<tr><td>SR-2.7</td><td>Existing SR-01 located at Lyndhurst Ave. to Ridgeview Park</td></tr>
<tr><td>SR0.1</td><td>Constitution Park/Waynesboro Reach</td></tr>
<tr><td>SR11.8</td><td>Dooms to Crimora Reach</td></tr>
<tr><td>SR23.5</td><td>Harriston to Port Republic Reach</td></tr>
<tr><td>SF26.6</td><td>South Fork Shenandoah @ Lynwood</td></tr>
<tr><td>SF48</td><td>SFS @ Shenandoah (above dam)</td></tr>
</table>
Note: Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.

Timeframe
Sampling and analysis will occur annually in the fall.
Sample Type
Samples for analysis will consist of individual, whole-body, YOY smallmouth bass.
</td></tr>
<tr><td>STEP 5: Develop the analytical approach</td><td>Samples will be analyzed for total mercury (EPA 1631) and percent solids analysis (SM 2540 G-1997).</td></tr>
<tr><td>STEP 6: Specify performance or acceptance criteria</td><td>
Field quality control sampling (field duplicates) will not be collected for biological samples. Laboratory duplicate samples will be analyzed from separate aliquots of the same parent sample after homogenization of the sample media.

Acceptance criteria for laboratory quality assurance samples and reporting limits are provided below.
<table>
<tr><th>Analyte</th><th>Laboratory Precision % RPD (LCSD)</th><th>Laboratory Accuracy % Recovery (LCS)</th><th>Laboratory Precision % RPD (MSD or Lab DUP)</th><th>Laboratory Accuracy % Recovery (MS)</th><th>Laboratory Reporting Limit (MDL)</th><th>Laboratory Reporting Limit (RL)</th><th>Project Reporting Limit (RL)</th></tr>
<tr><td>Total Mercury</td><td>30</td><td>75 - 125</td><td>30</td><td>70 - 130</td><td>0.12 ng/g</td><td>0.40 ng/g</td><td>0.40 ng/g</td></tr>
<tr><td>% Total Solids / % Dry Weight</td><td>N/A</td><td>N/A</td><td>15%</td><td>N/A</td><td>0.10%</td><td>0.1 ng/g</td><td>0.1 ng/g</td></tr>
</table>
Notes:

N/A - Not analyzed; LCS and LCSD will not be run for % solids analysis
</td></tr>
</table>

Table 3-2
Data Quality Objectives for Young-of-Year Bass Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 7: Develop the detailed plan for obtaining data	Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018).

References:

AECOM, 2018. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April, 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

Murphy, G.W. 2004. Uptake of Mercury and Relationship to Food Habits of Selected Fish Species in the Shenandoah River Basin, Virginia. Masters Thesis. Virginia Tech, Blacksburg, Virginia.

Table 3-3
Data Quality Objectives for Sediment Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	Sediment within the South River is impacted by mercury. These sediments serve as a potential source of methylmercury exposure to ecological receptors.
STEP 2: Identify the goals of the study	The sediment monitoring program has the following primary objectives: • Monitor exposure of invertebrates to sediment methylmercury. • Monitor natural recovery of sediment.
STEP 3: Identify the information inputs	Existing Data • A number of studies have evaluated mercury concentrations in sediment within the South River and South Fork Shenandoah Rivers. These studies include: CRG, 2008; Pizzuto 2009, 2011; URS, 2012. • Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017). New Data to Be Collected • Three interstitial sediment samples will be collected from coarse grained substrate beds at each study location. Samples will be analyzed for total and methylmercury as described below.

Table 3-3
Data Quality Objectives for Sediment Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4: Define the boundaries of the study</td><td>
Geographic Area
Sediment samples will be collected at 7 stations on the South River and South Fork Shenandoah River. The stations include:
<table>
<tr><th>Station ID</th><th>Description</th></tr>
<tr><td>SR-2.7</td><td>Existing SR-01 located at Lyndhurst Ave. to Ridgeview Park</td></tr>
<tr><td>SR0.1</td><td>Constitution Park/Waynesboro Reach</td></tr>
<tr><td>SR3.5</td><td>RRM 3.5</td></tr>
<tr><td>SR11.8</td><td>Dooms to Crimora Reach</td></tr>
<tr><td>SR23.5</td><td>Harriston to Port Republic Reach</td></tr>
<tr><td>SF26.6</td><td>South Fork Shenandoah @ Lynwood</td></tr>
<tr><td>SF48</td><td>SFS @ Shenandoah (above dam)</td></tr>
</table>
Note: Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.

Timeframe
Sampling and analysis will occur semi-annually in the spring and fall.
Sample Type
Interstitial sediment samples will be collected from coarse grained beds.
</td></tr>
<tr><td>STEP 5: Develop the analytical approach</td><td>Samples will be analyzed for total mercury (EPA 1631), methylmercury (EPA 1630, modified) and percent solids analysis (SM 20 2540 G-1997).</td></tr>
</table>

Table 3-3
Data Quality Objectives for Sediment Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 6: Specify performance or acceptance criteria</td><td>Field quality control sampling (field duplicates) will not be collected for biological samples. Laboratory duplicate samples will be analyzed from separate aliquots of the same parent sample after homogenization of the sample media.

Acceptance criteria for laboratory quality assurance samples and reporting limits are provided below.
<table>
<tr><th>Analyte</th><th>Laboratory Precision % RPD (LCSD)</th><th>Laboratory Accuracy % Recovery (LCS)</th><th>Laboratory Precision % RPD (MSD or Lab DUP)</th><th>Laboratory Accuracy % Recovery (MS)</th><th>Laboratory Reporting Limit (MDL)</th><th>Laboratory Reporting Limit (RL)</th><th>Project Reporting Limit (RL)</th></tr>
<tr><td>Total Mercury</td><td>30</td><td>75 - 125</td><td>30</td><td>70 - 130</td><td>0.12 ng/g</td><td>0.40 ng/g</td><td>0.40 ng/g</td></tr>
<tr><td>Methylmercury</td><td>35</td><td>65 - 135</td><td>35</td><td>65 - 135</td><td>1 ng/g</td><td>3 ng/g</td><td>3 ng/g</td></tr>
<tr><td>% Total Solids / % Dry Weight</td><td>N/A</td><td>N/A</td><td>15%</td><td>N/A</td><td>0.10%</td><td>0.1 ng/g</td><td>0.1 ng/g</td></tr>
</table>
Notes:
N/A - Not analyzed; LCS and LCSD will not be run for % solids analysis</td></tr>
<tr><td>STEP 7: Develop the detailed plan for obtaining data</td><td>Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018).</td></tr>
</table>

References:

AECOM, 2018. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

Pizzuto, J., M. O'Neal, D. Hubacz, D. Jurk, and S. Pomraning, 2011. Geomorphology Update. Presented at South River Science Team Meeting, Harrisonburg, Virginia, April 2011.

Pizzuto, J.P., and M. O'Neal, 2009. Increased mid-twentieth century riverbank erosion rates related to the demise of mill dams, South River, Virginia. *Geology* 37: 19-22.

URS, 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.

Table 3-4
Data Quality Objectives for Benthic Invertebrate Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	Benthic invertebrates including the Asiatic clam (*Corbicula fluminea*) and larval *Heptageniidae* mayflies play an important role in the aquatic and terrestrial food webs of the South River. They are also a key component of the trophic transfer of MeHg to ecological receptors within in the South River ecosystem (URS 2012).
STEP 2: Identify the goals of the study	The benthic invertebrate monitoring program has the following primary objectives: • Identify trends in potential ecological exposure to mercury and methylmercury through consumption of benthic invertebrates. • Monitor responses to decreasing mercury loads.
STEP 3: Identify the information inputs	Existing Data • A number of studies have evaluated mercury concentrations within the South River and South Fork Shenandoah Rivers. These studies include: o Phase I Ecological Study (CRG, 2008) o Ecological Study Final Report (URS 2012) • Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017). New Data to Be Collected • Three composite samples each of Asiatic clams (caged) and larval *Heptageniidae* mayflies will be collected for mercury analysis at each site.

Table 3-4
Data Quality Objectives for Benthic Invertebrate Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4: Define the boundaries of the study</td><td>
Geographic Area

Benthic invertebrate samples will be collected at seven stations on the South River and South Fork Shenandoah River. The stations include:

<table>
<tr><th>Station ID</th><th>Description</th></tr>
<tr><td>SR-2.7</td><td>Existing SR-01 located at Lyndhurst Ave. to Ridgeview Park</td></tr>
<tr><td>SR0.1</td><td>Constitution Park/Waynesboro Reach</td></tr>
<tr><td>SR3.5</td><td>RRM 3.5</td></tr>
<tr><td>SR11.8</td><td>Dooms to Crimora Reach</td></tr>
<tr><td>SR23.5</td><td>Harriston to Port Republic Reach</td></tr>
<tr><td>SF26.6</td><td>South Fork Shenandoah @ Lynwood</td></tr>
<tr><td>SF48</td><td>SFS @ Shenandoah (above dam)</td></tr>
</table>
Notes:
Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.

Timeframe

Sampling and analysis will occur semi-annually in the spring and fall for Asiatic clams and once annually in the spring for larval Heptageniidae mayflies.

Sample Type

Asiatic clams will be collected from a suitable reference area (Middle River) and transported to the South River for deployment. Caged clams will be placed into mesh cages suspended 2 inches above the sediment in the approximate center of the river (i.e. away from the banks) to determine the aqueous exposure regime. Clam samples will be harvested after a five-week deployment and depurated for 24 hours in aerated, distilled water to purge gut contents. Three composite samples of 10 individuals will be collected from each site.
Heptageniidae mayfly samples will also be composites of ~ 10 individuals of similar size (i.e., smallest individual > 75% of the size largest individual). Mayflies will be depurated for 24 hours in aerated distilled water to purge gut contents.

</td></tr>
<tr><td>STEP 5: Develop the analytical approach</td><td>Asiatic clams will be analyzed for total mercury (EPA 1631) and methylmercury (EPA 1630, modified; larval Heptageniidae mayflies are analyzed for total mercury (EPA 1631) only.
Percent solids analysis (SM 2540 G-1997) will be performed if there is sufficient sample mass.</td></tr>
</table>

Table 3-4
Data Quality Objectives for Benthic Invertebrate Tissue Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 6: Specify performance or acceptance criteria</td><td>Field quality control sampling (field duplicates) will not be collected for biological samples. Laboratory duplicate samples will be analyzed from separate aliquots of the same parent sample after homogenization of the sample media.

Acceptance criteria for laboratory quality assurance samples and reporting limits are provided below.
<table>
<tr><th>Analyte</th><th>Laboratory Precision % RPD (LCSD)</th><th>Laboratory Accuracy % Recovery (LCS)</th><th>Laboratory Precision % RPD (MSD or Lab DUP)</th><th>Laboratory Accuracy % Recovery (MS)</th><th>Laboratory Reporting Limit (MDL)</th><th>Laboratory Reporting Limit (RL)</th><th>Project Reporting Limit (RL)</th></tr>
<tr><td>Total Mercury</td><td>30</td><td>75 - 125</td><td>30</td><td>70 - 130</td><td>0.12 ng/g</td><td>0.40 ng/g</td><td>0.40 ng/g</td></tr>
<tr><td>Methylmercury</td><td>35</td><td>65 - 135</td><td>35</td><td>65 - 135</td><td>1 ng/g</td><td>3 ng/g</td><td>3 ng/g</td></tr>
<tr><td>% Total Solids / % Dry Weight</td><td>N/A</td><td>N/A</td><td>15%</td><td>N/A</td><td>0.10%</td><td>0.1 ng/g</td><td>0.1 ng/g</td></tr>
</table>
Notes:
N/A - Not analyzed; LCS and LCSD will not be run for % solids analysis</td></tr>
<tr><td>STEP 7: Develop the detailed plan for obtaining data</td><td>Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018).</td></tr>
</table>

References:

AECOM, 2018. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

CRG. 2008. *Phase 1, Year 1 Progress Report: Ecological study of the South River and a segment of the South Fork Shenandoah River, Virginia*. Wilmington, Delaware.

URS, 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.

Table 3-5
Data Quality Objectives for Carolina Wren Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	Previous studies conducted on the South River and South Fork Shenandoah river have found that Carolina wren (*Thryothorus ludovicianus*) had mercury in their blood and feathers at concentrations that were elevated above reference (Cristol et al., 2008; Jackson and Evers, 2011).
STEP 2: Identify the goals of the study	The overall objective of avian blood sampling and analyses is to evaluate recent (e.g., weeks to months) dietary exposure of mercury to a representative aerial insectivore (e.g., Carolina wren) potentially foraging in the South River watershed.

STEP 3: Identify the information inputs	Existing Data
	• Several studies have been conducted to evaluate the potential accumulation of mercury in songbirds in habitat adjacent to South River and South Fork Shenandoah River. These studies include:
	  ○ Cristol et al., 2008;
	  ○ Jackson and Evers, 2011.
	• Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017).
	
	New Data to Be Collected
	• Blood samples from three to eight individuals will be collected at each study site during the spring/summer and analyzed for total mercury.

Table 3-5
Data Quality Objectives for Carolina Wren Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4: Define the boundaries of the study</td><td>
Geographic Area
Carolina wren blood samples will be collected at nine stations on the South River and South Fork Shenandoah River. The stations include:
<table>
<tr><th>Station ID</th><th>Description</th></tr>
<tr><td>SR-6.2</td><td>Waynesboro Nursery</td></tr>
<tr><td>SR-1.2</td><td>Ridgeview Park</td></tr>
<tr><td>SR0.1 to 2.3</td><td>Basic Park</td></tr>
<tr><td>SR9</td><td>Crimora</td></tr>
<tr><td>SR22</td><td>Grottoes Town Park</td></tr>
<tr><td>SF31</td><td>South Fork Shenandoah @ the Power Dam</td></tr>
<tr><td>SF50</td><td>Shuler’s Island</td></tr>
<tr><td>SF66</td><td>Long Bend Farm</td></tr>
<tr><td>SF85</td><td>Bealer’s Ferry</td></tr>
</table>
Notes:
Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.
Timeframe
Sampling and analysis will occur every three years in June-July.
Sample Type
Carolina wren blood samples will be collected from three to eight individuals at each study site.
</td></tr>
<tr><td>STEP 5: Develop the analytical approach</td><td>Samples will be analyzed for total mercury (EPA 1631).</td></tr>
</table>

Table 3-5
Data Quality Objectives for Carolina Wren Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 6: Specify performance or acceptance criteria</td><td>Field quality control sampling (field duplicates) will not be collected for biological samples. Laboratory duplicate samples will be analyzed from separate aliquots of the same parent sample after homogenization of the sample media.

Acceptance criteria for laboratory quality assurance samples and reporting limits are provided below.
<table>
<tr><th>Analyte</th><th>Laboratory Precision % RPD (LCSD)</th><th>Laboratory Accuracy % Recovery (LCS)</th><th>Laboratory Precision % RPD (MSD or Lab DUP)</th><th>Laboratory Accuracy % Recovery (MS)</th><th>Laboratory Reporting Limit (MDL)</th><th>Laboratory Reporting Limit (RL)</th><th>Project Reporting Limit (RL)</th></tr>
<tr><td>Total Mercury</td><td>30</td><td>75 - 125</td><td>30</td><td>70 - 130</td><td>0.12 ng/g</td><td>0.40 ng/g</td><td>0.40 ng/g</td></tr>
</table></td></tr>
<tr><td>STEP 7: Develop the detailed plan for obtaining data</td><td>Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018).</td></tr>
</table>

References:

AECOM, 2018. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

Cristol, D.A., R.L. Brasso, A.M. Condon, R.E. Fovargue, S.L. Friedman, K.K. Hallinger, A.P. Monroe, A.E. White. 2008. The movement of aquatic mercury through terrestrial food webs. Science. 320: 335.

Jackson, A.K., D.C. Evers, S.B. Folsom, A.M. Condon, J. Diener, L.F. Goodrick, A.J. McGann, J. Schmerfeld, D.A. Cristol. 2011a. Mercury exposure in terrestrial birds far downstream of an historical point source. Environmental Pollution. 159(12): 3302-3308.

Jackson, A.K., D.C. Evers, M.A. Etterson, A.M. Condon, S.B. Folsom, J. Detweiler, J. Schmerfeld, D.A. Cristol. 2011b. Mercury exposure affects the reproductive success of a free-living terrestrial songbird, the Carolina Wren (Thryothorus ludovicianus). The Auk. 128(4): 759-769.

Table 3-6
Data Quality Objectives for Terrestrial Invertebrate Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	Spiders are an important food item for songbirds and may be an important potential link in the transfer of MeHg between the aquatic and terrestrial components of the South River (Cristol et al. 2008).
STEP 2: Identify the goals of the study	The terrestrial invertebrate monitoring program has the following primary objectives: • Monitor exposure of terrestrial ecological receptors to mercury. • Monitor mercury transfer between aqueous and terrestrial compartments of the South River. • Monitor potential terrestrial bioaccumulation.
STEP 3: Identify the information inputs	Existing Data • A number of studies have evaluated mercury concentrations in spiders within the South River watershed. These studies include: Cristol et al. (2008) and Newman et al. (2011). • Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017). New Data to Be Collected • Five individual wolf spiders (*Lycosidae*) will be collected at each study location and analyzed for total mercury.

Table 3-6
Data Quality Objectives for Terrestrial Invertebrate Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4:
Define the boundaries of the study</td><td>Geographic Area
• Terrestrial invertebrate samples will be collected at 9 stations on the South River and South Fork Shenandoah River. The stations include:
<table><tr><th>Station ID</th><th>Description</th></tr><tr><td>SR-6.2</td><td>Waynesboro Nursery</td></tr><tr><td>SR-2.7</td><td>Existing SR-01 located at Lyndhurst Ave. to Ridgeview Park</td></tr><tr><td>SR2.0</td><td>Basic Park</td></tr><tr><td>SR8.9</td><td>Crimora</td></tr><tr><td>SR22</td><td>Grottoes Town Park</td></tr><tr><td>SF31</td><td>South Fork Shenandoah @ the Power Dam</td></tr><tr><td>SF50</td><td>Shuler’s Island</td></tr><tr><td>SF66</td><td>Long Bend Farm</td></tr><tr><td>SF85</td><td>Bealer’s Ferry</td></tr></table>Notes:
Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.
Timeframe
• Sampling and analysis will occur annually in the spring/summer.
Sample Type
• Wolf spider samples will be analyzed individually. Five individuals will be collected at each study site.</td></tr>
<tr><td>STEP 5:
Develop the analytical approach</td><td>Samples will be analyzed for total mercury (EPA 1631).
Percent solids analysis (SM 2540 G-1997) will be performed if there is sufficient sample mass.</td></tr>
</table>

Table 3-6
Data Quality Objectives for Terrestrial Invertebrate Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 6: Specify performance or acceptance criteria</td><td>Field quality control sampling (field duplicates) will not be collected for biological samples. Laboratory duplicate samples will be analyzed from separate aliquots of the same parent sample after homogenization of the sample media.

Acceptance criteria for laboratory quality assurance samples and reporting limits are provided below.
<table>
<tr><th>Analyte</th><th>Laboratory Precision % RPD (LCSD)</th><th>Laboratory Accuracy % Recovery (LCS)</th><th>Laboratory Precision % RPD (MSD or Lab DUP)</th><th>Laboratory Accuracy % Recovery (MS)</th><th>Laboratory Reporting Limit (MDL)</th><th>Laboratory Reporting Limit (RL)</th><th>Project Reporting Limit (RL)</th></tr>
<tr><td>Total Mercury</td><td>30</td><td>75 - 125</td><td>30</td><td>70 - 130</td><td>0.12 ng/g</td><td>0.40 ng/g</td><td>0.40 ng/g</td></tr>
<tr><td>% Total Solids / % Dry Weight</td><td>N/A</td><td>N/A</td><td>15%</td><td>N/A</td><td>0.10%</td><td>0.1 ng/g</td><td>0.1 ng/g</td></tr>
</table>
Notes:
N/A - Not analyzed; LCS and LCSD will not be run for % solids analysis</td></tr>
<tr><td>STEP 7: Develop the detailed plan for obtaining data</td><td>Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018).</td></tr>
</table>

References:

AECOM, 2018. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

Cristol, D.A., R.L. Brasso, A.M. Condon, R.E. Fovargue, S.L. Friedman, K.K. Hallinger, A.P. Monroe, A.E. White. 2008. The movement of aquatic mercury through terrestrial food webs. Science. 320: 335.

Newman, M. C., L. Liang, and X. Xu. 2011. South River Trophic Studies. Prepared for E.I. duPont de Nemours and Company.

Table 3-7
Data Quality Objectives for Surface Water Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	Routine surface water monitoring conducted by DuPont and VADEQ (1999-present) show that mercury and methylmercury are widely present in the South River watershed.
STEP 2: Identify the goals of the study	Surface water samples will be collected in AOC-4 to monitor potential long-term changes to mercury concentrations, ancillary parameters and nutrients in response to remediation (AECOM, 2018a).
STEP 3: Identify the information inputs	Existing Data • Surface water sampling integrates existing routine monitoring programs conducted by DuPont and VADEQ, and builds on a long-term (1999-present) database. Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017). New Data to Be Collected • One to two samples will be collected monthly and analyzed for total mercury (filtered and unfiltered), methylmercury (filtered and unfiltered), total suspended solids, total organic carbon, dissolved organic carbon, phosphorous, chloride, sulfate, nitrogen, alkalinity, calcium, magnesium, potassium, sodium, and water quality parameters (Temperature, pH, dissolved oxygen, conductivity). See the RCRA Quality Assurance Project Plan (QAPP) for a comprehensive list of all surface water analytes (AECOM, 2018b).

Table 3-7
Data Quality Objectives for Surface Water Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4:
Define the boundaries of the study</td><td>
Geographic Area
Surface water samples will be collected at 10 stations on the South River and South Fork Shenandoah River. The stations include:
<table>
<tr><th>Station ID</th><th>Description</th></tr>
<tr><td>RRM -2.7</td><td>Lyndhurst Avenue Bridge</td></tr>
<tr><td>RRM 0.2</td><td>Main Street Bridge</td></tr>
<tr><td>RRM 2.3</td><td>Hopeman Parkway Bridge</td></tr>
<tr><td>RRM 5.2</td><td>Dooms Crossing Bridge</td></tr>
<tr><td>RRM 9.9</td><td>New Hope Crimora Road Bridge</td></tr>
<tr><td>RRM 16.5</td><td>Harriston (Patterson Mill Road Bridge)</td></tr>
<tr><td>RRM 23.5</td><td>Port Republic Road Bridge</td></tr>
<tr><td>SF26.6</td><td>South Fork Shenandoah River at Lynwood</td></tr>
<tr><td>SF48</td><td>South Fork Shenandoah River at Shenandoah (below dam)</td></tr>
<tr><td>SF94</td><td>South Fork Shenandoah River at Rt. Rt. 663 bridge</td></tr>
</table>
Notes:
Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.

Timeframe
Sampling and analysis will occur monthly. Sampling is to be conducted in concert with VADEQ routine monitoring; as a result, some parameters are analyzed on a different frequency or for different numbers of replicates.
Sample Type
Water samples will be collected using either a diaphragm or submersible pump following the methods outlined in sampling protocol SRSW-1 (Appendix A).
</td></tr>
<tr><td>STEP 5:
Develop the analytical approach</td><td>Samples will be analyzed for THg/FTHg, MeHg/FMeHg, TSS, TOC/DOC, phosphorous, chloride/sulfate, nitrogen, alkalinity, and calcium/magnesium/potassium/sodium, in accordance with EPA Methods 1631, 1630, 2540 D-1997, 5310 C-2000, 365.1, 300, 353.2, 2320 B-1997, and 6010B, respectively. See the RCRA Quality Assurance Project Plan (QAPP) for a comprehensive list of all surface water analytes (AECOM, 2018b).</td></tr>
</table>

Table 3-7
Data Quality Objectives for Surface Water Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 6: Specify performance or acceptance criteria	Field quality and laboratory QA/QC sampling (field duplicates, MS/MSD, etc.) will be collected and analyzed at a rate of 5%. MS/MSD samples may be collected as additional sample volume within the same bottle as the parent sample. Acceptance criteria for laboratory quality assurance samples and reporting limits are provided in Table 4 of the RCRA Quality Assurance Project Plan (QAPP) (AECOM, 2018b).
STEP 7: Develop the detailed plan for obtaining data	Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018a).

References:

AECOM, 2018a. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April 2018.

AECOM, 2018b. RCRA Quality Assurance Project Plan (QAPP) Former DuPont Waynesboro Site Area of Concern (AOC) 4: South River and a Segment of the South Fork Shenandoah River, Virginia. Conshohocken, Pennsylvania. Prepared by URS Corporation. May, 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

Table 3-8
Data Quality Objectives for Benthic Invertebrate Community Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

DQO Step	Description
STEP 1: State the problem	The benthic invertebrate community of the South River is listed as impaired (VDEQ 2009) for a number of reasons including sedimentation among other environmental stressors.
STEP 2: Identify the goals of the study	The benthic invertebrate monitoring program has the following primary objectives: • Monitor improvements to the benthic community in response to remediation.
STEP 3: Identify the information inputs	Existing Data • A number of studies have evaluated benthic invertebrate community dynamics within the South River and South Fork Shenandoah Rivers. These studies include: o Phase I Ecological Study (CRG, 2008) o Ecological Study Final Report (URS, 2012) o Bacteria and Benthic Total Maximum Daily Load for South River (VDEQ, 2009) • Baseline Long-term Monitoring data (pre-remediation; 2014 to 2016) are summarized in the Long-Term Monitoring Baseline Report (AECOM, 2017). New Data to Be Collected • Six benthic community samples will be collected at each study location.

Table 3-8
Data Quality Objectives for Benthic Invertebrate Community Monitoring
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

<table>
<tr><th>DQO Step</th><th>Description</th></tr>
<tr><td>STEP 4:
Define the boundaries of the study</td><td>
Geographic Area
Benthic invertebrate samples will be collected at six stations on the South River and South Fork Shenandoah River. The stations include:
<table>
<tr><th>Station ID</th><th>Description</th></tr>
<tr><td>SR-2.7</td><td>Existing SR-01 located at Lyndhurst Ave. to Ridgeview Park</td></tr>
<tr><td>SR0.1</td><td>Constitution Park/Waynesboro Reach</td></tr>
<tr><td>SR3.5</td><td>RRM 3.5</td></tr>
<tr><td>SR11.8</td><td>Dooms to Crimora Reach</td></tr>
<tr><td>SR23.5</td><td>Harriston to Port Republic Reach</td></tr>
<tr><td>MR-01</td><td>Middle River Reference location</td></tr>
</table>
Notes:
Numbers associated with station IDs are river miles downstream of the footbridge at the former DuPont plant in Waynesboro, VA. Negative numbers indicate distance upstream of the footbridge.

Timeframe
Sampling and analysis will occur every three years in the spring and fall.
Sample Type
Benthic community samples will be collected as a three-surber composite sample collected from the left, center and right hand sides of the wetted channel at each location.
</td></tr>
<tr><td>STEP 5:
Develop the analytical approach</td><td>Benthic community samples will have a random 300 organism sub-count performed in accordance with the methods outlined in Barbour et al. (1999). Organisms will be identified to the lowest taxonomical level practical, typically genus or species.</td></tr>
<tr><td>STEP 6:
Specify performance or acceptance criteria</td><td>Field quality control sampling (field duplicates) will not be collected for benthic community samples.
Quality control on sorting procedures will be checked by re-sorting 20 percent of each sample to ensure a 90% sorting efficiency. The accuracy of taxonomic identification will be evaluated by the re-identification of 10% of the samples by an experienced taxonomist to ensure a 90% similarity.</td></tr>
<tr><td>STEP 7:
Develop the detailed plan for obtaining data</td><td>Detailed plans for data collection are provided in the AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia (AECOM, 2018).</td></tr>
</table>

References:

AECOM, 2018. AOC 4 Long-Term Monitoring Plan of the South River and a Segment of the South Fork of the Shenandoah River, Virginia. Conshohocken, Pennsylvania. Final Work Plan prepared by AECOM. April 2018.

AECOM. 2017. Long-Term Monitoring Baseline Report, Former DuPont Waynesboro Site, Area of Concern 4, Waynesboro, Virginia. March 2017; Revised December 2017.

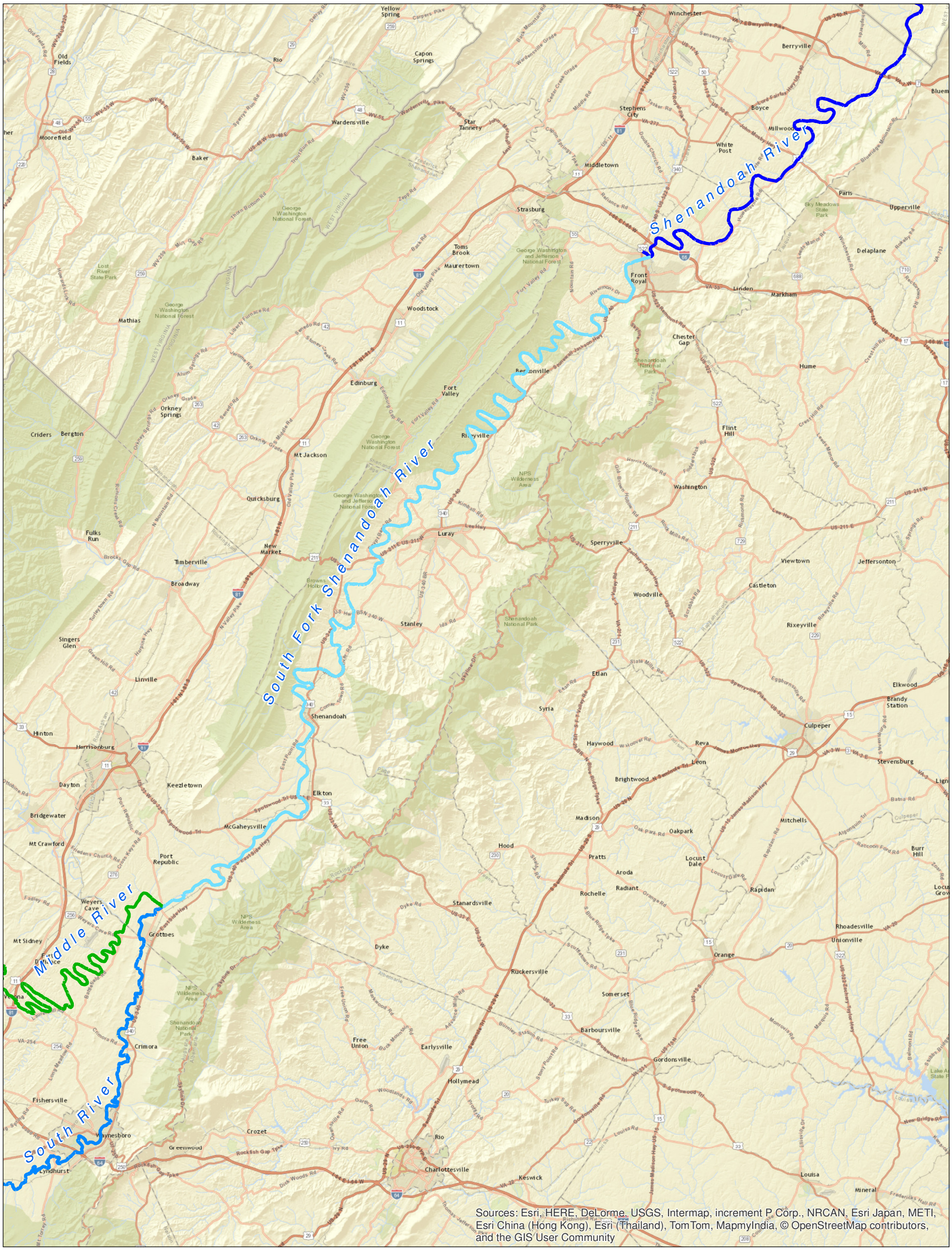
Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling, 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. USEPA 841-B-99-002. USEPA Office of Water, Washington, D.C.

CRG. 2008. *Phase 1, Year 1 Progress Report: Ecological study of the South River and a segment of the South Fork Shenandoah River, Virginia*. Wilmington, Delaware.

URS, 2012. Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River, Virginia. Fort Washington, Pennsylvania. Final report prepared by URS Corporation. September 2012.

Virginia Department of Environmental Quality (VDEQ), 2009. Bacteria and Benthic Total Maximum Daily Load for South River. Prepared by Engineering Concepts, Inc. July 2009.

Figures



Legend

- Middle River
- South River
- South Fork Shenandoah River
- Shenandoah River

N

0 5 10 20 Miles

Reference:
esri Streets

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

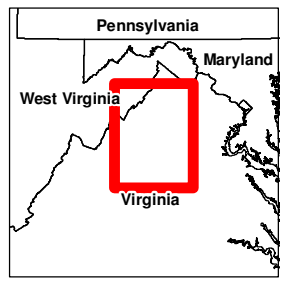


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Figure 1-1
Investigation Area Overview Map
AOC 4 Long-Term Monitoring Plan

Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\LongtermMonitoringPlan\Figure 1-1 Investigation Area Overview Map.mxd

Figure 2-1
Integration of Monitoring with Adaptive Management and Relative Risk Model
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River

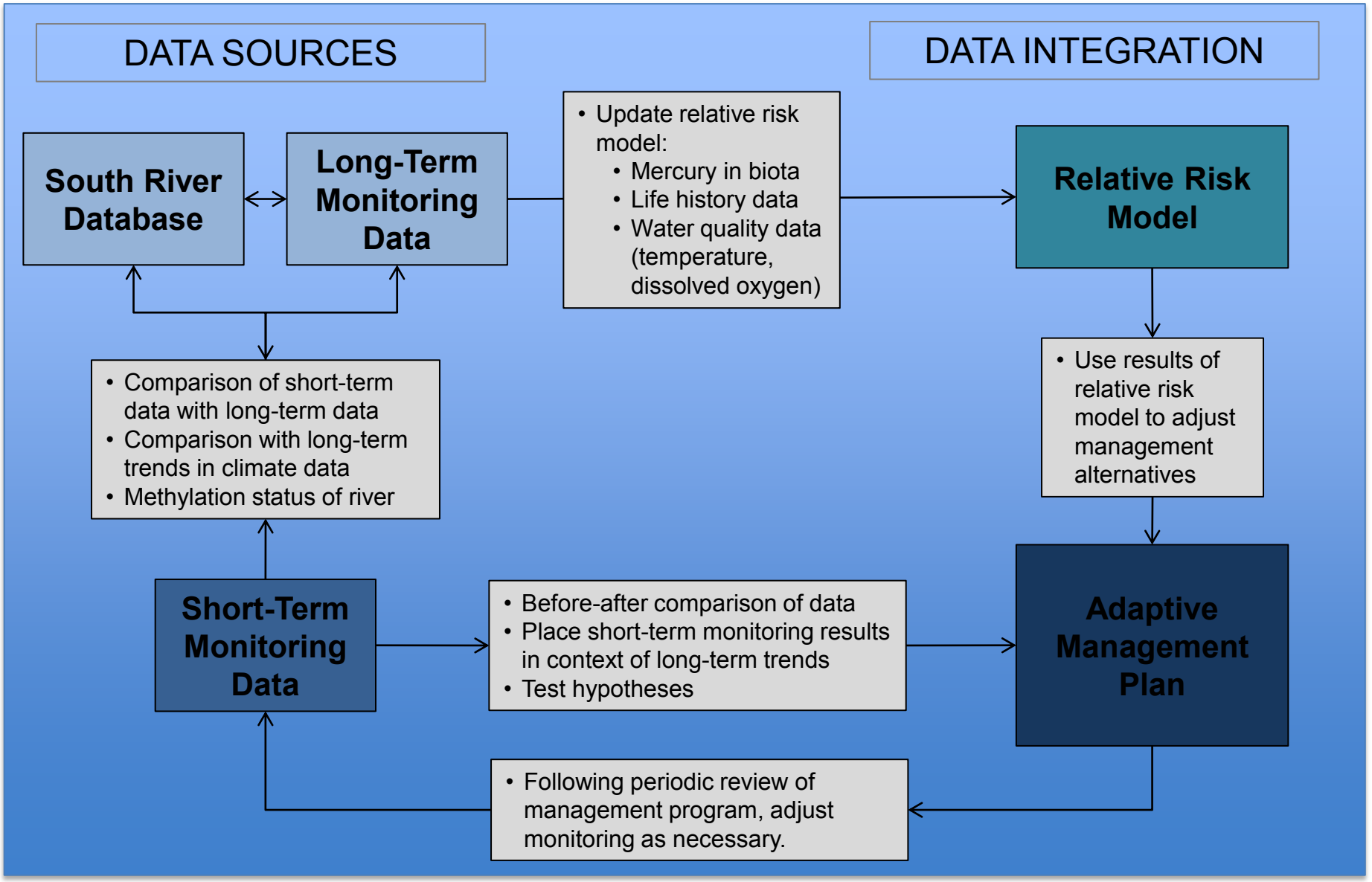
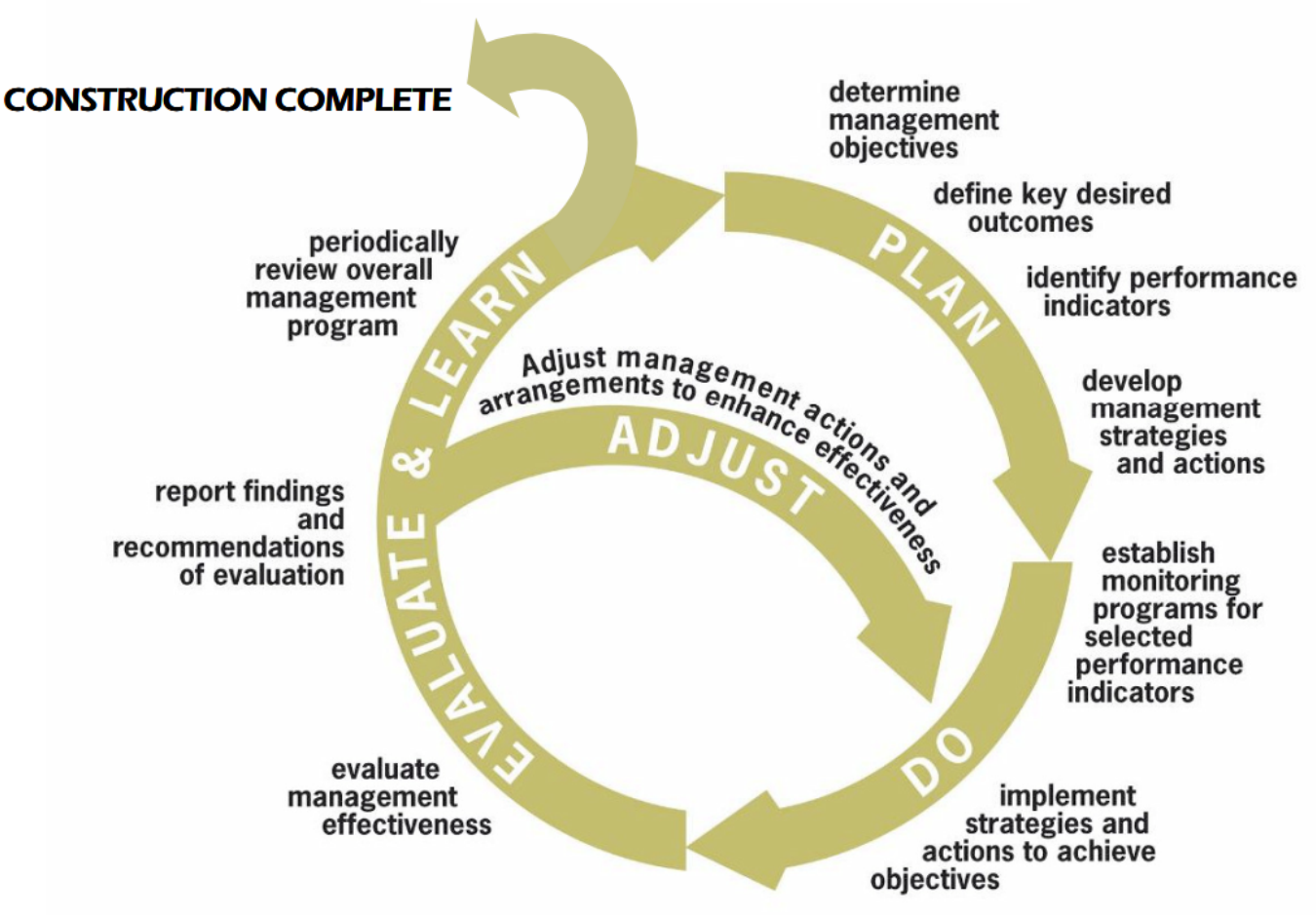


Figure 2-2
Basis for Adaptations to Monitoring Plan
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River



Notes:
Source: Jones (2005), Tasmanian Parks and Wildlife Service

RRM 23.5

Grottoes City Park
(RRM 22)

Middle River
(MR-01)

RRM 16.5

RRM 11.8

RRM 9.9

RRM 5.2

RRM 3.5

RRM 2.3

RRM 0.2

RRM 0.1

Ridgeview Park
(RRM -1.2)

RRM -2.7

Waynesboro Nursery
(RRM -6.2)

Legend

- Water Quality - Surface Water
- Ecological Exposure (Aquatic) - Sediment; Benthic Invertebrates; Asiatic Clam
- Ecological Exposure (Aquatic) - YOY Fish
- Ecological Exposure (Terrestrial) - Carolina Wren; Wolf Spider
- Benthic Community
- Human Exposure - Largemouth Bass; Smallmouth Bass

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

N

0 1 2 4 Miles

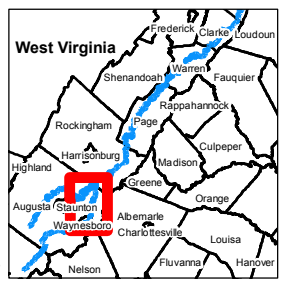


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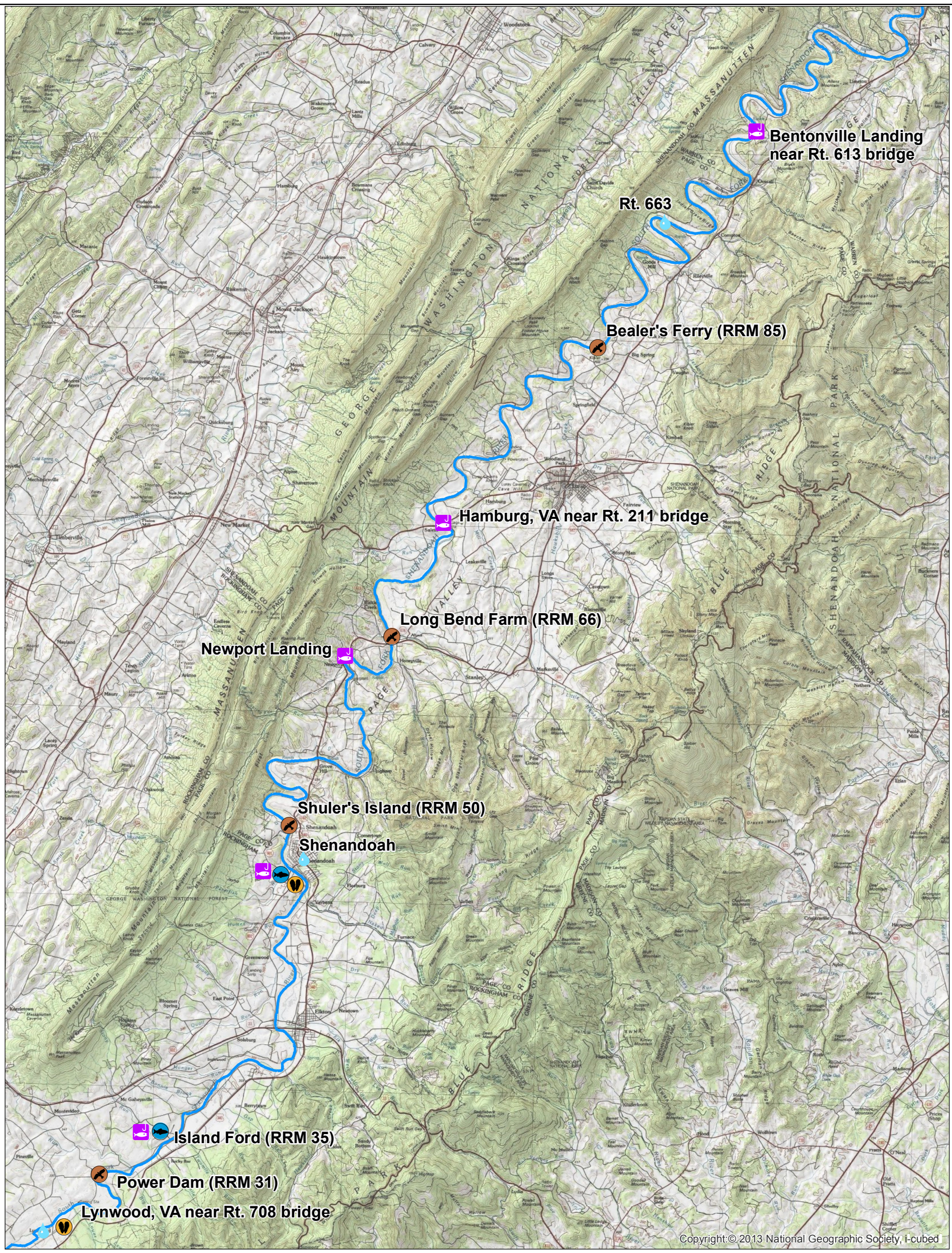
Figure 3-1a
Long-Term Monitoring Program Stations
AOC 4 Long-Term Monitoring Plan
Former DuPont Waynesboro Site,
Area of Concern 4

S:\Projects\IMS\DUPONT\STHRIVER\Projects\LongtermMonitoringPlan\2017_Work_Plan\Figure 3-1 Sample Location Map_AECOMformat_WP.mxd



Legend

- Water Quality - Surface Water
- Ecological Exposure (Aquatic) - Sediment; Benthic Invertebrates; Asiatic Clam
- Ecological Exposure (Aquatic) - YOY Fish
- Ecological Exposure (Terrestrial) - Carolina Wren; Wolf Spider
- Human Exposure - Largemouth Bass; Smallmouth Bass

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

N

0 1 2 4 Miles

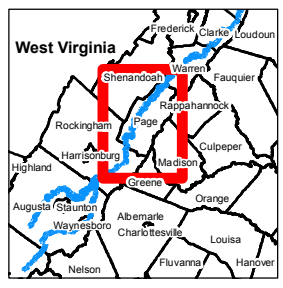


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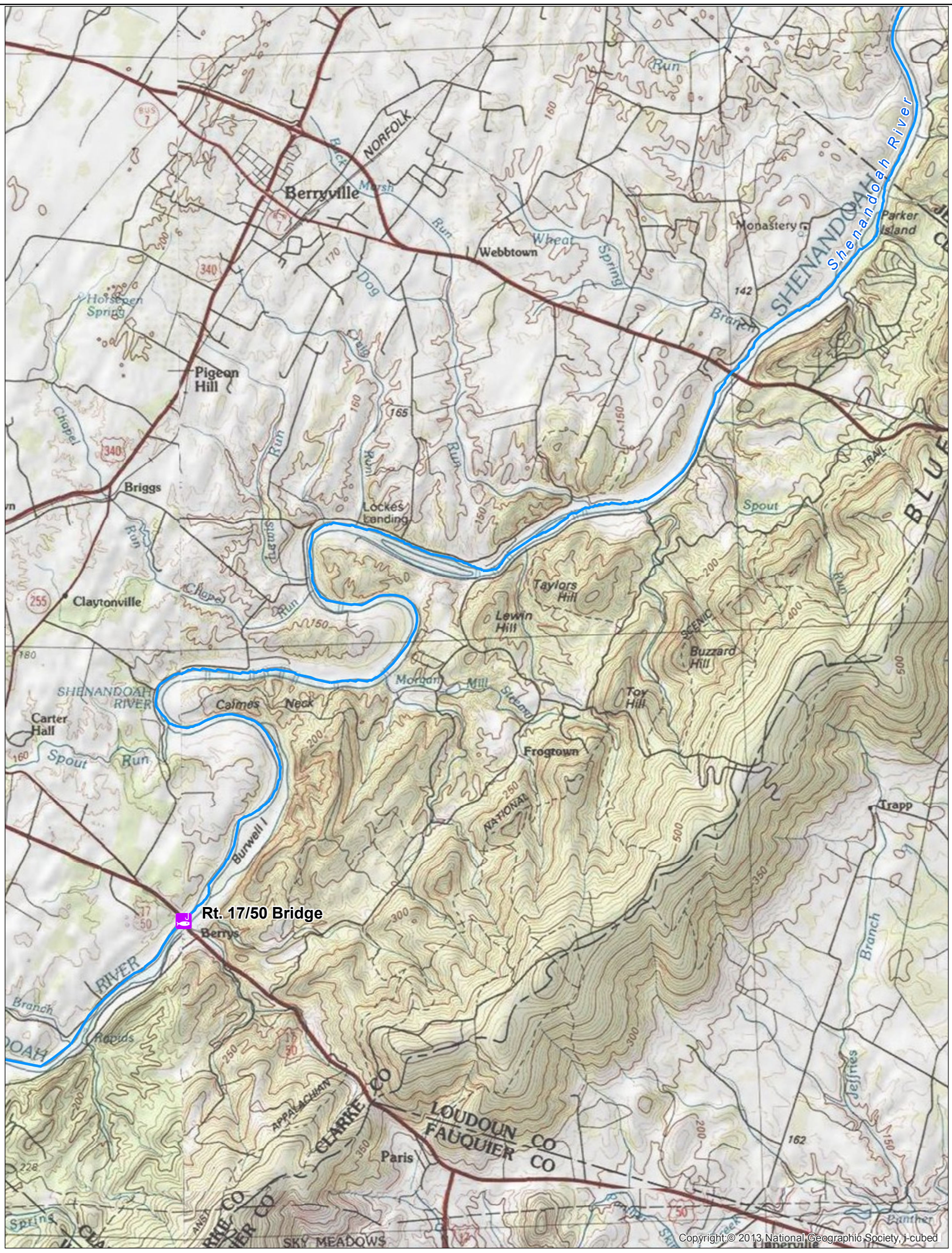
Figure 3-1b
Long-Term Monitoring Program Stations
AOC 4 Long-Term Monitoring Plan
Former DuPont Waynesboro Site,
Area of Concern 4

S:\Projects\IMS\DUPONT\STHRIVER\Projects\LongtermMonitoringPlan\2017_Work_Plan\Figure 3-1 Sample Location Map_AECOMformat_WP.mxd



Legend

Human Exposure - Largemouth Bass; Smallmouth Bass

NAD 1983 StatePlane Virginia North
Projection: Transverse Mercator
Linear Unit: Foot US

N

0 1 2 4 Miles

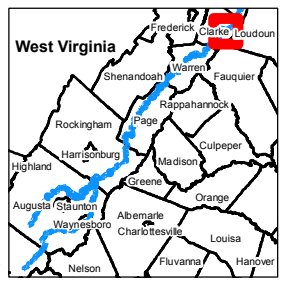


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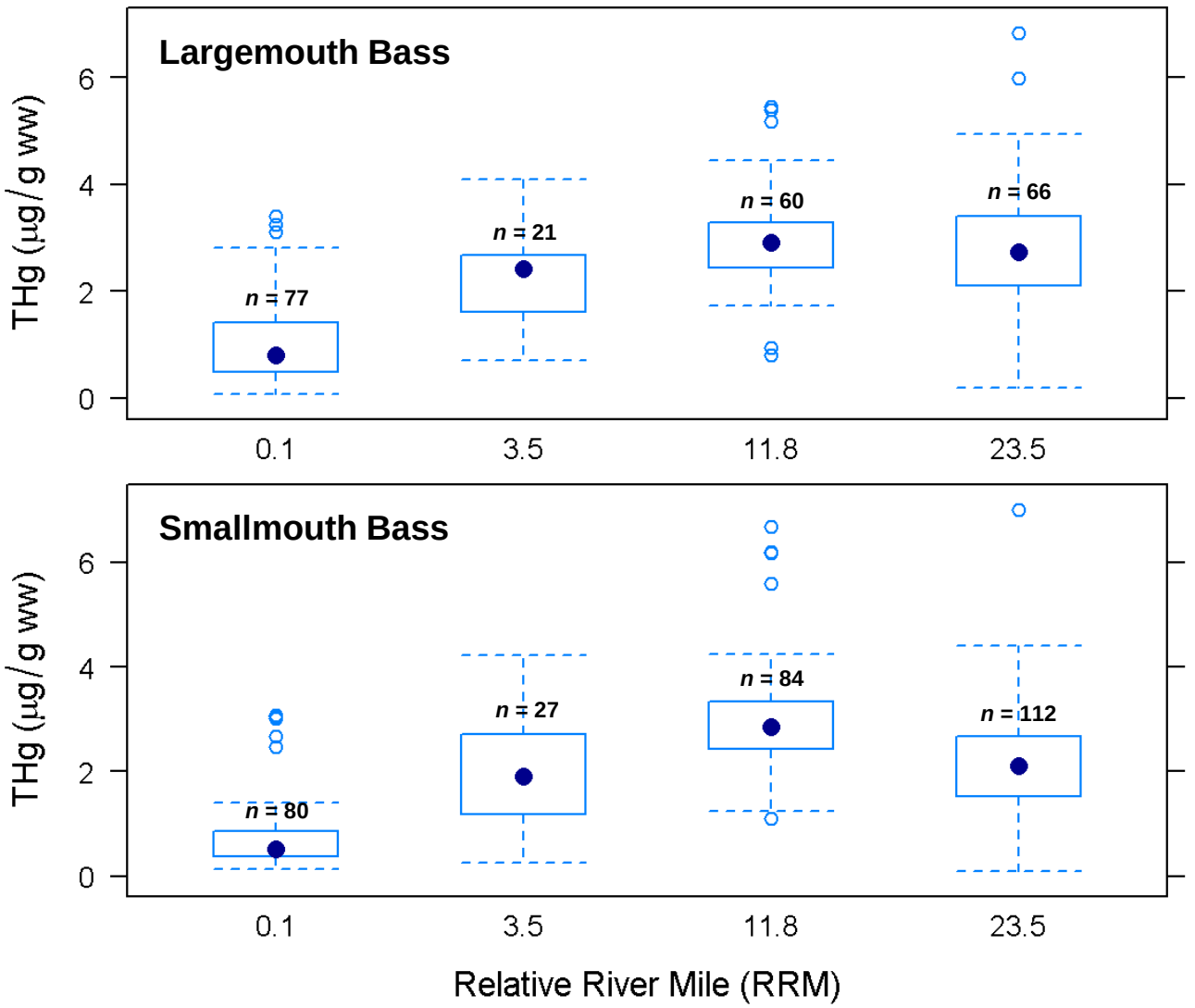
Figure 3-1c
Long-Term Monitoring Program Stations
AOC 4 Long-Term Monitoring Plan

Former DuPont Waynesboro Site,
Area of Concern 4

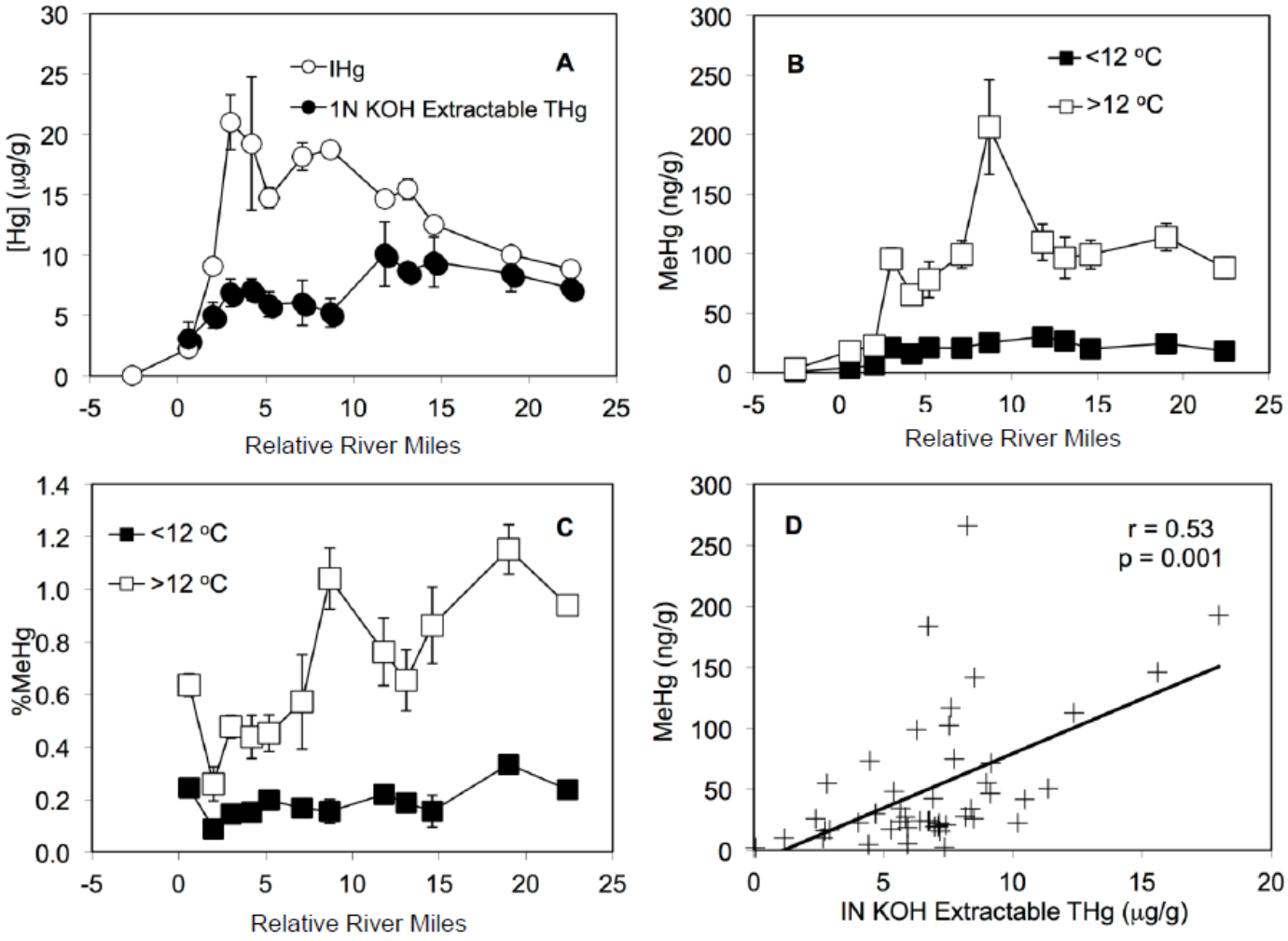
S:\Projects\IMS\DUPONT\STHRIVER\Projects\LongtermMonitoringPlan\2017_Work_Plan\Figure 3-1 Sample Location Map_AECOMformat_WP.mxd

Figure 3-2
Summary of Mercury Concentrations in Largemouth Bass and Smallmouth Bass
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River



Notes:
THg = Length-normalized total mercury concentrations. Samples were collected as tissue plugs. Smallmouth bass and largemouth bass data were collected May and September 2009, May and September 2010, and May 2011 (Data were not collected at RRM 3.5 in 2009). The filled circle is the median value, and the box surrounding the filled circle depicts the 25th and 75th quartile. The range of values is given by the dotted lines outside of each box, and possible outliers are given by the open circles outside the box.
ww – wet weight

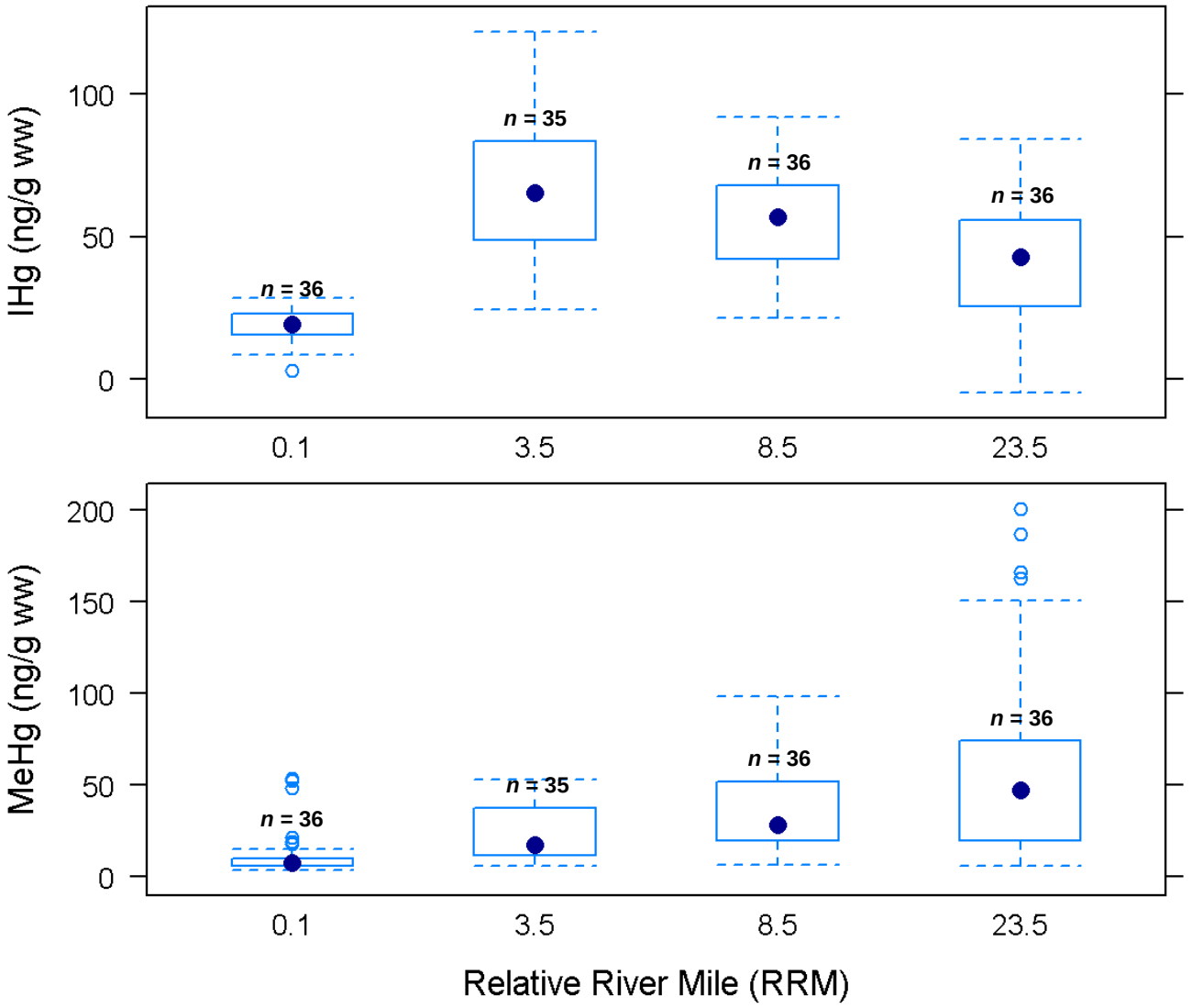
Figure 3-3
Summary of Mercury Concentrations in Channel Sediment
AOC4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River



Notes:
IHg, 1N KOH extractable THg and MeHg in fine-grained sediment collected from cobble/gravel interstices. Symbols represent the mean and the standard error. Panel A: IHg and 1N KOH extractable THg as a function of distance, in relative river miles (RRM). MeHg (Panel B) and the percentage of IHg as MeHg (Panel C) as a function of distance and water temperature. Panel D: (+) represents the correlation between 1N KOH extractable THg and MeHg. Concentrations are as dry weight. Figure reprinted with permission from Flanders et al. (2010).

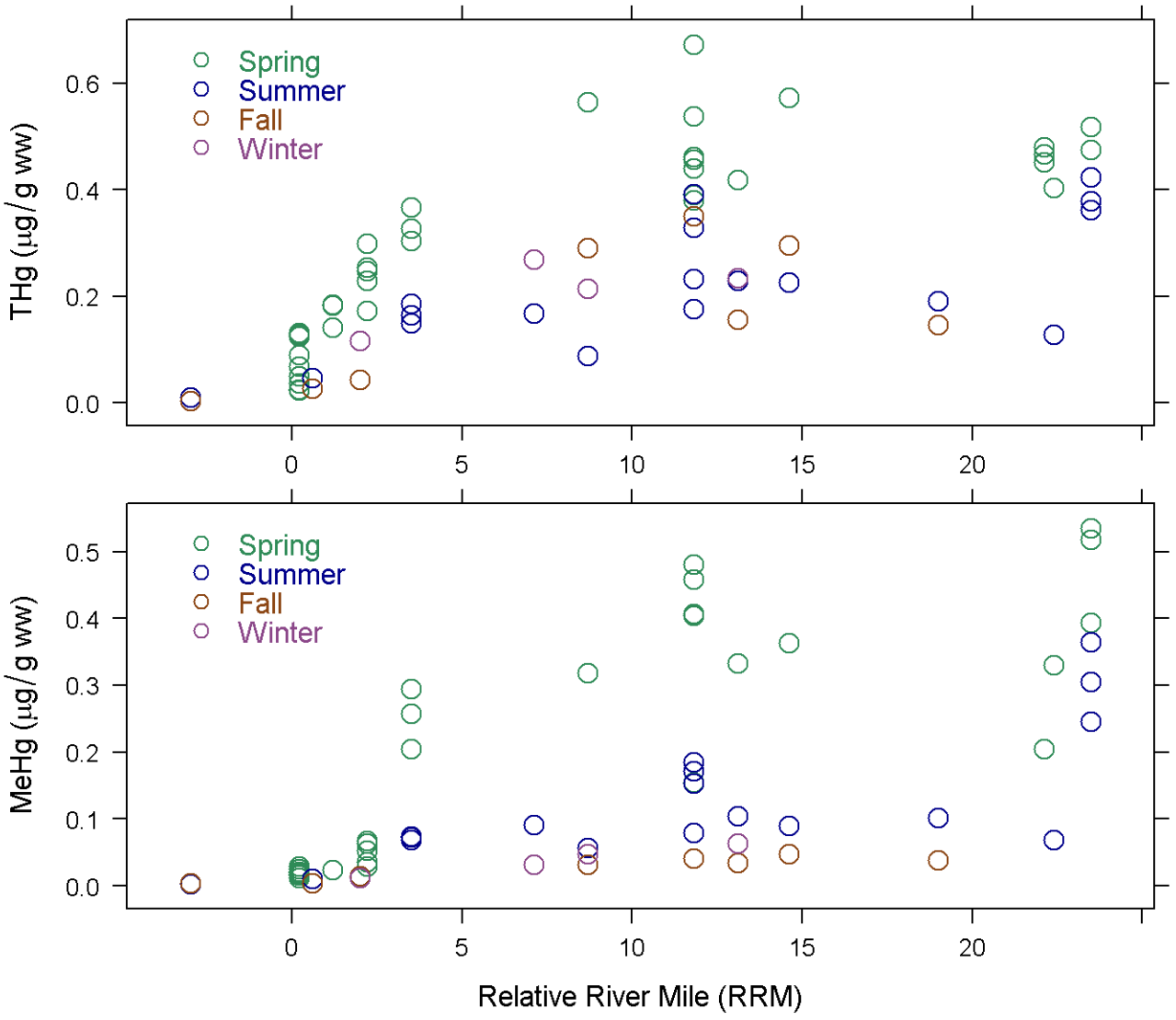
Source: Flanders et al. (2010)

Figure 3-4
Summary of Mercury Concentrations in Asiatic Clams
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River



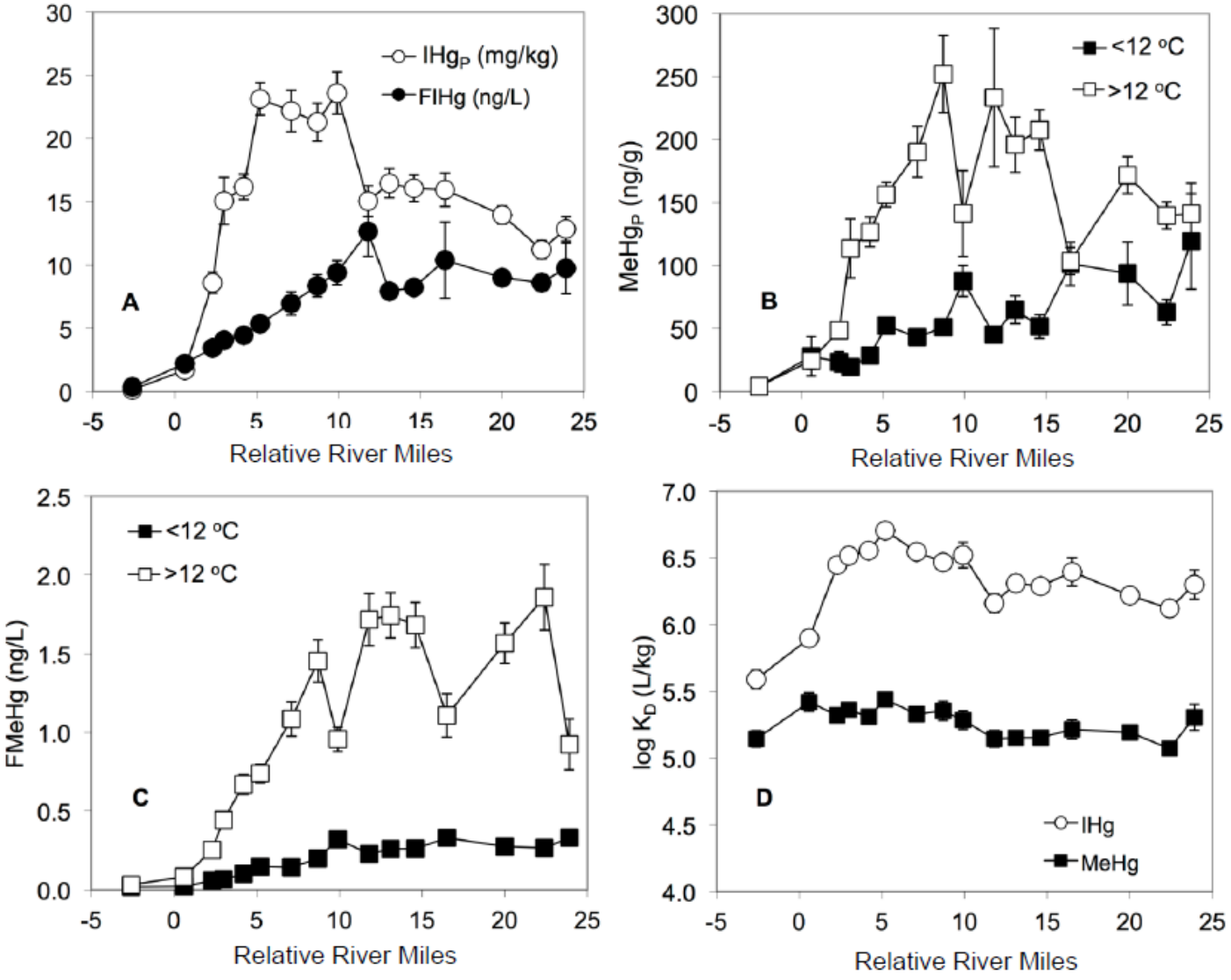
Notes:
RRM = Relative River Mile, IHg = Inorganic Mercury, MeHg = Methylmercury. Data were collected from May to June 2009. The filled circle is the median value, and the box surrounding the filled circle depicts the 25th and 75th quartile. The range of values is given by the dotted lines outside of each box, and possible outliers are given by the open circles outside the box.
ww – wet weight

Figure 3-5
Summary of Mercury Concentrations in Mayflies
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River



Notes:
RRM = Relative River Mile, THg = Total Mercury, MeHg = Methylmercury. Data were collected from 2007 to 2013 during multiple ecological investigations
ww – wet weight

Figure 3-6
Summary of Mercury Concentrations in Surface Water
AOC 4 Long-Term Monitoring Plan
South River and a Segment of the South Fork Shenandoah River



Notes:
Behavior of IHg and MeHg in surface water data collected between 2006 and 2010. Symbols represent the mean and the standard error. Panel A: IHg on TSS particles (IHgP, in mg/kg dry wt.), and in filtered (0.45µm filter) samples (FIHg, in ng/L) as a function of distance, in relative river miles. MeHg on TSS particles (MeHgP, in ng/g dry wt.; Panel B) and in filtered (0.45µm filter) samples (FMeHg; Panel C) as a function of distance and temperature regime. The log of the particle-water distribution coefficient (KD; Panel D) for IHg and MeHg.

Source: Flanders et al. (2010)

Appendices

Appendix A
Monitoring SOPs

Protocol SRAT-1
Biological Sampling Guidelines for Avian Tissue Analysis

The overall objective of avian blood sampling and analyses is to evaluate recent (e.g., weeks to months) dietary exposure of mercury to a representative aerial insectivore (e.g., Carolina wren) potentially foraging in the South River watershed.

Equipment

The following equipment/supplies may be used to collect avian tissue samples:

- Mist nets, or other avian nets or traps
- Avian holding bags
- Small crotchet hooks
- Small clippers
- Sterilized 29-30 gauge needles and 1-3 ml syringes
- Swabs
- Heparinized micro-containers
- 'Sharps' container
- Boat and motor
- Chest waders/rubber boots
- Gloves
- Field book/field data sheets
- Global positioning system (GPS)
- Tweezers/forceps
- Magnifying glass
- Sample containers from laboratory
- Sample container labels
- Cooler
- Dry ice
- Chain-of-Custody (COC) forms
- Custody seals
- Camera
- Pencils and waterproof/permanent marking pens
- Scientific collector's permit and field identification guides, as necessary

- Appropriate health and safety equipment

Standard Operating Procedure for Collection of Birds

Sampling will be performed in accordance with the conditions stated in applicable U.S. Fish and Wildlife Service (USFWS) and VDGIF scientific collection permits. The following sections describe each sampling approach, methodologies for avian blood collection, and analytical data quality objectives.

Mist Net Sampling

One to two nylon mist nets will be used to collect target species. Mist nests have three to four panels that overlap to form bottom pockets. When the bird strikes the net, it drops into a pocket where it is retrieved by an experienced handler. Nets will be positioned in the shade or in areas without direct sun exposure and will be checked every 15 to 20 minutes while active. Nets will be closed during unfavorable conditions such as weather, predation, or if proper monitoring is not possible.

The area where the net is deployed will be monitored from a distance. If a bird is detected, it will be removed immediately and processed similarly to the nest box sampling protocol described above. If there are multiple target species collected in the net, individual birds will be removed immediately and placed into small holding bags or buckets in a cool shady location. Captured birds will be processed as quickly as possible and will not be left in the bags for longer than 15 minutes. Special care will be taken to avoid harming captured birds. Several tools will be on hand to remove entangled birds from the net, including a small crotchet hook and small clippers. Following retrieval from the net, the bird will be evaluated and blood will be sampled under the protocol detailed in the following section.

Collection of Avian Blood Samples

Avian blood sampling methods and techniques will follow standard songbird sampling methodology (Evers, 2009; Kramer and Harris, 2010; Owen, 2011). Whole blood will be directly collected from the right jugular vein of the bird using a sterilized 29 – 30 gauge needle and 1 – 3 mL syringe. The area around the jugular vein will be sterilized with an alcohol swab prior to insertion of the needle. A blood sample with a target volume of at least 0.1 mL will be targeted for collection; however, sample volume will not exceed one percent of the total body weight of the bird (i.e., less than 0.2 mL based on a 20 gram (g) tree swallow; Evers, 2009). The blood sample will be collected and placed into a dedicated 1 mL heparinized microtainer; heparin is used to prevent coagulation in the blood sample. Microtainers will be labeled with the sample identification number and collection date and time. Needles will be used once and discarded into a sharps container immediately after use. Each bird will be released at the site of collection after data have been recorded. Birds will not be banded or retained; however, a temporary marking (e.g., feather clip or non-permanent color mark) will be made on the bird to prevent later re-sampling during the current study.

Immediately after collection, blood samples will be frozen and carefully packaged to prevent breakage and placed on dry ice for shipment to the laboratory. Blood samples will be shipped under proper chain-of-custody via overnight courier and analyzed for THg by a certified laboratory.

Field Quality Assurance/Quality Control Samples

Field quality assurance/quality control (QA/QC) samples are designed to help identify and minimize potential sources of sample contamination due to field procedures and to evaluate potential error introduced by sample collection and handling.

Duplicate Samples

Collecting duplicate samples allows for evaluation of sample homogeneity by comparing the analytical results of two samples from the same individual. Duplicate samples also check for the consistency of laboratory analysis. Duplicate samples will be collected by the analytical laboratory from primary samples with sufficient mass. Duplicates will be analyzed at a rate of five (5) percent of the total samples collected for in the study.

Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicate (MSD) samples will be obtained by the analytical laboratory from primary samples with sufficient mass. MS and MSD samples are prepared at the laboratory by dividing a control sample into two aliquots, then spiking each with identical concentrations of specific analytes. The spike samples are then analyzed separately, and the results are compared to evaluate the effects of the sample matrix on the analytical accuracy and precision. MS/MSD samples will be collected from baseline samples to ensure sufficient volume for laboratory QA/QC. MS/MSD samples will be analyzed at a rate of five (5) percent of the total samples collected for in the study.

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described in this sampling guideline. The sample parameters for analysis, preservation, and handling are specified in scope of work. Each sample container has a sample label affixed to the outside. The sampler marks each label using waterproof ink with the following information:

- Project name
- Sample identification number
- Date and time of collection
- Initials of sampling technician
- Requested analysis
- Method of preservation

Dry ice will be placed around sample containers and additional cushioning material will be added to the cooler, if necessary. Paperwork (i.e., signed Chain-of-Custody forms) will be put in a Ziploc bag and placed on top of the sample containers or taped to the inside lid of the cooler. The cooler will be taped closed and a signed custody seal will be affixed to the side of the cooler. Laboratory address labels will be placed on top of the cooler.

All samples are expected to contain low levels of contamination and will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations. All shipments containing dry ice will conform to federal, state, and carrier regulations. Standard

procedures to be followed for shipping environmental samples to the analytical laboratory are outlined below.

- All environmental samples collected will be transported to the laboratory by AECOM or University of Delaware personnel, shipped through Federal Express or equivalent overnight service, or picked up by a lab courier.
- Shipments will be scheduled to meet holding time requirements.

The laboratory will be notified to be prepared to receive a shipment of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed.

AECOM has established a program of sample COC that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession
- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed inside the shipping container, and the container will be sealed. Samples are considered to be in custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number
- Name of sampler and field personnel

- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Sampling media
- Sample type
- Observations at the sampling site (e.g., weather conditions)
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Health and Safety Procedures

To avoid incidents or injuries during sampling, the following task-specific health and safety procedures should be followed in addition to those indicated in the HASP:

- Toxic or otherwise harmful concentrations of metals or other constituents are unlikely to be encountered while sampling avian tissue.
- However, sampling crews should be trained in the general hazards of field sampling (e.g., waterborne pathogens) and how to minimize risks of exposure.
- Operating in or around water bodies carries the inherent risk of drowning. U.S. Coast Guard approved personal flotation devices must be worn when sampling from a boat.
- Collecting samples in extremely hot and humid weather carries the risk of dehydration and heat stroke. Sampling team members should wear adequate clothing and should carry an adequate supply of water or other liquids for protection against dehydration in hot weather.
- Sampling team members must cover exposed skin and/or use sunscreen for protection from sun exposure.
- When working on all water bodies, sampling teams must develop and employ an emergency response plan, including the use of an onshore monitor that is accountable for the whereabouts of the team. The monitor can request aid if the team fails to report in at end of workday and can provide assistance to rescuers or the team under any emergency situation.

References

Evers, D.C. 2009. BioDiversity Research Institute. *Protocol for Sampling Bird and Mammal Tissue for Contaminant Analysis.* Report BRI 2009-01, BioDiversity Research Institute, Gorham, Maine.

Friedman, S.L., Brasso, RL., and A.M. Condon. 2008. *An improved, simple nest box trap*. J. Field Ornithol. 79(1):99–101.

Kramer, M.H. and D.J. Harris. 2010. *Avian Blood Collection*. Journal of Exotic Pet Medicine 19(1): 82-86.

Owen, Jennifer. 2011. *Collecting, Processing and Storing Avian Blood: A Review.* Journal of Field Ornithology 82(4): 339-354.

Protocol SRBF-1:
Biological Sampling Guidelines for
Fish Tissue Analysis

Fish tissue sampling procedures generally follow *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA 2000).

Equipment

The following equipment/supplies may be used to collect fish tissue samples:

- Boat and motor
- Collection equipment, including a tote-barge electrofisher, boat electrofisher, and/or backpack electrofisher
- Insulated dip nets
- Insulated rubber gloves
- Insulated chest waders/rubber boots
- Field book/field data sheets
- Global positioning system (GPS)
- Live wells/pens for holding fish
- Measuring board
- Electronic scale
- Tray for the electronic scale
- Distilled or deionized (DI) water
- Nitrile gloves
- Lint-free wipes (Kimwipe or equivalent)
- Uni-Punch dermal biopsy punches or equivalent
- Scalpel
- Forceps
- Betadine/vaseline mixture
- Fish scale envelopes
- Sample containers from laboratory
- Sample container labels
- Cooler
- Wet ice
- Chain-of-Custody (COC) forms
- Custody seals

- Field data sheets
- Paper towels
- Aluminum foil
- Tables and chairs
- Camera
- Pencils and waterproof/permanent marking pens
- Decontamination supplies
    - Brushes
    - Wash tubs
    - Buckets
    - Sponges and paper towels
    - Formula 409 (low mercury-content cleaner)
    - DI or distilled water
    - Hand-held sprayers or spray bottles
    - Trash bags
    - Plastic sheeting
    - Appropriate personal protective equipment (PPE)
- Scientific collector's permit and field identification guides, as necessary
- Appropriate health and safety equipment

Decontamination Procedures

Between sampling locations, the measuring board and tray for weighing will be thoroughly cleaned and rinsed with DI or distilled water to prevent potential sample contamination. Following decontamination, the equipment will be wrapped in clean plastic sheeting or trash bags to prevent contact with dust and unclean surfaces. Fish tissue sampling equipment (e.g. scalpel, forceps) will be decontaminated with alcohol and rinsed using DI or distilled water after every fish biopsy tissue sample is collected. Dedicated biopsy plugs will be used for each biopsy sample to avoid potential contamination.

Fish Tissue Collection Procedures

Wading will be considered if the water depth is shallow and the substrate is cohesive enough to make wading feasible. If not, a boat may be used to reach some of the sampling locations. Caution will be used when conducting sampling from the boat or by wading. Health and safety procedures are detailed in AOC-4 Project HASP.

All collection permits will be obtained well in advance of the target sampling period to allow for flexibility in the timing of sampling.

The following procedures will be used for electrofishing:

- Electrofish areas of potential fish habitat using a tote-barge mounted, boat-mounted, or backpack electrofisher.
- Wearing insulated rubber gloves and boots and using nets with insulated handles, collect fish stunned by the electrical field.
- Place all target fish in buckets or a livewell for the duration of the sampling effort.
- If sufficient numbers of target species are present, continue to shock until the required number of individuals of target species is obtained.
- If sufficient individuals of target species cannot be collected in a reasonable period of time, document sampling efforts and sample available fish.

Fish Tissue Biopsy Sampling Procedure[1]

Sample Preparation

The following procedures will be used for sample preparation:

- Record fish total length, weight, and morphological or histopathological anomalies on the field data sheet. Sampling conditions (e.g., water depth, time of sampling, general observations of the weather) should also be noted on the field data sheet.
- Using tip of dermal punch, or scalpel, remove several scales from the mid-dorsal (1-2 centimeters below the dorsal fin) region of the fish.
- With a firm grip on the fish, take a new dermal punch and press firmly with a slight twisting motion into the muscle tissue where scales were removed, until the dermal punch is completely inserted.
- Use a short quick sideways motion to separate the tissue from the fish and remove the dermal punch with the muscle tissue inside.
- Remove the tissue plug from the dermal punch using clean forceps.
- Use a clean scalpel to remove the skin from the tissue plug and place the plug in a pre-labeled laboratory supplied sample container which will be stored on dry ice.
- Decontaminate forceps and scalpel after every sample.
- Complete appropriate COC forms and ship overnight to the laboratory for processing and analysis.

Field Quality Assurance/Quality Control Samples

Field quality assurance/quality control (QA/QC) samples are designed to help identify and minimize potential sources of sample contamination due to field procedures and to evaluate potential error introduced by sample collection and handling.

[1] Fillet and MeHg samples were collected in 2014 and the spring of 2015. Fillet samples were discontinued as part of the monitoring program and replaced with only THg plug samples (VDEQ, 2015).

Equipment Blank Samples

An equipment rinsate sample of sampling equipment is not needed.

Duplicate Samples

Collecting duplicate samples allows for evaluation of natural variability by comparing the analytical results of two samples from the same location. Duplicate samples also check for the consistency of field techniques and laboratory analysis. The duplicate samples will be handled in the same manner as the primary sample, assigned a distinct identification number, and shipped to the laboratory along with the primary sample it duplicates. The number of duplicate samples will be determined based on the sampling program.

Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicate (MSD) samples will be obtained by collecting additional material at a selected station. MS and MSD samples are prepared at the laboratory by dividing a control sample into two aliquots, then spiking each with identical concentrations of specific analytes. The spike samples are then analyzed separately, and the results are compared to evaluate the effects of the sample matrix on the analytical accuracy and precision. MS/MSD samples will be collected from baseline samples to ensure sufficient volume for laboratory QA/QC. MS/MSD samples will be labeled and shipped to the laboratory along with the primary sample from which they were collected.

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described in this sampling guideline. The sample parameters for analysis, preservation, and handling are specified in the Programmatic AOC-4 QAPP. Each sample container has a sample label affixed to the outside. The sampler marks each label using waterproof ink with the following information:

- Project name
- Sample identification number
- Date and time of collection
- Initials of sampling technician
- Requested analysis
- Method of preservation

Sample containers will be packed in bubble wrap to minimize breakage or damage to samples and placed in metal or plastic coolers. Dry will be placed around sample containers and additional cushioning material will be added to the cooler, if necessary. Paperwork (i.e., signed Chain-of-Custody forms) will be put in a Ziploc bag and placed on top of the sample containers or taped to the inside lid of the cooler. The cooler will be taped closed and a signed custody seal will be affixed to the side of the cooler. Laboratory address labels will be placed on top of the cooler.

All samples are expected to contain low levels of contamination and will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations.

All shipments containing dry ice will conform to federal, state, and carrier regulations. Standard procedures to be followed for shipping environmental samples to the analytical laboratory are outlined below.

- All environmental samples collected will be transported to the laboratory by AECOM personnel, shipped through Federal Express or equivalent overnight service, or picked up by a lab courier.
- Shipments will be scheduled to meet holding time requirements.

The laboratory will be notified to be prepared to receive a shipment of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed.

AECOM has established a program of sample COC that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession
- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed inside the shipping container, and the container will be sealed. Samples are considered to be in custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number

- Name of sampler and field personnel
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Sampling media
- Sample type
- Observations at the sampling site (e.g., weather conditions)
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Health and Safety Procedures

To avoid incidents or injuries during sampling, the following task-specific health and safety procedures should be followed in addition to those indicated in the AOC-4 Project HASP:

- Toxic or otherwise harmful concentrations of metals or other constituents are unlikely to be encountered while sampling fish tissue in rivers and streams. However, sampling crews should be trained in the general hazards of field sampling (e.g., waterborne pathogens) and how to minimize risks of exposure.
- Operating in or around waterbodies carries the inherent risk of drowning. U.S. Coast Guard approved personal flotation devices must be worn when operating or sampling from a boat, when sampling in more than a few feet of water, or when sampling in swift currents.
- Collecting samples in cold weather, especially around cold waterbodies, carries the risk of hypothermia, and collecting samples in extremely hot and humid weather carries the risk of dehydration and heat stroke. Sampling team members should wear adequate clothing for protection in cold weather and should carry an adequate supply of water or other liquids for protection against dehydration in hot weather.
- Sampling team members must cover exposed skin and/or use sunscreen for protection from sun exposure.
- When working on all waterbodies, sampling teams must develop and employ an emergency response plan, including the use of an onshore monitor that is accountable for the whereabouts of the team. The monitor can request aid if the team fails to report in at end of workday and can provide assistance to rescuers or the team under any emergency situation.

References

SRST. February 2006. South River Science Team Safety Program.

USEPA. 2000. *Guidance for assessing chemical contaminant data for use in fish advisories: Volume 1 Fish sampling and analysis. Third Edition*. U.S. Environmental Protection Agency. EPA 823-B-00-007.

VDEQ. 2015. *AOC#4 - Proposed Revision of LTM Plan Former DuPont Waynesboro Plant, Waynesboro, Virginia.* EPA ID# VAD003114832. Commonwealth of Virginia. Department of Environmental Quality; Richmond, Virginia.

Protocol SRBI-1:
Biological Sampling Guidelines for Clam (*Corbicula*) Tissue Collection

Equipment

The following equipment/supplies may be used to collect clam tissue samples:

- Dip net
- Clam cages
- Cement pavers
- Sorting tray/sieves
- Calipers
- Decontamination supplies
    - Brushes
    - Wash tubs
    - Buckets
    - Sponges and paper towels
    - Formula 409 (low mercury content cleaner)
    - Organic-free water DI or distilled water
    - Hand-held sprayers or spray bottles
    - Trash bags
    - Plastic sheeting
- Sample bottles/vials and labels provided by the laboratory
- Lint-free wipes (Kimwipes or equivalent)
- Cooler
- Dry ice
- Field notebook/field data sheets
- Pencils and waterproof/permanent marking pens
- Nitrile gloves
- Sampling location map
- Global positioning system (GPS)
- Camera
- Chain-of-custody (COC) forms
- Custody seals

- Depuration chambers
- Shellfish tags
- Plastic label tape (Dymo brand)
- Scientific collector's permit and field identification guides, as necessary
- Appropriate health and safety equipment

Decontamination Procedures

Before collecting each sample, the sampling and sorting equipment will be thoroughly cleaned and rinsed with deionized (DI) or distilled water to prevent potential sample contamination. Following decontamination, the equipment will be wrapped in clean plastic sheeting or trash bags to prevent contact with dust and unclean surfaces.

Initial *Corbicula* Collection Procedures

The following procedures will be used for initial *Corbicula* collection at the reference site:

- Using a GPS unit, document location prior to sampling. Collect *Corbicula* by dipnet or shovel in designated stream reach.
- Place collected *Corbicula* into containers with river water, and limit the size of clams collected to between 15 and 25 millimeter (mm).

The following procedures will be used for caged clam studies:

- Place clams of similar size into mesh sleeves and label sleeves with waterproof labels
- Place sleeves into containers filled with water for transport to site.
- Upon arrival at the sampling location, attach mesh sleeves to cage frames and deploy cages at chosen locations
- Document cage locations with GPS.

The following procedures will be used for recovering caged clams:

- Locate clam cages visually or with the aid of GPS if marker cannot be seen.
- Collect the specified number of clams by hand picking or using a small hand trowel, ensuring they have the appropriate tag for the location.
- Place tagged clams into labeled containers filled with site water.
- Return all clams to lab and prepare for depuration.

The following procedures will be used for depurating clams:

- Each sampling location will have separate depuration chambers to prevent cross contamination.
- Place clams into mesh bags by location (near bank or center channel).
- Suspend clams off of the bottom of the chamber to prevent uptake of fecal matter.
- Depuration chambers will be filled with DI or distilled water.

- Clams will be allowed to depurate for approximately 24 hours.
- After 24 hours the mesh bags of clams for each location will be placed into laboratory supplied containers and immediately frozen. The laboratory is responsible for shucking the clams to remove the tissue.
- Samples will be shipped overnight on dry ice to the contract laboratory.

Field Quality Assurance/Quality Control Samples

Field quality assurance/quality control (QA/QC) samples are designed to help identify and minimize potential sources of sample contamination due to field procedures and to evaluate potential error introduced by sample collection and handling.

Equipment Blank Samples

An equipment rinsate sample of sampling equipment is not needed.

Duplicate Samples

Collecting duplicate samples allows for evaluation of natural variability by comparing the analytical results of two samples from the same location. Duplicate samples also check for the consistency of field techniques and laboratory analysis. The duplicate samples will be handled in the same manner as the primary sample, assigned a distinct identification number, and shipped to the laboratory along with the primary sample it duplicates. Duplicate samples will be determined by the sample collection program. Stations where duplicates will be collected will be determined in the field based on professional judgment.

Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicate (MSD) samples will be obtained by collecting additional material at a selected station. MS and MSD samples are prepared at the laboratory by dividing a control sample into two aliquots, then spiking each with identical concentrations of specific analytes. The spike samples are then analyzed separately, and the results are compared to evaluate the effects of the sample matrix on the analytical accuracy and precision. MS/MSD samples will be collected from baseline samples to ensure sufficient volume for laboratory QA/QC. MS/MSD samples will be labeled and shipped to the laboratory along with the primary sample from which they were collected.

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described in this sampling guideline. The sample parameters for analysis, preservation, and handling are specified in the Programatic AOC-4 QAPP. Each sample container has a sample label affixed to the outside. The sampler marks each label using waterproof ink with the following information:

- Project name
- Sample identification number
- Date and time of collection
- Initials of sampling technician
- Requested analysis

- Method of preservation
- Selected taxa

Sample containers will be packed in bubble wrap to minimize breakage or damage to samples and placed in metal or plastic coolers. Dry ice will be placed around sample containers and additional cushioning material will be added to the cooler, if necessary. Signed COC forms will be put in a Ziploc bag and placed on top of the sample containers or taped to the inside lid of the cooler. The cooler will be taped closed and a signed custody seal will be affixed to the side of the cooler. Laboratory address labels will be placed on top of the cooler.

All samples are expected to contain low levels of contamination and will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations. All shipments containing dry ice will conform to federal, state, and carrier regulations. Standard procedures to be followed for shipping environmental samples to the analytical laboratory are outlined below.

- All environmental samples collected will be transported to the laboratory by AECOM personnel, shipped through Federal Express or equivalent overnight service, or picked up by a lab courier.
- Shipments will be scheduled to meet holding time requirements.

The laboratory will be notified to be prepared to receive a shipment of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed.

AECOM has established a program of sample COC that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession
- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed inside the shipping container, and the container will be sealed. Samples are considered to be in

custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number
- Name of sampler and field personnel
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Sampling media
- Sample type
- Sample physical characteristics
- Observations at the sampling site (e.g., weather conditions)
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Health and Safety Procedures

To avoid incidents or injuries during sampling, the following health and safety procedures should be followed:

- Toxic or otherwise harmful concentrations of metals or other constituents are unlikely to be encountered while invertebrate sampling in rivers and streams. However, sampling crews should be trained in the general hazards of field sampling (e.g., waterborne pathogens) and how to minimize risks of exposure.
- Operating in or around waterbodies carries the inherent risk of drowning. U.S. Coast Guard approved personal flotation devices must be worn when operating or sampling from a boat, when sampling in more than a few feet of water, or when sampling in swift currents.
- Collecting samples in cold weather, especially around cold waterbodies, carries the risk of hypothermia, and collecting samples in extremely hot and humid weather carries the risk of dehydration and heat stroke. Sampling team members should wear adequate clothing for protection in cold weather and should carry an adequate supply of water or other liquids for protection against dehydration in hot weather.

- Sampling team members must cover exposed skin and/or use sunscreen for protection from sun exposure.
- When working on all waterbodies, sampling teams must develop and employ an emergency response plan, including the use of an onshore monitor that is accountable for the whereabouts of the team. The monitor can request aid if the team fails to report in at end of workday and can provide assistance to rescuers or the team under any emergency situation.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition.* EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Protocol SRBI-2:
Biological Sampling Guidelines for
Aquatic Macroinvertebrate Tissue Collection

Aquatic Macroinvertebrate tissue sampling guidelines were developed based on collection procedures for rivers outlined in the *Rapid Bioassessment Protocols: For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition* (Barbour, et al., 1999).

Equipment

The following equipment/supplies may be used to collect aquatic macroinvertebrate tissue samples:

- Invertebrate sampling equipment
    - D-frame net
- Stainless-steel forceps
- Stainless-steel sorting tray/glass Petri dish
- Calipers
- Decontamination supplies
    - Brushes
    - Wash tubs
    - Buckets
    - Sponges and paper towels
    - Formula 409 (low mercury content cleaner)
    - Organic-free water deionized (DI) or distilled water
    - Hand-held sprayers or spray bottles
    - Trash bags
    - Plastic sheeting
- Sample bottles/vials and labels provided by the laboratory
- Lint-free wipes (Kimwipes or equivalent)
- Ziploc bags or similar dry storage materials
- Depuration chambers
- Cooler
- Dry ice
- Field notebook/field data sheets
- Pencils and waterproof/permanent marking pens
- Magnifying glass/hand lens

- Paper towels
- Nitrile gloves
- Sampling location map
- Global positioning system (GPS)
- Camera
- Scientific collector's permit and field identification guides, as necessary
- Chain-of-custody (COC) forms
- Custody seals
- Appropriate health and safety equipment

Decontamination Procedures

Before collecting each sample, the sampling and sorting equipment will be thoroughly cleaned and rinsed with DI or distilled water to prevent potential sample contamination. Following decontamination, the equipment will be wrapped in clean plastic sheeting or trash bags to prevent contact with dust and unclean surfaces.

Invertebrate Sample Collection Procedures

The following procedures will be used when collecting aquatic insect larvae tissue by D-frame dip net:

- Place the dip net on the substrate and disturb the upstream substrate with a kicking and shuffling of the feet. For shallow and smaller sized gravel, a hand may be used to disturb the substrate and also rub larger cobbles to dislodge organisms into the net.
- The net may also be forcefully jabbed into submerged aquatic vegetation, root mats, and snag piles to acquire target species.
- After a collection has been obtained, the net is rinsed two to three times with clean stream water to wash all organisms to the back of the net.
- The contents of the net are placed into a sorting pan, and selected individuals are prepared for analysis.
- After the sample has been collected, turn the net inside out and rinse the net with clean stream water. Visually inspect the net to ensure that all debris and benthic organisms have been removed from the net and repeat as necessary prior to moving to different sampling locations.
- This process is repeated to obtain sufficient numbers of target species which will be composited into replicate samples.

The following procedures will be used when collecting aquatic insect larvae tissue by hand:

- Cobbles will be removed from the river and rinsed into a sorting tray
- Target invertebrates will be transferred from the sorting tray to a depuration container using a dedicated pipet

- This process is repeated to obtain sufficient numbers of target species which will be composited into replicate samples.

The following procedures will be used for aquatic insect larvae depuration:

- Each sampling location and organism type will have separate depuration chambers to prevent cross contamination.
- Depuration chambers will be filled with distilled water
- Organisms will be allowed to depurate for 24 hours
- After 24 hours organisms will be grouped into composite samples and placed into laboratory supplied containers and immediately frozen. Larvae that have hatched will not be included in the sample.
- Samples will be shipped overnight on dry ice to the contract laboratory.

The following procedures will be used for aquatic insect sample preparation:

- Place target species into a sorting pan.
- Separate a pre-specified number of the target species for each sample using pre-cleaned stainless-steel forceps, and place into a decontaminated Petri dish.
- Group target species together according to size class as best as possible with available numbers.
- Total length [millimeter (mm)] of ten organisms per sample will be measured and recorded on data sheets. A total of three samples will be collected at each location.
- Rinse specimens with DI or distilled water.
- Wipe or blot with lint-free wipes to remove excess water.
- Place specimens into sampling containers provided by the laboratory.
- Place samples in a cooler and pack securely with dry ice.

Field Quality Assurance/Quality Control Samples

Field quality assurance/quality control (QA/QC) samples are designed to help identify and minimize potential sources of sample contamination due to field procedures and to evaluate potential error introduced by sample collection and handling.

Equipment Blank Samples

An equipment rinsate sample of sampling equipment is not needed.

Duplicate Samples

Collecting duplicate samples allows for evaluation of natural variability by comparing the analytical results of two samples from the same location. Duplicate samples also check for the consistency of field techniques and laboratory analysis. The duplicate samples will be handled in the same manner as the primary sample, assigned a distinct identification number, and shipped to the laboratory along with the primary sample it duplicates. Duplicate samples will be determined by the sample collection program. Stations will be determined in the field based on professional judgment.

Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicate (MSD) samples will be obtained by collecting additional material at a selected station. MS and MSD samples are prepared at the laboratory by dividing a control sample into two aliquots, then spiking each with identical concentrations of specific analytes. The spike samples are then analyzed separately, and the results are compared to evaluate the effects of the sample matrix on the analytical accuracy and precision. MS/MSD samples will be collected from baseline samples to ensure sufficient volume for laboratory QA/QC. MS/MSD samples will be labeled and shipped to the laboratory along with the primary sample from which they were collected.

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described in this sampling guideline. Each sample container has a sample label affixed to the outside. The sampler marks each label with the following information using waterproof ink:

- Project name
- Sample identification number
- Date and time of collection
- Initials of sampling technician
- Requested analysis
- Method of preservation
- Selected taxa

  Sample containers will be packed in bubble wrap to minimize breakage or damage to samples and placed in metal or plastic coolers. Dry ice will be placed around sample containers and additional cushioning material will be added to the cooler, if necessary. Paperwork (i.e., signed COC forms) will be put in a Ziploc bag and placed on top of the sample containers or taped to the inside lid of the cooler. The cooler will be taped closed and a signed custody seal will be affixed to the side of the cooler. Laboratory address labels will be placed on top of the cooler.

  All samples are expected to contain low levels of contamination and will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations. All shipments containing dry ice will conform to federal, state, and carrier regulations. Standard procedures to be followed for shipping environmental samples to the analytical laboratory are outlined below.

- All environmental samples collected will be transported to the laboratory by AECOM personnel, shipped through Federal Express or equivalent overnight service, or picked up by a lab courier.
- Shipments will be scheduled to meet holding time requirements.

  The laboratory will be notified to be prepared to receive a shipment of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed.

AECOM has established a program of sample COC that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession
- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed inside the shipping container, and the container will be sealed. Samples are considered to be in custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number
- Name of sampler and field personnel
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Sampling media
- Sample type
- Sample physical characteristics
- Observations at the sampling site (e.g., weather conditions)

- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

  Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Health and Safety Procedures

To avoid incidents or injuries during sampling, the following health and safety procedures should be followed. Specific details regarding Health and Safety are included in the AOC-4 Project HASP:

- Toxic or otherwise harmful concentrations of metals or other constituents are unlikely to be encountered while invertebrate sampling in rivers and streams. However, sampling crews should be trained in the general hazards of field sampling (e.g., waterborne pathogens) and how to minimize risks of exposure.
- Operating in or around waterbodies carries the inherent risk of drowning. U.S. Coast Guard approved personal flotation devices must be worn when operating or sampling from a boat, when sampling in more than a few feet of water, or when sampling in swift currents.
- Collecting samples in cold weather, especially around cold waterbodies, carries the risk of hypothermia, and collecting samples in extremely hot and humid weather carries the risk of dehydration and heat stroke. Sampling team members should wear adequate clothing for protection in cold weather and should carry an adequate supply of water or other liquids for protection against dehydration in hot weather.
- Sampling team members must cover exposed skin and/or use sunscreen for protection from sun exposure.
- When working on all waterbodies, sampling teams must develop and employ an emergency response plan, including the use of an onshore monitor that is accountable for the whereabouts of the team. The monitor can request aid if the team fails to report in at end of workday and can provide assistance to rescuers or the team under any emergency situation.

References

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Protocol SRBI-3:
Guidelines for Macroinvertebrate Community Sampling and Laboratory Analyses

Macroinvertebrate community sampling guidelines were developed based on collection procedures for rivers outlined in the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition* (Barbour et al. 1999).

Equipment

The following equipment/supplies may be used to collect macroinvertebrate community samples:

- Boat and motor
- Surber sampler
- Stainless-steel spoon
- 500-μm sieve
- Forceps
- Water quality meter
- Measuring calipers
- Macroinvertebrate sample containers and labels
- 70% reagent alcohol
- Field notebook/field data sheets
- Pencils and waterproof and permanent marking pens
- Sampling location map
- GPS unit
- YSI 556 multiprobe water quality meter
- Camera
- Scientific collector's permit and field identification guides, as necessary
- Appropriate health and safety equipment

Instrument Calibration

In addition to a GPS, electronic equipment used during sampling will likely include a multi-functional water sample meter (YSI 556). The meter will be operated, calibrated, and maintained according to manufacturer's guidelines and recommendations. Calibration of the field instruments will be performed on a daily basis, and the stability of the calibration will be verified during sampling activities as warranted. Operation and calibration of the field instruments will be performed by AECOM personnel properly

trained in these procedures and calibration data will be documented in the field logbook or data sheet.

Sample Collection Procedures

Health and safety procedures for conducting the work over water are detailed in the AOC-4 Project HASP. These procedures will be followed as a required component of the sampling.

The following procedures will be used during the macroinvertebrate community sampling:

- Use the GPS system or aerial photos to locate the appropriate section within reach habitat to be sampled.
- Obtain water quality measurements and document the water quality conditions. Parameters to be measured include temperature (degrees Celsius), dissolved oxygen (mg/L), conductivity (mS/cm), pH, dissolved oxygen (% saturated), ORP (mV).

At each sampling location, six replicate samples along a gradient from toe of pool, transitional, and head of riffle habitats will be collected within the sampling area. The following procedure describes the collection of one replicate:

- Prior to collecting the first sample, and between sample replicates, rinse the surber with stream water to remove any organisms/debris. Visually check that all organisms/debris are out of the Surber sampler prior to collecting each sample.
- Place a Surber sampler (500-µm mesh; sample area 1.0 ft^2) firmly on the substrate with the bag facing downstream.
- Be sure that the bottom of the Surber is flush with the bed of the surface, preventing organisms from washing through.
- Using a gloved hand, disturb the substrate within the Surber sampler to dislodge any organisms associated with the substrate. All large substrate (e.g., cobble and larger) should be gently removed from the frame, wiped with a brush or gloved hand and inspected to insure all attached organisms are washed into the net.
- Rinse the sampler with clean stream water, washing all organisms and debris into the back of the net.
- Sample additional locations within the designated sampling area.

The following procedures will be used for sample collection:

- Transfer all organisms and debris from the net into a sample container and preserve with 70% ethanol. Forceps may be needed to remove organisms from the dip net. Place a label indicating the project name, sample identification code, date, stream name, and collector name into the sample container. A label with the same information is to be placed on the outside of the container.
- In the field notebook/data sheet, note the type of sampler, depth, time of sampling, and relevant observations, including but not limited to weather, turbidity, velocity, depth, and type of substrate.

To the extent practical, consistent sampling techniques are to be used among all sampling stations for consistency and comparability.

Sample Handling and Chain of Custody

AECOM has established a program of sample chain-of-custody (COC) that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession
- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed in sealed Ziploc bags and taped to the inside of the shipping container, and the container will be sealed. Samples are considered to be in custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number
- Name of sampler and field personnel
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method

- Sampling media
- Sample type
- Sample physical characteristics
- Observations at the sampling site (e.g., weather conditions)
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

  Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Laboratory Sample Sorting and Specimen Identification Procedures

In the laboratory, the following procedures are to be followed for sorting and taxonomic identification of samples:

- Rinse sample through a 500-micron mesh sieve to remove excess alcohol and detritus.
- Spread rinsed sample evenly over a numbered grid at the bottom of a sorting tray.
- Select one grid using a random number table and remove all organisms from within the grid.
- Randomly select subsequent grids until 300 organisms are obtained.
- Place organisms into vials of 70% ethanol, sorted by major taxonomic grouping.
- When the entire sample has been sorted, preserve the remaining sediment in 70% ethanol for QA/QC analysis.
- Identify all organisms removed from each sample to the lowest practical taxonomic unit, generally to genus (family for chironomids, class for oligochaetes). Identifications of organisms are to be performed using a dissecting microscope. The most current manuals and publications are to be used for identifications.
- Place identified organisms into vials of 70% ethanol for taxonomic verification.
- Approximately 10% of the total number of replicate samples or sampling trays will be reexamined following the sorting procedures to ensure complete and accurate sorting. If more than 20% of the total number of organisms has been missed, all replicate samples sorted by that person shall be reexamined. Any samples where more than 20% of the total number of organisms was missed must be resorted.
- Information regarding identification and abundance will be recorded on data sheets.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition*. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Protocol SRBS-1:
Biological Sampling Guidelines for
Spider Tissue Analysis

These data will be used to evaluate potential exposure of invertivorous songbirds that forage on predatory terrestrial invertebrates (spiders) present within the riparian zone surrounding the South River, to mercury.

Equipment

The following equipment/supplies may be used to collect spider tissue samples:

- Chest waders/rubber boots
- Collection equipment, including dry pitfall traps and dip nets
- Shovel
- Gloves
- Field book/field data sheets
- Global positioning system (GPS)
- Tweezers/forceps
- Magnifying glass
- Sample containers from laboratory
- Sample container labels
- Cooler
- Dry ice
- Chain-of-Custody (COC) forms
- Custody seals
- Camera
- Pencils and waterproof/permanent marking pens
- Scientific collector's permit and field identification guides, as necessary
- Appropriate health and safety equipment

Standard Operating Procedure for Collection of Spiders

Dry pitfall trapping arrays consisting of 5-10 pitfall traps per sample location will be deployed at each sampling area. Trap arrays will be positioned on the shoreline or on gravel bars within the river 10 meters of the edge of the water. Traps will be set up monitored at least every day. Spiders will also be collected through a variety of active capture techniques including sweep nets, and hand capture.

Procedures for Collecting Spiders Using Dry Pitfall Sampling:

- Locate site where dry pitfall traps are to be deployed; approximately 5-10 pitfall traps will be deployed per sampling location. Spacing of the pitfall traps will be at the discretion of the Field Team leader and will be dependent on available habitat. Collect GPS coordinates once sample location is chosen and record in field book/field data sheets.

- Using a trowel, dig a hole to the desired depth and width so the top of the trap sits flush with the soil and place the plastic container in the hole. Backfill dirt as necessary to ensure there are no gaps around the edges of the pitfall trap.
- When checking traps, remove spiders; place target organisms into sample containers on dry ice to euthanize.
- Record the number of spiders collected and released on field data sheets
- Upon return to the lab, record combined cephalo thorax/abdomen length and weight.
- Place target spiders into labeled laboratory supplied containers and place on dry ice.
- Complete appropriate Chain-of-Custody forms and ship overnight to the laboratory for processing and analysis.

  To the extent practical, consistent sampling techniques are to be used among all sampling stations for consistency and comparability.

Procedures for Collecting Spiders Using Sweep Net Sampling:

- Locate sites where habitat for wolf spiders is present; the discretion of the Field Team leader will determine the exact sampling location. Collect GPS coordinates once sample location is chosen and record in field book/field data sheets.
- Using dip nets, gently drag the tip of the net through areas with tall grass or brush with a sweeping motion.
- Check net after each sweep. If spiders are present, remove spiders; place target organisms into sample containers on dry ice to euthanize.
- Record the number of spiders collected and released on field data sheets
- Upon return to the lab, record combined cephalo thorax/abdomen length and weight.
- Place target spiders into labeled laboratory supplied containers and place on dry ice.
- Complete appropriate Chain-of-Custody forms and ship overnight to the laboratory for processing and analysis.

  To the extent practical, consistent sampling techniques are to be used among all sampling stations for consistency and comparability.

Procedures for Collecting Spiders Using Hand Capture Sampling:

- Locate sites where habitat for wolf spiders is present; the discretion of the Field Team leader will determine the exact sampling location. Collect GPS coordinates once sample location is chosen and record in field book/field data sheets.
- While donning gloves and holding a plastic sampling container, over turn rocks or brush where wolf spider habitat is likely. Gently place the sampling container over the spider and scoop the spider into it using the edge of the container.

- Place target organisms into sample containers on dry ice to euthanize.
- Record the number of spiders collected and released on field data sheets
- Upon return to the lab, record combined cephalo thorax/abdomen length and weight.
- Place target spiders into labeled laboratory supplied containers and place on dry ice.
- Complete appropriate Chain-of-Custody forms and ship overnight to the laboratory for processing and analysis.

To the extent practical, consistent sampling techniques are to be used among all sampling stations for consistency and comparability.

Field Quality Assurance/Quality Control Samples

Field quality assurance/quality control (QA/QC) samples are designed to help identify and minimize potential sources of sample contamination due to field procedures and to evaluate potential error introduced by sample collection and handling.

Duplicate Samples

Collecting duplicate samples allows for evaluation of sample homogeneity by comparing the analytical results of two samples from the same individual. Duplicate samples also check for the consistency of laboratory analysis. Duplicate samples will be collected by the analytical laboratory from primary samples with sufficient mass. Duplicates will be analyzed at a rate of five (5) percent of the total samples collected for in the study.

Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicate (MSD) samples will be obtained by the analytical laboratory from primary samples with sufficient mass. MS and MSD samples are prepared at the laboratory by dividing a control sample into two aliquots, then spiking each with identical concentrations of specific analytes. The spike samples are then analyzed separately, and the results are compared to evaluate the effects of the sample matrix on the analytical accuracy and precision. MS/MSD samples will be collected from baseline samples to ensure sufficient volume for laboratory QA/QC. MS/MSD samples will be analyzed at a rate of five (5) percent of the total samples collected for in the study.

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described in this sampling guideline. The sample parameters for analysis, preservation, and handling are specified in scope of work. Each sample container has a sample label affixed to the outside. The sampler marks each label using waterproof ink with the following information:

- Project name
- Sample identification number
- Date and time of collection
- Initials of sampling technician

- Requested analysis
- Method of preservation

Dry ice will be placed around sample containers and additional cushioning material will be added to the cooler, if necessary. Paperwork (i.e., signed Chain-of-Custody forms) will be put in a Ziploc bag and placed on top of the sample containers or taped to the inside lid of the cooler. The cooler will be taped closed and a signed custody seal will be affixed to the side of the cooler. Laboratory address labels will be placed on top of the cooler.

All samples are expected to contain low levels of contamination and will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations. All shipments containing dry ice will conform to federal, state, and carrier regulations. Standard procedures to be followed for shipping environmental samples to the analytical laboratory are outlined below.

- All environmental samples collected will be transported to the laboratory by AECOM personnel, shipped through Federal Express or equivalent overnight service, or picked up by a lab courier.
- Shipments will be scheduled to meet holding time requirements.

The laboratory will be notified to be prepared to receive a shipment of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed.

AECOM has established a program of sample COC that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession
- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed inside the shipping container, and the container will be sealed. Samples are

considered to be in custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number
- Name of sampler and field personnel
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Sampling media
- Sample type
- Observations at the sampling site (e.g., weather conditions)
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Health and Safety Procedures

To avoid incidents or injuries during sampling, the following task-specific health and safety procedures should be followed in addition to those indicated in the Health and Safety Plan (HASP):

- Toxic or otherwise harmful concentrations of metals or other constituents are unlikely to be encountered while sampling spider tissue in South River. However, sampling crews should be trained in the general hazards of field sampling (e.g., waterborne pathogens) and how to minimize risks of exposure.
- Operating in or around waterbodies carries the inherent risk of drowning. U.S. Coast Guard approved personal flotation devices must be worn when sampling from a boat.
- Collecting samples in extremely hot and humid weather carries the risk of dehydration and heat stroke. Sampling team members should wear adequate clothing and should carry an adequate supply of water or other liquids for protection against dehydration in hot weather.
- Sampling team members must cover exposed skin and/or use sunscreen for protection from sun exposure.
- When working on all waterbodies, sampling teams must develop and employ an emergency response plan, including the use of an onshore monitor that is accountable for

the whereabouts of the team. The monitor can request aid if the team fails to report in at end of workday and can provide assistance to rescuers or the team under any emergency situation.

Protocol SRDA-1
Data Analysis for the Long-Term Monitoring Plan

Timely and accurate data analysis is a critical component of the monitoring plan. The goal of the monitoring plan is to differentiate trends in mercury concentrations due to remediation vs. trends in mercury concentrations due to non-remediation related variability in climate and other factors that affect mercury fate and transport. This protocol describes the data analysis approach for the long-term monitoring plan.

A qualified statistician will be employed by DuPont to help design field and laboratory experiments and will be the primary resource for analyzing the ensuing data. Statistical methods will be fully described in all written reports and will be consistent with currently accepted scientific practices.

Objective

The objective of the long-term monitoring is to be able to determine if there is at least a 75% probability of finding a statistically significant ($p = 0.05$) downward trend in mercury concentrations in key monitoring elements (e.g., fish tissue) within 5 to 10 years.

Statistical Approach

To be able to determine a significant downward trend in mercury concentrations, statistical tests were selected that can provide robust analysis of changes in concentration over time with a wide variety of data types. Three different statistical tests for trend were considered:

- Simple linear regression
- Jonckheere-Terpstra test
- Williams' test

Simple linear regression is a powerful technique when the data are well behaved (i.e., normally distributed with homogeneous variances) and the trend is linear in time. There is no sound reason to expect linearity and the other approaches require only a monotone relationship between time and mercury levels. Williams' test is parametric but assumes well behaved data. The Jonckhere-Terpstra test is non-parametric. Very extensive computer modeling has shown the latter has very similar power properties to the former for well-behaved data and is far superior for highly variable data such as likely to be collected in ecosystems.

Power simulations were conducted to select adequate sample sizes using the data from existing samples for determining the mean total mercury (THg) levels and the variance in selected stretches of the river. The monitoring plans were developed to produce at least 75% power by one or more of the three statistical tests to detect 10% decrease in THg levels (at $p = 0.05$). These are conservative sampling plans in that no additional information was used to obtain the powers of detection, such as season, topography, and river conditions that might be used in the final analyses. These are described in the subsequent section on "Explanatory Variables."

Explanatory Variables

Where possible, statistical analysis of monitoring data will utilize the extensive data collected on mercury in a wide array of biological and inorganic matrices, and variation in climate and physical parameters. Previous statistical modeling approaches were designed to understand relationships between the following responses in the South River:

- Surface water THg and methylmercury (MeHg)
- Sediment THg and MeHg
- Floodplain THg
- Fish tissue THg

In addition, all organisms sampled in or near the river were modeled and some relevant species (i.e., those that could be considered food items for fish) were included as components of fish models. For explanatory variables, the statistical model for the South River accounts for the interaction between different media (e.g., surface water, sediment, floodplain soil, rainfall, pore water, and alluvial bank soil) and other factors (e.g., land use). Three main types of explanatory variables can be used in the South River statistical models:

- Variables that are collected recurrently (e.g., surface water mercury), continuously (temperature, discharge) or that are time-dependent (e.g., season)
- Environmental variables that were measured once (e.g., floodplain area, land use, gradient, floodplain THg, erosion, fish diet) and are expected to be relatively constant stable over time
- Explanatory variables that interact with each other (e.g., rainfall, floodplain soil THg concentration, and land use)

This underlying data set will be used to differentiate trends in mercury concentration from changes that are due to natural annual variability in parameters that affect mercury fate and transport.

Monitoring Element	Reach (RRM)	Percent Decrease	Sample Size	Timeframe	Statistical Power		
					Linear Regression	Jonckheere-Terpstra	Williams'
Adult Bass	<0	10	7	5	71	80	91
				10	100	100	100
	0.1 to 2.3	10	5	5	91	95	98
				10	100	100	100
	5.2 to 11.8	10	5	5	100	100	100
				10	100	100	100
	16 to 23.5	10	5	10	100	100	100
Benthic Invertebrate Tissue	<0	10	3	10	100	100	18
		10	10	5	100	100	84
	0.1 to 2.3	10	3	10	100	100	20
	5.2 to 11.8	10	3	10	100	100	16
		10	10	5	73	81	35
	16 to 23.5	10	3	10	94	93	9
Asiatic Clam Tissue	<0	10	3	10	100	100	22
		10	10	5	90	94	44
	0.1 to 2.3	10	3	10	100	100	19
		10	10	5	77	85	34
	5.2 to 11.8	10	3	10	100	100	19
		10	10	5	68	77	35
	16 to 23.5	10	3	10	100	100	14
Interstitial Sediment	<0	10	2	10	98	85	100
	0.1 to 2.3	10	2	10	91	71	100
	5.2 to 11.8	10	2	10	100	88	100
	16 to 23.5	10	2	10	93	72	100
Surface Water	<0	10	2	10	100	97	100
	0.1 to 2.3	10	2	10	100	94	100
	5.2 to 11.8	10	2	10	97	84	100
	16 to 23.5	10	2	10	96	81	100
Carolina Wren	<0	10	3	10	100	100	100
	0.1 to 2.3	10	3	10	100	100	100
		10	5	5	55	65	83
	5.2 to 11.8	10	3	10	100	100	100
	16 to 23.5	10	3	10	100	99	100

Table 1. Sample size necessary to detect a 10% decrease (at p = 0.05) in THg concentrations in key long-term monitoring elements. Three statistical tests are considered: linear regression, Jonckheere-Terpstra, and Williams' test. Sample sizes were calculated for either a 5- or 10-year window over which declines may be observed. If no result is listed for a 5-year sampling window, then there was no test with at least 75% power to detect a 10% decrease (at p = 0.05).

Protocol SRSE-1:
Guidelines for Sampling Size-Classified Sediments Using a Beckson Pump

Note: Specific sampling procedures described below may be modified once the detailed scope of work has been developed

This method describes the guidelines for collection of riverbed sediment samples. The method is applicable to small rivers and streams that can be waded or that have maximum water depths less than about eight feet. The method is generally used in high gradient streams where sediment grain size is rarely more than a few millimeters in thickness and where scoops would be ineffective for collection. The method is based on general guidance and principles outlined in EPA's *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual* (USEPA, 2001).

Equipment

The following equipment/supplies may be used to collect sediment samples:

- Piston type bilge pump (similar to Grainger Item: Portable Hand Pump, item # 4P018)
- HDPE 5-gallon buckets (three per location)
- Wrist watch or other timing device with second hand/display
- Portable analytical balance, 2 kilogram (kg) capacity, 1.0 gram (g) resolution
- Analysis-appropriate sample containers
- Waders
- Dry ice (if methylmercury analysis is requested)
- Decontamination equipment
    - Reagent Water - Reagent water is water in which metals and nutrients and potentially inferring substances are not detected at the minimum detectable level (MDL) of the analytical method used for analysis of samples or are detected at concentration no greater than three times the MDL. Reagent water is used to prepare field blanks and equipment blanks and to rinse apparatus.
    - Formula 409 - This is a commercial liquid cleaner suitable for decontaminating bilge pump and buckets. It is an effective degreaser as well as providing good removal of surface metal contamination.
- Powder-free Nitrile gloves
- Pencils and waterproof/permanent marking pens
- Sampling location maps
- Global positioning system (GPS)
- Camera

- Appropriate health and safety equipment
- Cooler
- Chain-of-custody (COC) forms
- Custody seals

Decontamination Procedures

The buckets and bilge pump will be decontaminated before sampling begins and between sampling locations.

The following steps will be used to decontaminate sampling equipment:

- Don appropriate personal protective equipment (PPE) and review safety procedures and plan.
- The buckets should be scrubbed with Formula 409 and then flushed with river water initially and prior to reuse.
- River water should be flushed through the bilge pump at the end of each sampling use followed by flushing with diluted (10:1) Formula 409 cleaner and more river water. Flush the pump at the end of each day with reagent water and drain off any water that is not expelled by operating the pump. No other cleaning is needed unless oily sediments are encountered. Store the pump in a clean polyethylene bag.

Contamination and Interference

Avoidance of sample and apparatus contamination is of paramount importance for this method. The most important factors in avoiding/reducing sample contamination are as follows: (1) an awareness of potential sources of contamination and (2) strict attention to work being performed. The following procedures should be followed to prevent contamination and interferences:

- Sampling personnel must wear clean, nonpowdered gloves during all operations involving handling of the apparatus and sample bottles. Gloves should be changed if there is any suspicion that the gloves have contacted surfaces that could be contaminated.
- The specific items comprising the apparatus have been demonstrated to effectively avoid contamination when deployed and operated as described in this method. Do not substitute items or change procedures without first demonstrating that the substitution or procedural change maintains sample integrity.
- In general, there are no or few analytical interferences that may be encountered in ambient sediment sampling. However, samplers should record any odors, sheens, colors, or other unusual sample characteristics on the analytical request form to alert laboratory staff of potential analytical issues.

Sample Collection and Handling Procedures

The following procedures will be used to collect sediment samples:

- Identify sample location using GPS unit.

- Evaluate the conditions of the river and assess that both banks and the middle of the channel can be sampled safely. If not, modify location or move to a different station.
- Use a decontaminated pump to pump sediment and water from overlying substrate within an approximate 2 ft^2 area into one of the precleaned 5-gallon buckets. Start on near either the left or right bank. Three areas of the channel will be sampled (left, center, right) and composited to constitute each sample. Short pump strokes reduce the amount of water and maximize the sediment recovered. Move the intake end of pump around as sediment is collected to maximize the volume of sediment obtained. In so far as possible, limit the depth of penetration of the pump tip to the upper 1 to 2 inches of sand, gravel, and cobble. Continue pumping until approximately 1/3 of the 5 gallon bucket is filled. Move to the next location and repeat the above procedure until approximately 2/3 of the bucket is full. Move to the final location and fill the bucket with sediment/water.
- After 5 gallons have been pumped, use a clean paddle or spoon to completely suspend the sediment. Stir for about 15 seconds.
- Allow sediment to settle for 30 seconds. All sand in the sample will settle to the bottom of the bucket in this interval.
- Pour the remaining suspension into a separate precleaned 5-gallon bucket. Stow the bucket someplace where it will be moved as little as possible for 30 minutes.
- At the end of the 30 minute settling period, carefully pour off and discard the as much of the overlying water as possible. Avoid resuspending or losing any of the sediment that has settled at the bottom of the bucket.
- Determine from the analytical lab(s) the minimum acceptable sample volume or mass. If, in the judgment of the field team, the amount of sediment procured from the first sample is insufficient, repeat the above procedure in an adjacent section of the stream. Then, composite each additional grab sample until sufficient volume is achieved.
- As a point of reference, typical dry mass obtained per 5-gallon volume initially pumped is between 30 to 80 g dry weight. This volume will be almost entirely composed of silt and clay because sand is excluded during the 30-second settling.
- In general, field preserve sediment samples for metals and nutrient analysis by chilling and maintaining them in the dark. Sediment samples for methylmercury analysis must be frozen and shipped on dry ice. Also refer to any specific instructions provided by the analytical laboratory.

Field Quality Assurance/Quality Control

Field quality assurance/quality control (QA/QC) samples are designed to help identify and minimize potential sources of sample contamination due to field procedures and to evaluate potential error introduced by sample collection and handling. Strict adherence to the procedures described above in the section titled “Contamination and Interference” will assure collection of uncompromised sediment samples.

Field/Equipment Blank Samples

Field and equipment blank samples will be collected each day that sampling occurs to demonstrate that contamination has been controlled. Field blanks will consist of reagent water that will be used to rinse equipment while equipment blanks will consist of reagent water after it has contacted the pump and buckets.

Duplicate Samples

Collecting duplicate samples allows for evaluation of natural variability by comparing the analytical results of two samples from the same location. Duplicate samples also check for the consistency of field techniques and laboratory analysis. The duplicate samples will be handled in the same manner as the primary sample, assigned a distinct identification number, and shipped to the laboratory along with the primary sample it duplicates. Duplicate samples will be determined by the sample collection program. Stations will be determined in the field based on professional judgment.

Matrix Spikes and Matrix Spike Duplicates

Matrix spikes (MS) and matrix spike duplicate (MSD) samples will be obtained by collecting additional material at a selected station. MS and MSD samples are prepared at the laboratory by dividing a control sample into two aliquots, then spiking each with identical concentrations of specific analytes. The spike samples are then analyzed separately, and the results are compared to evaluate the effects of the sample matrix on the analytical accuracy and precision. Separate samples for matrix spikes (MS) and matrix spike duplicates (MSD) must be collected unless the laboratory specifies that these analyses can be run using an actual sample. MS/MSD samples will be labeled and shipped to the laboratory along with the primary sample from which they were collected.

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described in this sampling guideline. The sample parameters for analysis, preservation, and handling are specified in the Programatic AOC-4 QAPP. Each sample container has a sample label affixed to the outside. The sampler marks each label using waterproof ink with the following information:

- Project name
- Sample identification number
- Date and time of collection
- Initials of sampling technician
- Requested analysis
- Method of preservation

Sample containers will be packed in bubble wrap to minimize breakage or damage to samples and placed in metal or plastic coolers. Dry ice will be placed around sample containers and additional cushioning material will be added to the cooler, if necessary. Paperwork will be put in a Ziploc bag and placed on top of the sample containers or taped

to the inside lid of the cooler. The cooler will be taped closed and a signed custody seal will be affixed to the side of the cooler. Laboratory address labels will be placed on top of the cooler.

All samples are expected to contain low levels of contamination and will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations. All shipments containing dry ice will conform to federal, state, and carrier regulations. Standard procedures to be followed for shipping environmental samples to the analytical laboratory are outlined below.

- All environmental samples collected will be transported to the laboratory by AECOM personnel, shipped through Federal Express or equivalent overnight service, or picked up by a lab courier.
- Shipments will be scheduled to meet holding time requirements.

The laboratory will be notified to be prepared to receive a shipment of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed.

AECOM has established a program of sample COC that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession
- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed inside the shipping container, and the container will be sealed. Samples are considered to be in custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number
- Name of sampler and field personnel
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Sampling media
- Sample type
- Sample physical characteristics
- Observations at the sampling site (e.g., weather conditions)
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Health and Safety Procedures

To avoid incidents or injuries during sampling, the following health and safety procedures should be followed. Complete health and safety information is provided in the AOC-4 Project HASP:

- Toxic or otherwise harmful concentrations of metals or other constituents are unlikely to be encountered while sampling ambient sediments in rivers and streams. However, sampling crews should be trained in the general hazards of field sampling (e.g., waterborne pathogens) and how to minimize risks of exposure.
- Operating in or around water bodies carries the inherent risk of drowning. U.S. Coast Guard approved personal flotation devices must be worn when operating or sampling from a boat, when sampling in more than a few feet of water, or when sampling in swift currents.
- Collecting samples in cold weather, especially around cold waterbodies, carries the risk of hypothermia, and collecting samples in extremely hot and humid weather carries the risk of dehydration and heat stroke. Sampling team members should wear adequate clothing for protection in cold weather and should carry an adequate supply of water or other liquids for protection against dehydration in hot weather.
- Sampling team members must cover exposed skin and/or use sunscreen for protection from sun exposure.

- When working on all water bodies, sampling teams must develop and employ an emergency response plan, including the use of an onshore monitor that is accountable for the whereabouts of the team. The monitor can request aid if the team fails to report in at end of workday and can provide assistance to rescuers or the team under any emergency situation.

References

USEPA. 2001. *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual*. EPA-823-B-01-002, US Environmental Protection Agency, Office of Water, Washington, DC, 208 p

Protocol SRSW-1:
Guidelines for Sampling Water
Using a Diaphragm Pump

This method is for the collection and field filtration of ambient surface and subsurface water samples for subsequent determination of total mercury (THg), filtered total mercury (FTHg), methylmercury (MeHg) and filtered methylmercury (FMeHg) at ultra-trace concentrations (THg and FTHg @ > 0.2 nanograms per liter (ng/L), MeHg and FMeHg @ > 0.02 ng/L) using EPA Methods 1631 (THg and FTHg) and EPA Method 1630 (MeHg and FMeHg). The method is also suitable for the collection and field filtration of ambient surface and subsurface water samples for the subsequent determination of general water quality, metals, nutrients, and polycyclic aromatic hydrocarbons (PAHs).

This method will be used whether sampling by wading, from a boat or from bridges. The method is based on general guidance and principles outlined in EPA Method 1669 *Sampling Ambient Water for Determination of Metals at EPA Water Quality Criteria Levels* (July 1996). It is a "performance validated" alternative to Method 1669, as allowed and encouraged by EPA Method 1669, that has been demonstrated to preclude contamination of samples and blanks as required by the original method.

Equipment

The following equipment/supplies may be used to collect surface water samples:

- Diaphragm pump – Shurflo Model 2088-433-344, 12 volt (V) DC, 3.3 gallons per minute (gpm) flow
- Submersible pump - Forestry Suppliers 12V DC Battery-Operated Purge Pumps
- Tubing – Cole Parmer, C-flex, 3/8" ID x 5/8"OD, Cat# 06424-79
- Hydro weight – Coated iron (not lead) downrigger weight [5, 10, or 15 pound (lbs)]
- Syringe – 25 mL BD plastic, rubber-free plunger
- Filter:
  - Capsule type, high capacity, with barb fitting (e.g., Pall AquaPrep 600)
  - Syringe-tip filter with Luer-Lok or friction fitting (0.45 μm pore size)
- Battery or power pack: 12 V deep cycle battery or portable power pack (e.g., Xantrex Xpower 300)
  - Sample bottles – 250 milliliter (mL) borosilicate glass, IChem Series 300 or equivalent
  - Mercury - 250 mL borosilicate glass, IChem Series 300
  - TSS – 1000 mL HDPE
  - Metals – 1000 mL HDPE (with nitric acid preservative)

- TOC – 125 mL glass (with sulfuric acid preservative)
- Anions – 50 mL HDPE
- Hardness – 100 mL HDPE (with sulfuric acid preservative)
- PAHs – 2 x 1000 mL amber glass (with $Na_2S_2O_3$ preservative)
- Organochlorine pesticides – 2 x 1000 mL amber glass (to be filled by dipping)

- Reagent water – water in which mercury and potentially inferring substances are not detected at the minimum detectable level (MDL) of the analytical method used for analysis of samples *or* are detected at concentration no greater than three times the MDL (e.g., typical MDL for total mercury by EPA Method 1631 is 0.20 ng/L, thus the allowable total mercury in reagent water should be < 0.6 ng/L).
- Powder-free Nitrile gloves
- Pencils and waterproof/permanent marking pens
- Sampling location maps
- Global Positioning System (GPS) unit
- Camera
- Appropriate health and safety equipment
- Ziploc bags or similar dry storage materials
- Cooler
- Ice
- Paper towels
- Field notebook/field data sheets
- Chain-of-custody (COC) forms
- Custody seals

Decontamination Procedures

The following is a list of equipment/supplies and procedures needed to perform decontamination:

- C-Flex Tubing
  When employed as described in this method, this product has demonstrated repeatedly to be acceptably clean from the manufacturer's packaging without laboratory precleaning and may be used within the same waterbody to collect samples from multiple locations without risk of cross-contamination. As a precaution, sampling should always proceed from the cleanest locations to the most contaminated.
- Diaphragm and Submersible Pump
  Reagent water should be flushed through the pump at the end of each sampling day and the pump drained of any water that is not expelled by operation. No other cleaning is needed. The pump should be stored in a clean polyethylene bag.

- The use of any chemicals, especially acids, to clean pump, tubing, or filters in the field is generally discouraged because such treatment may change the properties of the materials of which these items are constructed. In addition, inefficient flushing of such chemicals may cause sample contamination. If suspicion exists that any of these items may have been contaminated with mercury or with substances that might interfere with unbiased sampling and analysis for mercury, the item(s) should be discarded or transferred to a qualified laboratory for cleaning and testing. For example, if hydrocarbon-contaminated water is encountered and contacts the apparatus at any time, the sampling components (with the possible exception of the pump) should be discarded. Similarly, if an industrial outfall to be sampled using this method is known or suspected to contain elevated mercury levels, do not attempt to clean the apparatus after use. Discard all but the pump and do not use the pump again until it is confirmed to be clean with an equipment blank.

Contamination and Interference

Avoidance of sample and apparatus contamination is of paramount importance for this method. The most important factors in avoiding/reducing sample contamination are 1) an awareness of potential sources of contamination and 2) strict attention to work being performed. The following procedures should be followed to prevent contamination and interference:

- The continuous pumping apparatus (pump, tubing, hydro weight) should only be removed from its clean container (cooler or plastic bag) just prior to sampling. When not being used, the system should be stored in a clean plastic bag or a dedicated cooler.
- Sampling personnel must wear clean, nonpowdered gloves during all operations involving handling of the apparatus and sample bottles. Gloves should be changed if there is any suspicion that the gloves have contacted surfaces that could be contaminated.
- The specific items comprising the apparatus have been demonstrated to effectively avoid contamination when deployed and operated as described in this method. Do not substitute items or change procedures without first demonstrating that the substitution or procedural change maintains sample integrity.
- Adhere strictly to the rules provided in subsequent sections with regard to flushing rates and times to avoid contamination carryover. Whenever possible, conduct sampling sequentially from sites of lower to higher known or expected contamination.
- Do not use the apparatus to sample effluents known or suspected to contain elevated mercury concentrations. This method is intended only for ambient samples of lakes, rivers, estuaries, and the ocean.
- In general, there are few analytical interferences that may be encountered in ambient water sampling.

Surface Water Sample Collection, Filtration, and Handling

The setup of equipment for surface water sample collection is shown in Photographs 1 and 2. The following procedures will be used to collect surface water samples from wading or by boat:

- Select surface water sampling locations in accordance with study objectives.

- Sampling sites should exhibit a high degree of cross-sectional homogeneity. Because mixing is principally governed by turbulence and water velocity, the selection of a site immediately downstream of a riffle area will ensure good vertical mixing. Horizontal mixing occurs in constrictions in the channel.
- Look for and avoid flow eddies that often occur near banks and in-stream obstructions.
- Avoid sample locations very near heavily traveled roads, bridges, and overhead utilities. If these features cannot be avoided, then sample upstream and sample during periods when these features are least likely to introduce contamination into the river.
- Plan sampling activity to collect samples known or suspected to contain the lowest concentrations of mercury first, finishing with samples known or suspected to contain the highest concentrations.
- Follow "Clean hands – Dirty hands" sampling techniques below using a diaphragm pump with the intake tube resting on the bottom of the water body.

  The following procedures will be used to collect ambient surface water samples from bridges as part of the quarterly monitoring for the South River Program:

- Park vehicle a safe distance off of the road to ensure safe working conditions and turn on vehicle hazard lights.
- Locate thalweg and lower a weighted submersible purge pump into the water on the upstream side of the bridge. The pump is to be lowered to 1/3 of the depth of the water column.
- Follow "Clean hands – Dirty hands" sampling techniques below.

"Clean hands – Dirty hands" Sampling Technique

Upon arrival at the sampling site, one member of the two-person sampling team is designated as "dirty hands;" the second member is designated as "clean hands." All operations involving contact with the sample bottle and the transfer of the sample from the sample pumping system to the sample bottle are handled by the individual designated as "clean hands." "Dirty hands" is responsible for preparation of the sample pumping system, operation of the pump, and all other activities that do not involve direct contact with the sample or sample container.

- "Dirty hands" deploys the weighted sample line into a water mass not affected by the presence of the boat or samplers.
- "Dirty hands" activates the pump and times pump running time prior to indicating to "clean hands" that sampling for unfiltered analytes can begin Pump should be run for at least one minute prior to sampling.
- "Clean hands" opens sample bottle and rinses it twice with sample water prior to filling and recapping. If additional unfiltered samples (e.g., for TSS) are to be collected, the same procedure is followed for additional bottles.
- "Dirty hands" pinches the sample line on the suction side and installs a capsule filter on the discharge line. Then "dirty hands" flushes several liters of sample water through the

filter at a flow rate held low enough (by pinching the suction line) to avoid excessive back pressure in the filter.

- "Clean hands" opens sample bottle and rinses it twice with sample water prior to filling and recapping. If additional filtered samples (e.g., for other metals, anions) are to be collected, the same procedure is followed for additional bottles.
- "Dirty hands" secures the pumping system by returning the weighted sample line and pump to a dedicated plastic bag or clean cooler.
- "Clean hands" re-bags the water samples and places them on ice in a cooler.

In general, water samples are not field-preserved other than by chilling and maintaining in the dark due to the increased risk of contamination. However, when there is uncertainty about the elapsed time for arrival at an analytical laboratory and methylmercury is to be requested, samples should be field-preserved with hydrochloric acid as specified in EPA Method 1630.

Field Quality Assurance/Quality Control

Field quality assurance/quality control (QA/QC) samples are designed to help identify and minimize potential sources of sample contamination due to field procedures and to evaluate potential error introduced by sample collection and handling. Strict adherence to the procedures described above in the section titled "Contamination and Interference" will assure collection of uncompromised sediment samples.

Field/Equipment Blanks

It is necessary to collect field blank and equipment blank samples each day that sampling occurs or whenever the pump or tubing is changed to demonstrate that contamination has been controlled.

Duplicate Sample

Frequency of duplicates is identified in the work plan. Additional field duplicates may be collected if conditions suggest the need for more or more are specified in the sampling and analysis plan.

Matrix Spikes and Matrix Spike Duplicates

Separate samples for matrix spikes (MS) and matrix spike duplicates (MSD) do not have to be collected unless the laboratory requests because these analyses can be run by most laboratories using an actual sample.

Method Performance (QA/QC)

Recent results for field blanks and equipment blanks for mercury and methylmercury are summarized in Table 1. Because most laboratories that are qualified to run EPA Method 1631 can detect total mercury above the typical MDL (0.2 ng/L) even in the highest quality water that can be prepared, it is always necessary to request analysis of the water used to prepare equipment blanks. Methylmercury should not be detected in either field

blanks or equipment blanks, and total mercury and methylmercury in blanks should not exceed two times the MDL.

Table 1
Results for Field and Equipment Blanks Prepared Following Method SRSW-1

Date	Location	Field Blank (Source Water)		Pump+Tubing Blank		Pump+Tubing+Filter Blank	
		Total Hg	Methyl Hg	Total Hg	Methyl Hg	Total Hg	Methyl Hg
Sep 04	Penobscot	<0.03		<0.06		<0.04	
Oct 04	Penobscot	<0.03		<0.07		<0.03	
Jan 05	South River	0.30	<0.012			0.59	<0.012
Mar 05	South River	0.19				0.15	
	South River	0.22				0.21	
	South River	0.22				0.32	
	South River	0.21				0.23	
	South River	0.21				0.38	
Jan 05	Pompton	0.09	0.003			<0.08	<0.004
Jan 05	Pompton	0.06				0.06	
Aug 04	Pompton	0.07				0.25	
Aug 04	Pompton	0.30	<0.023			0.67	<0.003
May 04	Pompton	0.42	<0.007			0.20	<0.013

Note: Units are ng/L

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described in this sampling guideline. The sample parameters for analysis, preservation, and handling are specified in the Programatic AOC-4 QAPP. Each sample container has a sample label affixed to the outside. The sampler marks each label using waterproof ink with the following information:

- Project name
- Sample identification number
- Date and time of collection

- Initials of sampling technician
- Requested analysis
- Method of preservation

Sample containers will be packed in bubble wrap to minimize breakage or damage to samples and placed in metal or plastic coolers. Wet ice will be placed around sample containers and additional cushioning material will be added to the cooler, if necessary. Paperwork will be put in a Ziploc bag and placed on top of the sample containers or taped to the inside lid of the cooler. The cooler will be taped closed and a signed custody seal will be affixed to the side of the cooler. Laboratory address labels will be placed on top of the cooler.

All samples are expected to contain low levels of contamination and will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations. All shipments containing dry ice will conform to federal, state, and carrier regulations. Standard procedures to be followed for shipping environmental samples to the analytical laboratory are outlined below.

- All environmental samples collected will be transported to the laboratory by AECOM personnel, shipped through Federal Express or equivalent overnight service, or picked up by a lab courier.
- Shipments will be scheduled to meet holding time requirements.

The laboratory will be notified to be prepared to receive a shipment of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed.

AECOM has established a program of sample COC that will be followed during sample handling activities in both field and laboratory operations. The primary purpose of COC procedures is to document the possession of the samples from collection through shipping, storage, and analysis to data reporting and disposal. The Task Manager or his/her designee will be responsible for monitoring compliance with COC procedures.

Tracing sample possession will be accomplished using the COC record. A COC entry will be recorded for every sample, and a COC record will accompany every sample shipment to the laboratory. At a minimum, the COC record will contain the following information for each sample:

- Sample number and identification of sampling point
- Date and time of collection
- Sample type
- Number, type, and volume of sample container(s)
- Sample preservative
- Analysis requested
- Name, address, and phone number of laboratory or laboratory contact
- Signature, dates and times of persons in possession

- Any necessary remarks or special instructions

Once the COC is complete and the samples are ready for shipment, the COC will be placed inside the shipping container, and the container will be sealed. Samples are considered to be in custody if they are within sight of the individual responsible for their security or locked in a secure location. Each person who takes possession of the samples, except the shipping courier, is responsible for sample integrity and safekeeping.

Field Logbook and Field Data Sheet

The most important aspect of documentation is thorough, organized, and accurate record keeping. All information pertinent to the investigation will be recorded in the field logbook and/or field data sheets. Entries will include the following, as applicable:

- Project name and number
- Name of sampler and field personnel
- Date and time of sample collection
- Sample number, location, and depth
- Sampling method
- Sampling media
- Sample type
- Sample physical characteristics
- Observations at the sampling site (e.g., weather conditions)
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions

Field investigation situations vary widely. No general rules can include each type of information that must be entered in a logbook or data sheet for a particular site. Site-specific recording will include sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel.

Health and Safety Procedures

To avoid incidents or injuries during sampling, the following health and safety procedures should be followed:

- Toxic or otherwise harmful concentrations of mercury and methylmercury are unlikely to be encountered while sampling ambient surface water. However, sampling crews should be trained in the hazards of mercury and how to minimize risks of exposure.
- Operating in or around waterbodies carries the inherent risk of drowning. U.S. Coast Guard approved personal flotation devices must be worn when operating or sampling from a boat, when sampling in more than a few feet of water, or when sampling in swift currents.

- Collecting samples in cold weather, especially around cold waterbodies, carries the risk of hypothermia, and collecting samples in extremely hot and humid weather carries the risk of dehydration and heat stroke. Sampling team members should wear adequate clothing for protection in cold weather and should carry an adequate supply of water or other liquids for protection against dehydration in hot weather.
- Sampling team members must cover exposed skin and/or use sunscreen for protection against sunburn and melanoma.
- When working on all waterbodies, sampling teams must develop and employ an emergency response plan, including the use of an onshore monitor that is accountable for the whereabouts of the team. The monitor can request aid if team fails to report in at end of workday and can provide assistance to rescuers or team under any scenario where an emergency situation exists.

References

Parker, J.L. and N.S. Bloom. 2005. "Preservation and Storage Techniques for Low-Level Aqueous Mercury Speciation." *Science of the Total Environment*, 337:253-263.

USEPA. 1996. *Method 1669-Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels*. July 1996. U.S. Environmental Protection Agency, Office of Water, Engineering and Analysis Division (4303), 401 M Street SW, Washington, DC 204460

USGS. 2006. Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September, accessed February 20, 2009 at http://pubs.water.usgs.gov/twri9A4/

Photographs

Photograph 1. Use of clean cooler to protect sample inlet line and hydro weight from contamination when sampling from a boat in deeper water. Round yellow object on end of C-flex tubing is plastic screen to prevent end of inlet line from touching sediment or sucking in algae or other debris. Hydro weight (yellow sphere with fin) is typically only required where current is very swift (>0.5 m/s) and is tethered a foot or more below the sample inlet.

Photograph 2. Use of the continuous pumping system to collect water samples from a shallow stream. The inlet end of the tubing (out of picture) is screened and weighted. Capsule filter is shown installed on the discharge line from the pump.

Appendix B
Ecological Study Data Matrix

Appendix B
Ecological Study Data Matrix
AOC 4 Long-Term Monitoring Program
South River and a Segment of the South Fork Shenandoah River

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	SOURCE(S)
Habitat and Geophysical Characterizations																		
RRM 0 - 1	Discharge Characterization	2009						x	x	x			x		0.1	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS
										x					0.1	Velocity (f/s)	Pilot Bank Stabilization: Pre-Construction Study	URS
		2010						x							0.1	Velocity (f/s)	Pilot Bank Stabilization: Post-Construction Study	URS
	Habitat Characterization	2005									x				0.6		Phase I Ecostudy: Phase I Site Characterization	URS
		2006									x				0.6		Phase I Ecostudy: Phase I Site Characterization	URS
		2009			x			x							0.1		Phase II Ecostudy: Phase II Site Characterization	URS
										x					0.1		Pilot Bank Stabilization: Pre-Construction Study	URS
		2010			x		x		x			x			0.1		Pilot Bank Stabilization: Post-Construction Study	URS
		2011				x									0.1		Pilot Bank Stabilization: Post-Construction Study	URS
	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
		2006													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
		2007											x		0.1		Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
									x						NS		Comprehensive Geomorphological Study: Reconnaissance Investigation of Floodplain Deposits Formed Through Channel Migration	UD
		2009								x					0.1		Pilot Bank Stabilization: Pre-Construction Study	URS
		2010			x		x		x			x			0.1		Pilot Bank Stabilization: Post-Construction Study	URS
		2011					x								0.1		Pilot Bank Stabilization: Post-Construction Study	URS
									x						NS		Substrate and Aquatic Macrophyte Mapping	URS
Physical and Chemical Monitoring / Assessments																		
	Soil	2003										x			0.1 - 0.4	THg	Greenway Sampling	UE
		2006												x	0.5	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU
		2007		x											0.0 - 0.4	THg, MeHg, LOI, Other Analytes	Turner Plant Reach Sediments	UE
													x		0.1 - 0.2	THg, MeHg	University of Delaware Bank Survey Soils	UD
		2008								x					0 - 0.2, 0.9 - 1.0	THg, MeHg, VOCs	Bank Stabilization Sediment	UD
				x	x	x									0.0 - 1.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS
		2009			x										0.1	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS
		2010			x										0.1	THg	Pilot Bank Stabilization: River Bank Soil for Post-Construction Study	URS
	Sediment	2003									x				0.3 - 0.4	THg, Metals	VADEQ Historical Floodplain Monitoring	VADEQ
		2004					x								0.2 - 0.3	THg, Other Analytes	Sediment Sampling	UE
		2005									x				0.2 - 0.3	THg, MeHg, LOI, Other Analytes	Transect Program	UE
					x										0.3 - 0.6	THg, MeHg, LOI, Other Analytes	Water Sampling	UE
		2006			x	x	x	x	x	x	x	x	x	x	0.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
												x			0.0, 0.3	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE
		2007	x	x											0.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
										x					0.1 - 0.4	THg, Other Metals	VADEQ Sediment Sampling	VADEQ
		2009			x										0.1	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS
		2010				x									0.1	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS
					x										0.1	THg	Pilot Bank Stabilization: Near-Bank Sediment for Post-Construction Study	URS
		2011				x									0.1	THg	Pilot Bank Stabilization: Near-Bank Sediment for Post-Construction Study	URS
	Ground Water	2006	x						x			x	x	x	0.1	THg and Water Elev.	Mercury Source Tracing and Mechanistic Source Studies: Basic Park GW	RTG, UE
		2007		x		x	x	x	x	x	x	x			0.1	THg and Water Elev.	Mercury Source Tracing and Mechanistic Source Studies: Basic Park GW	RTG, UE
		2009						x	x	x			x		0.1	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
								x							0.1	THg	Pilot Bank Stabilization: Physical Loading Pre-Construction Study	URS
					x										0.0 - 1.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS
		2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS
	Pore Water	2006										x			0.0, 0.3	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE
		2007	x	x	x	x	x	x	x						0.1	THg	Mercury Source Tracing and Mechanistic Source Studies: Long-Profile Pore Water	RTG, UE
				x											0.0 - 0.4	THg	Turner Plant Reach Pore Water and Surface Water	UE
									x						0.2 - 0.3	MeHg	Turner Spin Pore Waters	UE
		2009						x	x	x			x		0.1	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
		2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS
		2011						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS
	Surface Water	2001											x		0.2 - 0.3	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2002	x		x			x		x		x		x	0.2 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
									x						0.9 - 1	THg, TSS, Other Analytes	VADEQ Historical Intensive 1	VADEQ
		2003								x					0.0 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Intensive 2	VADEQ
				x		x		x		x		x			0.2 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2004										x			0.1 - 0.2	THg	Cutback Survey Sampling	UE
											x				0.1 - 0.3	THg, MeHg, TSS	Flood Sampling	UE
										x					0.2 - 0.3	THg, MeHg, TSS	Hg Speciation Study	UE
			x	x		x		x		x		x			0.2 - 0.3	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2005	x	x											0.1 - 0.4, 0.5 - 0.6, 0.7 - 0.8, 0.9 - 1.0	THg, MeHg, TSS	Surface Water/Sediments	UE
											x				0.2 - 0.3	THg, MeHg, TSS	Transect Program	UE
					x		x		x		x		x		0.2 - 0.3	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x												0.2 - 0.3	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
							x								0.2 - 0.3, 0.4 - 0.5, 0.9 - 1	THg, MeHg, TSS	Water Sampling	UE
					x										0.4 - 0.5	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE
		2006										x			0.0	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE
								x		x			x		0.4	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
					x	x	x	x	x	x	x	x	x	x	0.6	THg, MeHg	Phase I Ecostudy	URS
											x	x			0.0 - 0.4	THg	Turner Plant Reach Pore Water and Surface Water	UE
			x		x		x		x		x		x		0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2007										x			0.1	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS
					x										0.4	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
				x											0.1 - 0.2	THg	Turner Plant Reach Pore Water and Surface Water	UE
			x		x		x		x		x		x		0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x		x	x			x		x		x	0.4, 0.6	THg, MeHg	Phase I Ecostudy	URS
		2008					x								0.1	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS
				x				x		x		x			0.4	THg, MeHg	Phase II Ecostudy	URS
			x		x		x		x		x		x		0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2009								x					0.1	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
								x	x	x			x		0.1	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
				x			x			x					0.4	THg, MeHg	Phase II Ecostudy	URS
			x												0.2 - 0.3	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Physical Loading Post-Construction Study	URS
			x	x	x		x	x	x	x	x	x	x	x	0.4	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS
					x		x		x		x		x		0.3 - 0.4	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ
		2011		x				x		x		x			0.1	THg, MeHg, Other Analytes	Phase II Ecostudy	URS
			x		x		x		x		x		x		0.1	THg, MeHg, Other Analytes	VADEQ Surface Water	VADEQ
Biological Monitoring / Assessments																		
Aquatic Vegetation / Algae																		
RRM 0 - 1	Tissue	2005							x						0.3, 1	THg, MeHg	Periphyton Assessment	VIMS
		2006								x					0.6	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	0.6	THg, MeHg	Phase I Ecostudy: Periphyton	URS
		2007					x		x						0.6	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
				x											0.6	THg, MeHg	Phase I Ecostudy: Periphyton	URS
		2008						x		x					0.3	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS
Aquatic Invertebrates																		
RRM 0 - 1	Population / Community	2006					x			x				x	0.6		Phase I Ecostudy	URS
		2007		x											0.6		Phase I Ecostudy	URS
		2010				x									0.1		Phase II Ecostudy: Sediment Quality Triad	URS
		2011					x	x							0.1		Phase II Ecostudy: Benthic Colonization Study	URS
	Feeding	2010						x		x		x			0.1	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS
	Tissue	2002											x		0.1, 0.4, 0.6, 0.8, 1.0	THg	Clam Tissue Study	JMU, EMU
		2003											x		0.1	THg, MeHg	Clam Tissue Study	JMU, EMU
		2006					x			x				x	0.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	0.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
		2007					x								0.6	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
				x											0.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											0.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
		2009					x	x							0.1	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS
		2010						x							0.1	THg, MeHg	Pilot Bank Stabilization: Asian Clam Uptake Study for Post-Construction Study	URS
		2011					x	x							0.1	THg, MeHg	Pilot Bank Study: Clam Tissue	URS
	Toxicity	2010							x						0.1		Phase II Ecostudy: Field Microcosm Study	URS
							x								0.1		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS
Fish																		
RRM 0 - 1	Population / Community	2006					x			x					0.6		Phase I Ecostudy	URS
		2010					x				x				0.1		Phase II Ecostudy	URS
	Stomach Contents	2010					x				x	x			0.1		Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS
	Tissue	2001				x									0.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2002				x									0.0	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2005				x									0.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2006					x			x					0.6	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
		2007				x									0.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
							x								0.6	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2009					x				x				0.1	THg, MeHg	Phase II Ecostudy: Bass	URS
		2010					x				x				0.1	THg, MeHg	Phase II Ecostudy: Bass	URS
							x				x	x			0.1	THg, MeHg	Phase II Ecostudy: Forage Fish	URS
							x				x				0.1	THg, MeHg	Phase II Ecostudy: Sunfish	URS
		2011					x								0.1	THg, MeHg	Phase II Ecostudy: Bass	URS
Herpetofauna																		
RRM 0 - 1	Tissue	2007					x								1.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
Terrestrial Invertebrates																		
RRM 0 - 1	Tissue	2006												x	0.5	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU

Appendix B
Ecological Study Data Matrix
AOC 4 Long-Term Monitoring Program
South River and a Segment of the South Fork Shenandoah River

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	SOURCE(S)
Habitat and Geophysical Characterizations																		
RRM 1 - 6	Discharge Characterization	2000	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2001	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2002	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2003	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2004	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2005	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2006	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2007	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2008	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
		2009	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
								x	x	x			x		3.5	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS
		2010	x	x	x	x	x	x	x	x	x	x	x	x	2.3	Q (cfs)	Daily River Discharge (Near Dooms)	USGS
	Precipitation Monitoring	2000										x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
		2001	x		x	x	x	x	x	x	x	x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
		2002	x	x	x	x	x		x	x	x	x	x		1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
		2003	x			x		x	x	x	x	x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
		2004	x		x	x		x	x	x			x		1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
		2005	x		x			x	x	x	x	x	x		1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
		2006	x	x	x	x	x	x	x	x	x	x	x	x	1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
		2007	x	x	x	x	x	x	x	x					1.4		Daily Precipitation Volume (Waynesboro Sewage Treatment Plant)	NOAA
	Habitat Characterization	2005									x				2.0, 3.0, 4.2, 5.2		Phase I Ecostudy: Phase I Site Characterization	URS
		2006									x				5.2		Phase I Ecostudy: Phase I Site Characterization	URS
		2009			x			x							3.0, 3.5, 3.7		Phase II Ecostudy: Phase II Site Characterization	URS
	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
		2006	x				x								1.8, 3.0		Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
															NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
		2007							x						NS		Comprehensive Geomorphological Study: Reconnaissance Investigation of Floodplain Deposits Formed Through Channel Migration	UD
					x										3.0, 5.4		Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
		2011							x						NS		Substrate and Aquatic Macrophyte Mapping	URS
Physical and Chemical Monitoring / Assessments																		
	Soil	2004						x							1.1 - 1.2, 1.6 - 1.9	THg	Floodplain Hg Sampling	UE
												x			2.5 - 2.6	THg	Cutback Survey Sampling	UE
		2005									x				2.1 - 2.2, 2.5 - 2.6	THg, MeHg	Core Sampling	UE
			x												2.5 - 2.6	THg	Floodplain Soil Sampling	UE
			x												2.5 - 2.6	THg	Surface Water/Sediments	UE
		2006										x	x	x	1.0, 2.1, 2.4, 5.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU
													x		1.7 - 1.8, 5.3 - 5.4	THg, MeHg, LOI, Other Analytes	Turner Crimora Sediments	UE
								x			x				2.1 - 2.2, 3.1 - 3.2, 5.3 - 5.4	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont
							x								2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Bank Flux Sediment / Soils	UE
											x				2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Turner Basic Park Sediment	UE
												x			2.9 - 3, 3.4 - 4.9, 5.4 - 5.5	THg	USEPA Shifflet Farm Sampling	USEPA
		2007													1.6, 2.2, 3.5, 4.8, 5.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
			x	x											2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Turner Basic Park Sediment	UE
			x	x											2.1 - 2.3	THg, MeHg, LOI, Other Analytes	Turner Basic Park Sediment Pore Water	UE
												x			2.9 - 3.0,	THg, MeHg, VOCs	Fine Grained Sediment Study	UD
		2008		x	x	x									1.1 - 6.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS
				x	x	x		x							1.6 - 1.8, 2.1 - 2.2, 2.9 - 3.1, 3.3 - 3.4, 3.5 - 3.7, 3.9 – 4.0, 4.1 - 4.2, 4.7 - 4.9, 5.1 - 5.2, 5.3 - 5.4, 5.8 - 5.9	THg, MeHg	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD
															1.6, 2.2, 3.5, 4.8, 5.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
												x			2.8 - 2.9, 3.1 - 3.2, 4.3 - 4.4, 4.6 - 4.7, 4.8 - 4.9	THg, MeHg, LOI	Flux Chamber Study (Loading)	DuPont
		2009						x							2.8 - 3.1	THg, MeHg	River Mile 3.0 Sediment Study	UD
					x										3.0, 3.5, 3.7	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS
		2011					x								0.0 - 0.3, 0.5 - 0.6	THg	Floodplain Soils Investigation	URS
	Sediment	2002									x				4.8 - 4.9, 5.6 - 5.7	THg, MeHg, LOI, Other Analytes	Sediment Core Study - LLI	URS
		2004						x							1.7 - 1.8	THg, % Moisture	Floodplain Hg Sampling	UE
		2005			x		x								1.5 - 1.6, 1.7 - 1.8, 2.5 - 2.6	THg, MeHg, LOI, Other Analytes	Water Sampling	UE
			x												1.7 - 1.8	THg, % Moisture	Oxbow Core Sampling	UE
									x	x					1.7 - 1.8, 2.1 - 2.2, 2.4 - 2.5, 3.8 - 3.9, 4.2 - 4.3, 4.6 - 4.7	THg, LOI, Other Analytes	University of Delaware Program	UD
											x				1.7 - 1.8, 2.4 - 2.6	THg, MeHg, LOI, Other Analytes	Core Sampling	UE
											x				1.7 - 1.9, 5.0 - 5.1	THg, MeHg, LOI, Other Analytes	Transect Program	UE
		2006			x	x	x	x	x	x	x	x	x	x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
		2007							x	x	x				1.0 - 1.2, 1.7 - 1.8, 2.3 - 2.4, 2.6 - 2.7, 3.5 - 3.6, 4.7 - 4.9, 5.0 - 5.1, 5.2 - 5.3, 5.5 - 5.6	THg, Other Metals	VADEQ Sediment Sampling	VADEQ
			x	x						x		x		x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
												x			3.0, 3.8, 3.9, 4.2, 4.6, 4.8, 5.4	THg, MeHg	Phase I Ecostudy: Channel Margin Deposit Cores for Phase I Site Characterization	URS
		2008		x		x		x		x		x			1.6, 3.0, 4.6, 5.2	THg, MeHg	Phase II Ecostudy: Interstitial Sediment	URS
		2009			x										3.0, 3.5, 3.7	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS
		2010				x									3.5	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS
	Ground Water	2006										x			2.1 - 2.3	THg	Turner Pore / Well Water I & II	UE
												x			2.1 - 2.3	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE
												x			3.7 - 4.3	THg, MeHg, TSS, TOC, VOCs, Other Analytes	Shifflet Farm GW and Pond Sampling: Direct Push Sampling	USEPA
		2007				x									2.1 - 2.3	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE
				x											2.1 - 2.3	THg	Turner Wells and Ultra	UE
		2009			x										1.1 - 6.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS
	Pore Water	2006										x			2.1 - 2.2	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE
							x		x						2.1 - 2.3	THg	Bank Flux Pore Water and Surface Water	UE
												x			2.1 - 2.3	THg	Turner Pore / Well Water I	UE
		2007						x							2.1 - 2.2	THg, MeHg, Other Analytes	Basic Park Surface Water Flux	UE
			x	x											2.1 - 2.2	THg, MeHg	Turner Basic Park Longitudinal Profile Pore Water and Surface Water	UE
			x	x											2.1 - 2.2	THg, MeHg	Turner Basic Park Sediment Pore Water	UE
						x									2.1 - 2.2	Fe	Turner Centrifuge Project	UE
									x						2.1 - 2.2, 5.3 - 5.4	MeHg	Turner Spin Pore Waters	UE
		2008						x							2.1 - 2.2	Fe, Mn	Turner Hyporheic Samples	UE
		2009						x	x	x			x		3.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
	Surface Water	2001											x		1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2002							x						1.0 - 2.6	THg, TSS, Other Analytes	VADEQ Historical Intensive 1	VADEQ
										x					1.2 - 1.3, 1.4 - 1.5, 2.4 - 2.5	THg, TSS	VADEQ Historical Intensive 2	VADEQ
										x					1.3 - 1.4	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x		x			x		x		x		x	1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2003		x		x		x		x		x			1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
										x					2.3 - 2.6	THg, TSS, Other Analytes	VADEQ Historical Intensive 2	VADEQ
									x		x			x	5 - 5.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2004									x				1.2 - 1.3, 1.7 - 1.8, 1.8 - 1.9, 5 - 5.1	THg, MeHg, TSS	Flood Sampling	UE
										x					1.2 - 1.3, 1.7 - 1.8, 1.8 - 1.9, 5 - 5.1	THg, MeHg, TSS	Hg Speciation Study	UE
			x	x		x		x		x		x			1.3 - 1.4, 2.3 - 2.4, 5 - 5.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
							x								1.7 - 1.8	THg, MeHg	Oxbow Water Sampling	UE
				x		x		x	x		x		x		5 - 5.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x	x											1.1 - 1.2, 1.3 - 2.0, 2.1 - 2.2, 2.4 - 2.5, 2.6 - 3.2, 3.4 - 3.5, 3.6 - 3.7, 3.8 - 3.9, 4.1 - 4.2, 4.4 - 4.6, 4.8 - 4.9, 5.0 - 5.1	THg, MeHg, TSS	Surface Water/Sediments	UE
			x												1.3 - 1.4, 5.0 - 5.1	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
											x				1.3 - 1.5, 1.7 - 1.9, 2.4 - 2.6, 3.2 - 3.3, 5.0 - 5.1	THg, MeHg, TSS	Transect Program	UE
					x										1.3 - 1.6, 1.7 - 1.8, 5.0 - 5.1, 5.2 - 5.5, 5.6 - 5.7, 5.8 - 5.9	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE
		2005					x								1.5 - 1.6, 1.8 - 2.0, 2.2 - 2.7, 3.4 - 3.5, 4.4 - 4.5, 4.7 - 4.9, 5.0 - 5.1, 5.2 - 5.3	THg, MeHg, TSS	Water Sampling	UE
					x		x			x		x		x	2.3 - 2.4, 5.0 - 5.1	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
					x		x								5 - 5.1	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ
			x												5 - 5.1	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x												5 - 5.1	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
											x				5 - 5.1	THg, TSS	VADEQ Storm Sampling	VADEQ
											x				5.2 - 5.3	THg, MeHg, TSS	Concurrent Sampling	RTG
		2006											x		3.8	THg, MeHg, TSS, TOC, VOCs, Other Analytes	Shifflet Farm GW and Pond Sampling: Direct Push Sampling	USEPA
					x	x	x	x	x	x	x	x	x	x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy	URS
												x			2.1 - 2.2	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE
								x			x				2.1 - 2.2, 3.1 - 3.2, 5.3 - 5.4	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont
							x		x						2.1 - 2.3	THg	Bank Flux Pore Water and Surface Water	UE
											x				2.1 - 2.3	THg, MeHg, Other Analytes	Basic Park Surface Water Flux	UE
												x			2.1 - 2.3	THg	Turner Pore / Well Water I & II	UE
			x		x		x		x		x		x		2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
								x		x					2.3, 5.1	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
		2007										x			1.5, 2.5, 4.7, 5.6	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS
			x	x		x	x								2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy	URS
			x					x							2.1 - 2.2	THg, MeHg, Other Analytes	Basic Park Surface Water Flux	UE
			x	x		x									2.1 - 2.2	THg, MeHg	Turner Basic Park Longitudinal Profile Pore Water and Surface Water	UE
						x									2.1 - 2.2	THg	Turner Uptake Study	UE
						x									2.1 - 2.2	THg, MeHg, Other Analytes	Turner Wells / Turner Wells and Extract	UE
			x	x				x	x						2.1 - 2.3	THg, MeHg	Basic Park Surface Water	UE
					x										2.3 - 2.4	Nutrients, Bacteria, Hg, Other Analytes	VADEQHIST Fishkill	VADEQ
			x		x		x		x		x		x		2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
										x		x		x	2.3, 5.1	THg, MeHg	Phase I Ecostudy	URS
					x										2.3, 5.1	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
			x	x	x	x	x	x	x	x	x		x	x	5.0 - 5.1	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2008					x								1.2, 5.2	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
							x								1.5, 3.1, 4.7, 5.6	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS
								x							2.3 - 2.4, 5.0 - 5.1	THg, MeHg, Mn, Fe	Flux Chamber Study (Loading)	DuPont
			x		x		x		x		x		x		2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
				x				x		x		x			2.3, 5.1	THg, MeHg	Phase II Ecostudy	URS
											x				2.7, 3.0, 4.0, 4.6, 4.9	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
								x							2.8, 4.0, 4.5, 4.6	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
										x					3.0, 4.6	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
											x				4.5 - 4.6	Fe, Mn	Turner Surface Waters	UE
		2009								x					3.5	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
								x	x	x			x		3.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
			x												1.3 - 1.4, 5.0 - 5.1	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x												2.3 - 2.4, 5.0 - 5.1	Nutrients, Bacteria, Hg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
				x		x				x					2.3, 5.1	THg, MeHg	Phase II Ecostudy	URS
		2010							x						1.3, 1.7, 2.0, 2.4	THg, MeHg, Nutrients	Sewage Treatment Plant Surface Water Studies	JMU
					x		x		x		x		x		2.3 - 2.4, 5.2 -5.3	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ
			x	x	x		x	x	x	x	x	x	x	x	2.3, 5.1	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS
		2011		x				x							3.5	THg, MeHg, Other Analytes	Phase II Ecostudy	URS
			x		x		x		x		x		x		3.5	THg, MeHg, Other Analytes	VADEQ Surface Water	VADEQ
							x								4.2, 5.4	THg, MeHg	Floodplain Ponds Investigation	URS

Appendix B
Ecological Study Data Matrix
AOC 4 Long-Term Monitoring Program
South River and a Segment of the South Fork Shenandoah River

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	SOURCE(S)
Biological Monitoring / Assessments																		
Aquatic Vegetation / Algae																		
RRM 1 - 6	Tissue	2005							x						2.0, 5.0	THg, MeHg	Periphyton Assessment	VIMS
		2006					x	x							5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
										x					2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Periphyton	URS
		2007		x											2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Periphyton	URS
							x		x						2.0, 5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2008						x		x					1.1, 2.1, 5.4	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS
Aquatic Invertebrates																		
RRM 1 - 6	Population / Community	2006					x			x				x	5.2		Phase I Ecostudy	URS
		2007		x											5.2		Phase I Ecostudy	URS
		2010				x									3.5		Phase II Ecostudy: Sediment Quality Triad	URS
		2011					x	x							3.5		Phase II Ecostudy: Benthic Colonization Study	URS
	Feeding	2010						x		x		x			3.5	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS
	Tissue	2002											x		1.2, 1.4, 1.8, 2.0, 2.5, 2.8, 3.3, 3.7, 4.2, 4.7, 5.0	THg	Clam Tissue Study	JMU, EMU
		2003											x		1.2, 1.8, 2.5, 5	THg, MeHg	Clam Tissue Study	JMU, EMU
						x									1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x		x	1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2006					x	x							5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
							x			x				x	2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	2.0, 3.0, 4.2, 5.2	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
		2007		x											2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											2.0, 3.0, 4.2, 5.2	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
							x								2.0, 5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2009					x			x					3.5	THg, δN15, δC13	Phase II Ecostudy: Aquatic Insect Metamorphosis Study	URS
							x	x							3.5	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS
		2010						x		x					3.5	THg, MeHg	Phase II Ecostudy: Aquatic Invertebrates Uptake Study	URS
	Toxicity	2010					x								3.5		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS
Fish																		
RRM 1 - 6	Population / Community	2006					x			x					5.2		Phase I Ecostudy	URS
		2010					x				x				3.5		Phase II Ecostudy	URS
	Stomach Contents	2010					x				x	x			3.5	THg, MeHg	Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS
	Tissue	2001				x									2.4	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2002				x									1.37, 2.4, 4.9	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2003				x	x								1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x			1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2005				x	x								1.37, 2.4, 4.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2006					x			x					2.0, 3.0, 4.2, 5.2	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
		2007				x									1.37, 2.4, 4.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
							x								2.0, 5.2	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2010					x				x	x			3.5	THg, MeHg	Phase II Ecostudy: Bass	URS
							x				x	x			3.5	THg, MeHg	Phase II Ecostudy: Forage Fish	URS
							x				x				3.5	THg, MeHg	Phase II Ecostudy: Sunfish	URS
		2011					x								3.5	THg, MeHg	Phase II Ecostudy: Bass	URS
							x								4.2, 5.4	THg, MeHg	Floodplain Ponds Investigation	URS
Herpetofauna																		
RRM 1 - 6	Tissue	2007			x	x	x								2.0, 5.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
Terrestrial Invertebrates																		
RRM 1 - 6	Tissue	2003				x									1.2	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						1.2, 2.2	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x			1.2, 2.2	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2006										x	x	x	1.0, 2.1, 2.4, 5.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU
		2008					x	x							3.0, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU
Birds																		
RRM 1 - 6	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
	Blood, Feather, Egg	2007				x	x								2.0, 5.0	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI
	Blood, Wing, Feather, Egg	2006				x	x	x	x	x					1.7, 2.0, 2.4, 2.7, 3.0, 4.1, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2007					x	x	x						1.7, 2.0, 2.4, 2.7, 3.0, 4.1, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2008					x	x	x						1.7, 2.0, 2.4, 2.7, 3.0, 4.1, 5.1	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
	Tissue, Liver	2008									x		x	x	2.6, 4.3	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ
		2010										x			3.0, 5.1, 5.6	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ
Mammals																		
RRM 1 - 6	Blood, Skin, Fur	2007						x							2.0	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI

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Habitat and Geophysical Characterizations																		
RRM 6 - 16	Discharge Characterization	2009						x	x	x			x		8.5	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS
		2010						x							11.8	Q (cfs)	Phase II Ecostudy: Physical Loading Study	URS
	Habitat Characterization	2005									x				7.1		Phase I Ecostudy: Phase I Site Characterization	URS
		2006									x				11.8		Phase I Ecostudy: Phase I Site Characterization	URS
		2009						x							8.5		Phase II Ecostudy: Phase II Site Characterization	URS
					x										8.5, 8.8		Phase II Ecostudy: Phase II Site Characterization	URS
		2010				x									11.8		Phase II Ecostudy: Phase II Site Characterization	URS
	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
		2006													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
		2007							x						NS		Comprehensive Geomorphological Study: Reconnaissance Investigation of Floodplain Deposits Formed Through Channel Migration	UD
		2011							x						NS		Substrate and Aquatic Macrophyte Mapping	URS
Physical and Chemical Monitoring / Assessments																		
RRM 6 - 16	Soil	2003				x	x					x			11.0 - 11.2, 11.4 - 11.7	THg	Forestry Center Soil	DuPont, UE
													x		11.5 - 11.6	THg	Forestry Center Garden	DuPont
		2004						x							9.8 - 10.0, 11.6 - 11.7	THg	Floodplain Hg Sampling	UE
								x							9.9 - 10	THg	Floodplain Hg Sampling	UE
		2005			x										11.5 - 11.6	THg	Water Sampling	UE
											x				9.9 - 10	THg, MeHg	Core Sampling	UE
		2006						x			x				13.2 - 13.3	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont
											x		x		7.6, 9.8, 11.7, 13.9	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU
							x								9.7 - 9.8	THg, MeHg, LOI, Other Analytes	Crimora Hot Spot	UE
									x						9.7 - 9.9	THg, MeHg, LOI, Other Analytes	Turner Crimora Sediments	UE
		2007										x			7.4 - 7.5, 8.1 - 8.2, 8.5 - 8.6, 8.8 - 8.9, 9.9 - 10, 12.8 - 12.9	THg, MeHg, VOCs	Fine Grained Sediment Study	UD
															7.4, 7.7, 8.8, 9.8, 11.6, 13.1, 15.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
		2008		x	x	x									6.1 - 16.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS
				x	x		x	x							7.4 - 7.5, 7.7 - 7.8, 8.0 - 8.1, 8.2 - 8.3, 8.4 - 8.9, 9.2 - 9.3, 9.4 - 9.6, 9.7 - 9.8, 13.1 - 13.2 , 13.7 -13.8, 15.3 -15.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
															7.4, 7.7, 8.8, 9.8, 11.6, 13.1, 15.4	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
		2009			x										8.5	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS
		2010						x	x						11.8	THg, MeHg	Mesocosm Study	JMU
						x									11.8	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS
		2011					x								9.8 - 9.9	THg	Floodplain Soils Investigation	URS
	Sediment	2003									x				11.9 - 12	THg, Metals	VADEQ Historical Floodplain Monitoring	VADEQ
		2005								x					11.5 - 11.6	THg, LOI, Other Analytes	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD
											x				9.9 - 10.0, 11.6 - 11.7	THg, MeHg, LOI, Other Analytes	Transect Program	UE
		2006			x	x	x	x	x	x	x	x	x	x	7.1, 8.7, 11.8, 8.2, 8.4, 8.6, 9.9, 12.7, 12.8	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
		2007								x		x		x	6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
										x	x				6.5 - 6.6, 7.4 - 7.5, 8.5 - 8.6, 9.4 - 9.6, 10.4 - 10.5, 11.3 - 11.4, 12.3 - 12.4, 13.2 -13.3, 14.2 -14.3, 15.2 -15.3	THg, Other Metals	VADEQ Sediment Sampling	VADEQ
			x	x											7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
												x			7.4, 8.2, 8.4, 8.6, 9.9, 12.7, 12.8	THg, MeHg	Phase I Ecostudy: Channel Margin Deposit Cores for Phase I Site Characterization	URS
		2008		x		x		x		x		x			6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase II Ecostudy: Interstitial Sediment	URS
		2009			x										8.5, 8.8	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS
		2010				x									11.8	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS
						x									11.8	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS
	Ground Water	2006					x								11.5 - 11.6	THg	Forest Station Ground Water	UE
		2007	x	x											11.5 - 11.7	THg	Turner Wells and Ultra	UE
		2009			x										6.1 - 16.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS
	Pore Water	2006							x						11.5 - 11.6	THg	Bank Flux Pore Water and Surface Water	UE
												x			11.5 - 11.6	THg	Turner Pore / Well Water I	UE
		2007							x						9.7 - 9.8, 11.5 - 11.6	MeHg	Turner Spin Pore Waters	UE
		2008						x							9.8 - 9.9	Fe, Mn	Turner Hyporheic Samples	UE
		2009						x	x	x			x		8.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
		2010						x							11.8	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
	Surface Water	2002								x					9.8 - 9.9	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
								x							9.8 - 9.9	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2003							x		x			x	9.8 - 9.9	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2004								x					6 - 6.1, 7.4 - 7.5, 9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Hg Speciation Study	UE
				x		x		x	x		x		x		9.8 - 9.9	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
												x			9.8 - 9.9	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
											x				9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Flood Sampling	UE
		2005			x										10.7 - 10.8	THg, Metals, Nutrients, Other Analytes	VADEQ Probability Monitoring	VADEQ
												x			11.5 - 11.6	THg	Forest Station Groundwater	UE
					x		x		x		x		x		11.6 - 11.7	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x												11.6 - 11.7	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
					x										6 - 6.1, 6.2 - 6.3, 6.4 - 6.5, 6.5 - 6.6, 6.8 - 6.9, 7 - 7.1, 7.2 - 7.3, 7.4 - 7.5, 7.7 - 7.8, 7.8 - 7.9, 8.1 - 8.2, 8.5 - 8.6, 8.7 - 8.8, 8.9 - 9, 9.2 - 9.3, 9.5 - 9.6, 9.6 - 9.7, 9.7 - 9.8, 9.8 - 9.9	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE
							x								6 - 6.1, 6.8 - 6.9, 7.7 - 7.8, 8.7 - 8.8, 9.6 - 9.7, 10.1 - 10.2, 10.4 - 10.5, 10.8 - 10.9, 11.3 - 11.4, 11.6 - 11.7, 12 - 12.1, 12.4 - 12.5, 12.9 - 13, 13.2 - 13.3, 13.7 - 13.8, 14.1 - 14.2, 14.7 - 14.8, 15.3 - 15.4	THg, MeHg, TSS	Water Sampling	UE
											x				6 - 6.1, 9.7 - 9.8, 9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Transect Program	UE
							x								9.8 - 9.9	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ
			x												9.8 - 9.9	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
				x											9.9 - 10, 11.6 - 11.7	THg, MeHg, TSS	Surface Water/Sediments	UE
		2006						x		x			x		9.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
			x		x		x		x		x		x		11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
								x			x				13.2 - 13.3	THg, MeHg, Mn, Fe, LOI	Flux Chamber Study (Loading)	DuPont
					x	x	x	x	x	x	x	x	x	x	7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy	URS
							x								9.7 - 9.9	THg, MeHg	Crimora Hot Spot	UE
									x				x		9.7 - 9.9	THg, MeHg	Crimora Surface Waters	UE
		2007			x										9.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
						x									11.5 - 11.6	THg	Turner Uptake Study	UE
			x		x		x		x		x		x		11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
										x		x		x	6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase I Ecostudy	URS
												x			6.7, 7.2, 8.8, 9.6	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS
			x	x		x	x								7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy	URS
			x	x											9.7 - 9.9	THg, MeHg	Crimora Surface Waters	UE
		2008	x		x			x			x		x		11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
							x								6.2, 12.8	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
				x				x		x		x			6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase II Ecostudy	URS
										x					6.2, 7.4, 8.7, 12.8	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
							x								6.7, 7.2, 8.6, 8.8, 9.9	THg, MeHg	Phase II Ecostudy: Targeted Tributary Loading Study	URS
			x	x	x	x	x	x	x	x	x	x	x	x	9.8 - 9.9	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
										x					8.5	THg, MeHg	Phase II Ecostudy: Benthic Flux Study (Loading)	URS
		2009							x	x			x		8.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
			x												11.6 - 11.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
				x			x			x					6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg	Phase II Ecostudy	URS
			x												9.8 - 9.9	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2010						x	x						11.8	THg, MeHg	Mesocosm Study	JMU
								x							11.8	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
									x	x					11.8	THg, MeHg, Nutrients	Sewage Treatment Plant Surface Water Studies	JMU
			x	x	x		x	x	x	x	x	x	x	x	6.2, 7.4, 8.6, 8.7, 9.9, 14.6	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS
					x		x		x		x		x		9.8 - 9.9	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ
		2011		x				x		x		x			11.8	THg, MeHg	Phase II Ecostudy	URS
			x		x		x		x		x		x		11.8	THg, MeHg	VADEQ Surface Water	VADEQ
							x								6.9, 7.7, 9.4, 9.6	THg, MeHg	Floodplain Ponds Investigation	URS

Appendix B
Ecological Study Data Matrix
AOC 4 Long-Term Monitoring Program
South River and a Segment of the South Fork Shenandoah River

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	SOURCE(S)
Biological Monitoring / Assessments																		
Aquatic Vegetation / Algae																		
RRM 6 - 16	Tissue	2006								x					7.1	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	7.1	THg, MeHg	Phase I Ecostudy: Periphyton	URS
							x	x							11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2007		x											7.1	THg, MeHg	Phase I Ecostudy: Periphyton	URS
							x		x						8.7, 11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2008						x		x					11.6	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS
		2010						x	x	x					11.8	THg, MeHg	Mesocosm Study	JMU
Aquatic Invertebrates																		
RRM 6 - 16	Population / Community	2006					x			x				x	11.8, 14.6		Phase I Ecostudy	URS
		2007		x											11.8, 14.6		Phase I Ecostudy	URS
		2010				x									11.8		Phase II Ecostudy: Sediment Quality Triad	URS
		2011					x	x							11.8		Phase II Ecostudy: Benthic Colonization Study	URS
	Feeding	2010						x		x		x			11.8	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS
	Tissue	2003											x		11.6	THg, MeHg	Clam Transplant Study	JMU, EMU
						x									11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x		x	11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2004	x		x		x	x							11.6	THg, MeHg	Clam Transplant Study	JMU, EMU
		2006					x	x							11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
							x			x				x	7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
		2007		x											7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
							x		x						8.7, 11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2009					x			x					8.5, 11.8	THg, δN15, δC13	Phase II Ecostudy: Aquatic Insect Metamorphosis Study	URS
							x	x							8.5	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS
		2010						x		x					11.8	THg, MeHg	Phase II Ecostudy: Aquatic Invertebrates Uptake Study	URS
	Toxicity	2010								x					11.8		Phase II Ecostudy: Field Microcosm Study	URS
							x								11.8		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS
Fish																		
RRM 6 - 16	Population / Community	2006					x			x					11.8, 14.6		Phase I Ecostudy	URS
		2010					x				x				11.8		Phase II Ecostudy	URS
	Stomach Contents	2010					x				x	x			11.8		Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS
	Tissue	2002				x									9.8	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2003				x									11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x			11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2005				x									9.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2006					x			x					7.1, 8.7, 11.8, 13.1, 14.6	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
		2007				x									11.6	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
							x								8.7, 11.8	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
		2009					x				x				11.8	THg, MeHg	Phase II Ecostudy: Bass	URS
		2010					x				x	x			11.8	THg, MeHg	Phase II Ecostudy: Bass	URS
							x				x	x			11.8	THg, MeHg	Phase II Ecostudy: Forage Fish	URS
							x				x				11.8	THg, MeHg	Phase II Ecostudy: Sunfish	URS
		2011					x								6.9, 7.7, 9.4, 9.6	THg, MeHg	Floodplain Ponds Investigation	URS
							x								11.8	THg, MeHg	Phase II Ecostudy: Bass	URS
Herpetofauna																		
RRM 6 - 16	Tissue	2006					x	x	x						9.7, 12.8, 13.7	THg, MeHg, δN15, δC13	Turtle Study	VT
		2007			x	x	x								9.0, 11.0, 13.0, 14.0, 16.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
		2008			x	x									9.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
		2009				x									9.0, 14.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
Terrestrial Invertebrates																		
RRM 6 - 16	Tissue	2003				x									11.6	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						11.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x			11.6	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2006									x		x		7.6, 9.8, 11.7, 13.9	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU
		2007					x	x	x						8.6, 9.6, 11, 11.4, 12, 14.3, 14.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU
		2008					x	x							9.6, 11.4, 14.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU
Birds																		
RRM 6 - 16	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
	Blood, Feather	2007				x	x								11.0	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI
	Blood, Feather, Egg	2007				x	x								17.0	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI
	Blood, Wing, Feather, Egg	2006				x	x	x	x	x					8.6, 9.0, 9.5, 9.6, 11.0, 11.4, 11.5, 11.8, 12.0, 12.1, 13.8, 14.3, 14.4, 14.5, 14.8, 15.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2007		x		x	x	x	x	x	x			x	8.6, 9.0, 9.5, 9.6, 11.0, 11.4, 11.5, 11.8, 12.0, 12.1, 13.8, 14.3, 14.4, 14.5, 14.8, 15.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2008				x	x	x	x						8.6, 9.0, 9.5, 9.6, 11.0, 11.4, 11.5, 11.8, 12.0, 12.1, 13.8, 14.3, 14.4, 14.5, 14.8, 15.5	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
	Tissue, Liver	2008									x		x	x	7.0, 7.6, 8.5, 8.9, 11.0, 12.8 14.5, 15.4	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ
		2010										x			7.8, 8.3, 10.8	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ
Mammals																		
RRM 6 - 16	Blood, Muscle, Fur	2008													10.0, 12.0, 14.5, 16.0, 16.7	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Muskrat and Shrews	BRI
	Blood, Skin, Fur	2007						x							12.0, 16.0	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI
	Tissue, Liver	2010			x										11.8	THg, MeHg	VADEQ White Tailed Deer Samples	VADEQ

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Habitat and Geophysical Characterizations																		
RRM 16 - 24	Discharge Characterization	2000	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2001	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2002	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2003	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2004	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2005	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2006	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2007	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2008	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
		2009	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
								x	x	x			x		23.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
		2010	x	x	x	x	x	x	x	x	x	x	x	x	16.5	Q (cfs)	Daily River Discharge (Harriston)	USGS
	Habitat Characterization	2005									x				19.0, 22.4		Phase I Ecostudy: Phase I Site Characterization	URS
		2006									x				19.0, 22.4		Phase I Ecostudy: Phase I Site Characterization	URS
		2009			x			x							23.5		Phase II Ecostudy: Phase II Site Characterization	URS
	Morphology Assessment	2005													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
		2006													NS		Comprehensive Geomorphological Study: Geomorphic Characterization and Annual Sediment Budget for Silt and Clay	UD
Physical and Chemical Monitoring / Assessments																		
RRM 16 - 24	Soil	2004						x							19.7 - 19.8, 22.0 - 22.1, 23.9 - 24.0	THg	Floodplain Hg Sampling	UE
		2006										x			19.8, 24.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU
		2007													19.8, 22.3, 22.6, 23.1	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
		2008		x	x	x									16.1 - 24.0	THg	Phase II Ecostudy: Floodplain Soil Investigation	URS
															19.8, 22.3, 22.6, 23.1	THg, MeHg	Comprehensive Geomorphological Study: LiDAR Study for Bank Erosion and Mercury Content	UD
				x		x	x								22.3 - 22.4, 22.6 - 22.7, 23.1 - 23.2, 23.4 - 23.5	THg, MeHg	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD
		2009			x										23.5	THg	Phase II Ecostudy: River Bank Soil for Phase II Site Characterization	URS
		2011					x								23.1 - 23.4, 23.4 - 23.5	THg	Floodplain Soils Investigation	URS
	Sediment	2003									x				16.4 - 16.5	THg, Metals	VADEQ Historical Floodplain Monitoring	VADEQ
		2005									x				16.5 - 16.6, 22.0 - 22.1	THg, MeHg, LOI, Other Analytes	Transect Program	UE
		2006			x	x	x	x	x	x	x	x	x	x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
		2007								x					17.1 - 17.2, 18.2 - 18.3, 19.2 - 19.3, 20.2 - 20.3, 21.2 - 21.3, 22.1 - 22.2, 23.0 - 23.1, 23.8 - 23.9	THg, Other Metals	VADEQ Sediment Sampling	VADEQ
			x	x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
		2009			x										23.5	THg	Phase II Ecostudy: Near-Bank Sediment for Phase II Site Characterization	URS
		2010				x									23.5	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS
	Ground Water	2009			x										16.1 - 24.0	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS
	Pore Water	2007							x						23.8 - 23.9	MeHg	Turner Spin Pore Waters	UE
		2009						x	x	x			x		23.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
	Surface Water	2000		x	x	x	x	x	x	x	x	x	x	x	16.4 - 16.5	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
										x		x		x	16.4 - 16.5	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2001		x		x		x		x		x			16.4 - 16.5	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x	x	x	x	x	x		x			x	16.4 - 16.5, 22 - 22.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2002		x		x		x	x	x	x	x	x	x	16.4 - 16.5, 22 - 22.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x		x			x		x		x		x	16.4 - 16.5, 22 - 22.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2003		x		x		x		x		x			16.4 - 16.5	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x	x	x	x	x	x		x			x	16.4 - 16.5, 22 - 22.1	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2004	x		x		x		x		x		x		16.4 - 16.5	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x	x		x		x		x	x	x			16.4 - 16.5, 22 - 22.1	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
										x					16.5 - 16.6, 19.8 - 19.9	THg, MeHg, TSS	Hg Speciation Study	UE
											x				16.5 - 16.6, 22 - 22.1	THg, MeHg, TSS	Flood Sampling	UE
							x								16.0 - 16.1, 16.5 - 16.6, 17.2 - 17.3, 17.8 - 17.9, 18.4 - 18.5, 19.0 - 19.1, 19.7 - 19.8, 20.2 - 20.3, 20.8 - 20.9, 21.4 - 21.5, 22.1 - 22.2, 22.7 - 22.8, 23.2 - 23.3, 23.9 - 24	THg, MeHg, TSS	Water Sampling	UE
		2005			x		x		x			x	x	x	16.4 - 16.5	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ
			x												16.4 - 16.5	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
					x				x					x	16.4 - 16.5	THg, TSS	VADEQ Storm Sampling	VADEQ
					x		x		x		x		x		16.4 - 16.5, 22 - 22.1	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x												16.4 - 16.5, 22 - 22.1	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
				x											16.5 - 16.6, 19.8 - 19.9, 22 - 22.1	THg, MeHg, TSS	Surface Water/Sediments	UE
											x				16.5 - 16.6, 19.8 - 19.9, 22 - 22.1, 23.9 - 24	THg, MeHg, TSS	Transect Program	UE
		2006	x			x	x		x		x		x		16.4 - 16.5	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
				x		x									16.4 - 16.5	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ
			x												16.4 - 16.5	THg, TSS	VADEQHIST Storm	VADEQ
			x		x		x		x		x		x		16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
										x			x		16.5, 19.5, 23.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
								x							16.5, 23.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
					x	x	x	x	x	x	x	x	x	x	19.0, 22.4	THg, MeHg	Phase I Ecostudy	URS
		2007								x		x		x	16.5	THg, MeHg	Phase I Ecostudy	URS
			x	x		x	x								19.0	THg, MeHg	Phase I Ecostudy	URS
			x	x	x	x	x	x							16.4 - 16.5	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
					x	x									16.4 - 16.5, 19.7 - 19.8	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ
			x		x		x		x		x		x		16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
					x										16.5, 19.5, 23.9	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
		2008		x				x		x		x			16.5, 19.9, 23.9	THg, MeHg	Phase II Ecostudy	URS
			x		x		x		x		x		x		16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2009						x	x	x			x		23.5	THg, MeHg	Phase II Ecostudy: Physical Loading Study	URS
				x			x			x					16.5, 19.9, 23.9	THg, MeHg	Phase II Ecostudy	URS
			x												16.4 - 16.5	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x												16.4 - 16.5, 22.0 - 22.1	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2010							x	x					23.4	THg, MeHg, Nutrients	Sewage Treatment Plant Surface Water Studies	JMU
			x												16.5, 19.9, 23.9	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS
				x	x		x	x	x	x	x	x	x	x	16.5, 23.9	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS
					x		x		x		x		x		16.4 - 16.5, 23.8 - 23.9	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ
		2011		x				x		x		x			23.5	THg, MeHg	Phase II Ecostudy	URS
			x		x		x		x		x		x		23.5	THg, MeHg	VADEQ Surface Water	VADEQ
							x								17.1, 17.3, 17.5, 22.1	THg, MeHg	Floodplain Ponds Investigation	URS
Biological Monitoring / Assessments																		
Aquatic Vegetation / Algae																		
RRM 16 - 24	Tissue	2006					x	x							19.0	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
										x					19.0, 22.4	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Periphyton	URS
		2007					x		x						22.4	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
				x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Periphyton	URS
		2008						x		x					22.1	THg, MeHg, δN15, δC13	VIMS Sed and Periphyton Study 2008	VIMS
Aquatic Invertebrates																		
RRM 16 - 24	Population / Community	2006					x			x				x	19.0, 22.4		Phase I Ecostudy	URS
		2007		x											19.0, 22.4		Phase I Ecostudy	URS
		2010				x									23.5		Phase II Ecostudy: Sediment Quality Triad	URS
		2011					x	x							23.5		Phase II Ecostudy: Benthic Colonization Study	URS
	Feeding	2010						x		x		x			23.5	δN15, δC13	Phase II Ecostudy: Basal Resource Utilization Study	URS
	Tissue	2003											x		24.0	THg, MeHg	Clam Tissue Study	JMU, EMU
		2006					x	x							19.0	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
							x			x				x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	19.0, 22.4	THg, MeHg	Phase I Ecostudy: Crayfish	URS
		2007					x								22.4	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
				x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											19.0, 22.4	THg, MeHg	Phase I Ecostudy: Crayfish	URS
		2009					x			x					22.1	THg, δN15, δC13	Phase II Ecostudy: Aquatic Insect Metamorphosis Study	URS
							x	x							23.5	THg, MeHg	Phase II Ecostudy: Asian Clam Uptake Study	URS
		2010						x		x					23.5	THg, MeHg	Phase II Ecostudy: Aquatic Invertebrates Uptake Study	URS
	Toxicity	2010					x								23.5		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS
Fish																		
RRM 16 - 24	Population / Community	2006					x			x					19.0, 22.4		Phase I Ecostudy	URS
		2010					x				x				23.5		Phase II Ecostudy	URS
	Stomach Contents	2010					x				x	x			23.5		Phase II Ecostudy: Bass, Sunfish, and Forage Fish	URS
	Tissue	2002				x									19.8	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2005				x									19.8	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2006					x			x					19.0, 22.4	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
		2007					x								22.4	THg, MeHg, δN15, δC13	Trophic Transfer Study	VIMS
						x									16.5, 22.1	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2009					x				x				23.5	THg, MeHg	Phase II Ecostudy: Bass	URS
		2010					x				x	x			23.5	THg, MeHg	Phase II Ecostudy: Forage Fish	URS
							x				x				23.5	THg, MeHg	Phase II Ecostudy: Sunfish	URS
							x				x				NS	THg, MeHg	Phase II Ecostudy: Bass	URS
		2011					x								17.1, 17.3, 17.5, 22.1	THg, MeHg	Floodplain Ponds Investigation	URS
							x								23.5	THg, MeHg	Phase II Ecostudy: Bass	URS
Herpetofauna																		
RRM 16 - 24	Tissue	2006					x	x							16.7, 20.1	THg, MeHg, δN15, δC13	Turtle Study	VT
		2007				x	x								20.0, 22.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
		2008				x									20.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
Terrestrial Invertebrates																		
RRM 16 - 24	Tissue	2006										x			19.8, 24.0	THg, MeHg	Survey of the Mercury Content of Earthworms	JMU
		2007					x	x							17.4, 19.6, 19.8, 21.9, 23.8		Examining the Fate and Effects of Mercury Contamination on Spiders	WMU
		2008					x	x							19.8, 21.9, 23.8		Examining the Fate and Effects of Mercury Contamination on Spiders	WMU
Birds																		
RRM 16 - 24	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
	Blood, Feather, Egg	2007				x	x								20.0, 24	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI
	Blood, Wing, Feather, Egg	2006				x	x	x	x	x				x	17.4, 18.6, 19.6, 19.8, 21.9, 23.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2007	x			x	x	x	x	x				x	17.4, 18.6, 19.6, 19.8, 21.9, 23.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2008				x	x	x							17.4, 18.6, 19.6, 19.8, 21.9, 23.8	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
	Tissue, Liver	2008									x		x	x	16.2, 19.1	THg, MeHg, Total Solids	VADEQ Waterfowl Samples	VADEQ
Mammals																		
RRM 16 - 24	Blood, Skin, Fur	2006							x	x					17.0, 18	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI

Appendix B
Ecological Study Data Matrix
AOC 4 Long-Term Monitoring Program
South River and a Segment of the South Fork Shenandoah River

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	SOURCE(S)
Habitat and Geophysical Characterizations																		
Reference	Discharge Characterization	2000	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2001	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2002	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2003	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2004	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2005	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2006	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2007	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2008	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2009	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
		2010	x	x	x	x	x	x	x	x	x	x	x	x	-2.7	Q (cfs)	Daily River Discharge (Near Waynesboro)	USGS
	Precipitation Monitoring	2000	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2001	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2002	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2003	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2004	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2005	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2006	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2007	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2008	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2009	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
		2010	x	x	x	x	x	x	x	x	x	x	x	x	MR		Daily Precipitation Volume (Staunton Sewage Treatment Plant)	NOAA
	Habitat Characterization	2005									x				NR - 01		Phase I Ecostudy: Phase I Site Characterization	URS
		2006									x				NR - 01		Phase I Ecostudy: Phase I Site Characterization	URS
		2007											x		MR - 01		Phase I Ecostudy: Phase I Site Characterization	URS
		2010			x	x									MR - 01		Phase II Ecostudy: Phase II Site Characterization	URS
					x										MR - 01		Phase II Ecostudy: Phase II Site Characterization	URS
Physical and Chemical Monitoring / Assessments																		
Reference Site	Soil	2003										x			-0.6 - -0.5, -0.5 - -0.4, -0.1 - -0.0	THg	Greenway Sampling	UE
		2006										x			-1.5	THg, MeHg	Survey of the Mercury Content of Earthworms on the South River Virginia Floodplain	JMU
											x				-2.6 - -2.5	THg, MeHg, LOI	Flux Chamber Study (Loading)	DuPont
		2010						x	x						NR	THg, MeHg	Mesocosm Study	JMU
	Sediment	2003			x								x		-4.1 - -4.2	THg, Metals, VOCs	VADEQ Historical Floodplain Sediments	VADEQ
													x		-4.1 - -4.2	VOCs, Pesticides, PCBs	VADEQ Probability Monitoring	VADEQ
		2004					x								-0.5 - -0.1	THg, Other Analytes	Sediment Sampling	UE
		2005								x					-2.7 - -2.8	THg, LOI, Other Analytes	Comprehensive Geomorphological Study: Bank Erosion and Mercury Content	UD
											x				-2.7 - -2.8	THg, MeHg, LOI, Other Analytes	Transect Program	UE
		2006										x			-1.0 , -0.7	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE
					x	x	x	x	x	x	x	x	x	x	NR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
					x	x	x	x	x	x	x	x	x	x	NR - 02	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
					x	x	x	x	x	x	x	x	x	x	SR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
		2007								x					0 - -0.1	THg, Other Metals	VADEQ Sediment Sampling	VADEQ
			x	x											NR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
			x	x											NR - 02	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
			x	x											SR - 01	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
		2010				x									MR - 01	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS
						x									SR - 01	THg, MeHg, PCBs, PAHs, Herbicides, Pesticides, Other Analytes	Phase II Ecostudy: Interstitial Sediment for Sediment Quality Triad	URS
	Pore Water	2006										x			-1.0 , -0.7	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE
		2007		x											-0.6 - -0.5, -0.4 - -0.3, -0.2 - -0.1, -0.1 - 0.0	THg	Turner Plant Reach Pore Water and Surface Water	UE
	Surface Water	2000	x	x	x	x	x	x	x	x	x	x	x	x	-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2001											x		-1.6 - -1.7, -0.7 - -0.8	THg, Metals, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x	x	x	x		x		x			x	-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2002	x		x			x		x		x		x	-1.6 - -1.7, -0.7 - -0.8	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
				x		x		x	x		x		x		-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2003								x					-0.8 - -0.7, -0.6 - 0.0	THg, TSS, Other Analytes	VADEQ Historical Intensive 2	VADEQ
				x		x		x		x		x			-1.6 - -1.7, -0.7 - -0.8	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
													x		-4.1 - -4.2	Pesticides	VADEQ Historical Sediments	VADEQ
			x		x		x		x		x			x	-4.1 - -4.2, -2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
		2004										x			-0.4 - -0.5	THg	Cutback Survey Sampling	UE
			x												-0.4 - -0.5	THg, TSS	VADEQ Historical Intensive 2 (Follow Up)	VADEQ
			x	x		x		x		x		x			-1.6 - -1.7, -0.7 - -0.8	THg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
										x					-2.7 - -2.8	THg, MeHg, TSS	Hg Speciation Study	UE
				x		x		x	x	x	x	x	x	x	-2.7 - -2.8	Nutrients, TSS, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
											x				-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, TSS	Flood Sampling	UE
		2005					x								-0.4 - -0.5	THg, MeHg, TSS	Water Sampling	UE
					x		x		x		x		x		-1.6 - -1.7, -0.7 - -0.8	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x												-1.6 - -1.7, -0.7 - -0.8	TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
											x				-2.7 - -2.8	THg, MeHg, TSS	Concurrent Sampling	RTG
					x	x	x	x	x	x	x		x	x	-2.7 - -2.8	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ
			x												-2.7 - -2.8	Nutrients	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
											x				-2.7 - -2.8	THg, TSS	VADEQ Storm Sampling	VADEQ
			x	x											-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, TSS	Surface Water/Sediments	UE
											x				-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, TSS	Transect Program	UE
					x										-2.7 - -2.8, -0.4 - -0.5	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE
		2006						x			x				-1.0	THg, MeHg	Flux Chamber Study (Loading)	DuPont
												x			-1.0 , -0.7	THg, MeHg	Mercury Source Tracing and Mechanistic Source Studies	RTG, UE
			x		x		x		x		x		x		-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
												x			-2.8 - -2.7	THg, MeHg	Turner Wells / Turner Wells and Extract	UE
			x	x	x	x	x	x		x	x	x	x	x	-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
											x	x			-2.8 - -2.7, -0.8 - -0.7, -0.6 - -0.5, -0.5 - -0.4, -0.1 - 0.0	THg	Turner Plant Reach Pore Water and Surface Water	UE
					x	x	x	x	x	x	x	x	x	x	NR - 01	THg, MeHg	Phase I Ecostudy	URS
					x	x	x	x	x	x	x	x	x	x	NR - 02	THg, MeHg	Phase I Ecostudy	URS
					x	x	x	x	x	x	x	x	x	x	SR - 01	THg, MeHg	Phase I Ecostudy	URS
								x		x			x		SR - 01	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
		2007	x			x		x		x		x			-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x		x	x		x	x	x	x		x	-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
				x											-2.8 - -2.7, -0.8 - -0.7, -0.5 - -0.4, -0.4 - -0.3	THg	Turner Plant Reach Pore Water and Surface Water	UE
			x	x											NR - 01	THg, MeHg	Phase I Ecostudy	URS
			x	x											NR - 02	THg, MeHg	Phase I Ecostudy	URS
			x	x		x	x								SR - 01	THg, MeHg	Phase I Ecostudy	URS
					x										SR - 01	THg, MeHg	Phase I Ecostudy: Storm Event Loading	URS
		2008	x		x		x		x		x		x		-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x	x	x	x	x	x	x	x	x	x	x	-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
														x	NS	Temperature	Analysis of South River Temperatures	JMU
		2009	x												-1.7 - -1.6, -0.8 - -0.7	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x											-2.8 - -2.7	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
				x			x			x					SR - 01	THg, MeHg	Phase II Ecostudy	URS
		2010			x		x		x		x		x		-2.8 - -2.7	Nitrate, Nitrite, Nitrogen	VADEQ Surface Water	VADEQ
			x	x	x		x	x	x	x	x	x	x	x	SR - 01	THg, MeHg, Nutrients, Other Analytes	Phase II Ecostudy	URS

Appendix B
Ecological Study Data Matrix
AOC 4 Long-Term Monitoring Program
South River and a Segment of the South Fork Shenandoah River

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	SOURCE(S)
Biological Monitoring / Assessments																		
Aquatic Vegetation / Algae																		
Reference Site	Tissue	2005							x						-4.1	THg, MeHg	Periphyton Assessment	VIMS
		2006								x					NR - 01	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	NR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS
										x					NR - 02	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	NR - 02	THg, MeHg	Phase I Ecostudy: Periphyton	URS
										x					SR - 01	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	SR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS
		2007		x											NR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS
				x											NR - 02	THg, MeHg	Phase I Ecostudy: Periphyton	URS
				x											SR - 01	THg, MeHg	Phase I Ecostudy: Periphyton	URS
Aquatic Invertebrates																		
Reference Site	Population / Community	2006					x			x				x	NR - 01		Phase I Ecostudy	URS
							x			x				x	NR - 02		Phase I Ecostudy	URS
							x			x				x	SR - 01		Phase I Ecostudy	URS
		2007		x											NR - 01		Phase I Ecostudy	URS
				x											NR - 02		Phase I Ecostudy	URS
				x											SR - 01		Phase I Ecostudy	URS
		2010				x									MR - 01		Phase II Ecostudy: Sediment Quality Triad	URS
						x									SR - 01		Phase II Ecostudy: Sediment Quality Triad	URS
		2011					x	x							MR - 01		Phase II Ecostudy: Benthic Colonization Study	URS
							x	x							SR - 01		Phase II Ecostudy: Benthic Colonization Study	URS
	Tissue	2002											x		-1.8, -0.7	THg	Clam Tissue Study	JMU, EMU
		2003											x		-1.8	THg, MeHg	Clam Tissue Study	JMU, EMU
						x									NR	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
		2004					x		x						NR	THg, MeHg	Clam Transplant Study	JMU, EMU
		2006					x			x				x	NR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	NR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
							x			x				x	NR - 02	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	NR - 02	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
							x			x				x	SR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	SR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
		2007		x											NR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											NR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
				x											NR - 02	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											NR - 02	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
				x											SR - 01	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											SR - 01	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
	Toxicity	2010					x								MR - 01		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS
										x					NR - 01		Phase II Ecostudy: Field Microcosm Study	URS
										x					NR - 02		Phase II Ecostudy: Field Microcosm Study	URS
										x					SR - 01		Phase II Ecostudy: Field Microcosm Study	URS
							x								SR - 01		Phase II Ecostudy: Laboratory Sediment Bioassays for Sediment Quality Triad	URS
Fish																		
Reference Site	Population / Community	2006					x			x					NR - 01		Phase I Ecostudy	URS
							x			x					NR - 02		Phase I Ecostudy	URS
							x			x					SR - 01		Phase I Ecostudy	URS
		2010					x				x				MR-01		Phase II Ecostudy	URS
							x				x				SR - 01		Phase II Ecostudy	URS
	Tissue	2001				x									-0.7	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2002				x									-0.7	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
						x									NR	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2003				x									NR	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
		2005				x	x								-0.7	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
						x									NR	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2006					x			x					NR - 01	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
							x			x					NR - 02	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
							x			x					SR - 01	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
		2007				x									-0.7	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
						x									NR	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
Herpetofauna																		
Reference Site	Tissue	2007			x	x	x								-1.0, -2.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
		2008			x	x									-1.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
Terrestrial Invertebrates																		
Reference Site	Tissue	2006										x			-1.5	THg, MeHg	Survey of the Mercury Content of Earthworms on the South River Virginia Floodplain	JMU
		2007					x								NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU
		2008					x								NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Spiders	WMU
Birds																		
Reference Site	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
	Blood, Feather	2007				x	x								MR	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI
	Blood, Feather, Egg	2007				x	x								NR	THg	Pilot Assessment of Methyl-Mercury Availability to Mallards	BRI
	Blood, Wing, Feather, Egg	2006				x	x	x	x						MR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
						x	x	x	x						NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2007				x	x	x	x						MR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
							x	x	x						NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
		2008					x	x							MR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
							x	x							NR	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU
Mammals																		
Reference Site	Blood, Skin, Fur	2007							x	x					MR	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI
		2008						x	x	x					MR	THg, MeHg	Pilot Assessment of Methyl-Mercury Availability to Bats	BRI
	Tissue, Liver	2010				x									MR	THg, MeHg	VADEQ White Tailed Deer Samples	VADEQ

Appendix B
Ecological Study Data Matrix
AOC 4 Long-Term Monitoring Program
South River and a Segment of the South Fork Shenandoah River

RIVER REACH	DATA TYPE	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RELATIVE RIVER MILE	MAIN PARAMETERS	PROJECT NAME / DESCRIPTION	SOURCE(S)
Habitat and Geophysical Characterizations																		
SFS	Habitat Characterization	2005									x				SFS - 1		Phase I Ecostudy: Phase I Site Characterization	URS
		2006									x				SFS - 1		Phase I Ecostudy: Phase I Site Characterization	URS
Physical and Chemical Monitoring / Assessments																		
SFS	Soil	2004										x			31 - 32	THg	Cutback Survey Sampling	UE
		2006					x								40 - 41	THg	VADEQ Probability Monitoring	VADEQ
								x							26 - 27, 72 - 73, 121 - 122	THg	VADEQ Fish Kill Sediment Sampling	VADEQ
	Sediment	2003											x		40 - 41	VOCs, Pesticides, PCBs	VADEQ Probability Monitoring	VADEQ
		2005									x				24 - 25, 34 - 35	THg, MeHg, LOI, Other Analytes	Transect Program	UE
											x				30 - 31, 32 - 33	THg, MeHg, LOI, Other Analytes	McGaheysville Dam Samples	UE
		2006			x	x	x	x	x	x	x	x	x	x	SFS - 1	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
		2007	x	x											SFS - 1	THg, MeHg	Phase I Ecostudy: Interstitial Sediment	URS
										x	x				26 - 27, 33 - 34, 40 - 41, 43 - 44, 50 - 51, 55 - 56, 57 - 58, 65 - 66, 72 - 73, 75 - 76, 79 - 80, 86 - 87, 91 - 92, 95 - 96, 103 - 104, 106 - 107, 110 - 111, 115 - 116, 121 - 122, 125 - 126	THg, Other Metals	VADEQ Sediment Sampling	VADEQ
	Ground Water	2009			x										NS	Spatial Analysis	River Corridor Infrared Thermal Imaging	SITS
	Surface Water	2003									x	x	x	x	26 - 27, 48 - 49, 65 - 66, 72 - 73, 121 - 122, 125 - 126	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ
												x			48 - 49, 72 - 73, 94 - 95	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2004									x				24 - 25	THg, MeHg, TSS	Flood Sampling	UE
										x					24 - 25, 30 - 31, 32 - 33	THg, MeHg, TSS	Hg Speciation Study	UE
			x		x		x	x	x	x	x	x	x	x	26 - 27, 48 - 49, 65 - 66, 72 - 73, 79 - 80, 121 - 122, 125 - 126	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ
			x	x		x		x		x		x			26 - 27, 48 - 49, 72 - 73, 94 - 95	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2005			x										24 - 25	THg, MeHg, Metals, TSS, Other Analytes	Water Sampling	UE
				x											24 - 25	THg, MeHg, TSS	Surface Water/Sediments	UE
											x				24 - 25, 30 - 31, 32 - 33, 34 - 35	THg, MeHg, TSS	Transect Program	UE
			x	x	x	x	x	x	x	x	x	x	x	x	26 - 27, 48 - 49, 65 - 66, 72 - 73, 79 - 80, 121 - 122, 125 - 126	Nutrients, E. Coli, Other Analytes	VADEQ Historical Ambient Water Quality Monitoring	VADEQ
			x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Hg, TSS, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
		2006		x	x	x	x	x	x	x	x	x	x	x	26 - 27, 33 - 34, 72 - 73, 121 - 122	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ
			x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
				x		x		x		x		x		x	26 - 27, 72 - 73, 121 - 122	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
						x	x						x		40 - 41, 72 -73	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Probability Monitoring	VADEQ
					x	x	x	x	x	x	x	x	x	x	SFS - 1	THg, MeHg	Phase I Ecostudy	URS
		2007	x	x	x	x	x	x	x	x					26 - 27, 33 - 34, 72 - 73, , 121 - 122	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ
			x	x	x	x	x	x	x	x	x	x	x	x	26 - 27, 48 - 49, 72 - 73, 79 - 80, 115 - 116, 121 - 122	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
			x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x											SFS-1	THg, MeHg	Phase I Ecostudy	URS
		2008	x		x		x		x		x		x		26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
			x	x	x	x	x	x	x	x	x	x	x	x	26 - 27, 72 - 73, 79 - 80, 115 - 116, 121- 122	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
					x	x	x								33 - 34	Nutrients, Bacteria, THg, Other Analytes	VADEQHIST Fishkill	VADEQ
		2009	x												26 - 27, 48 - 49, 94 - 95	Nutrients, Bacteria, THg, Other Analytes	VADEQ Historical Bimonthly Clean Hg	VADEQ
				x											26 - 27, 72 - 73	Nutrients, Bacteria	VADEQ Historical Ambient Water Quality Monitoring Samples	VADEQ
Biological Monitoring / Assessments																		
Aquatic Vegetation / Algae																		
SFS	Tissue	2003							x						92.6	THg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
		2006								x					SFS - 1	THg, MeHg	Phase I Ecostudy: Macrophytes	URS
							x			x				x	SFS - 1	THg, MeHg	Phase I Ecostudy: Periphyton	URS
		2007		x											SFS - 1	THg, MeHg	Phase I Ecostudy: Periphyton	URS
Aquatic Invertebrates																		
SFS	Population / Community	2006					x			x				x	SFS - 1		Phase I Ecostudy	URS
		2007		x											SFS - 1		Phase I Ecostudy	URS
	Tissue	2003				x									92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x		x	92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2006					x			x				x	SFS - 1	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
					x	x	x	x	x	x	x	x	x	x	SFS - 1	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
		2007		x											SFS - 1	THg, MeHg	Phase I Ecostudy: Asian Clams and Aquatic Insects	URS
			x	x											SFS - 1	THg, MeHg, PAHs, Other Analytes	Phase I Ecostudy: Crayfish	URS
Fish																		
SFS	Population / Community	2006					x			x					SFS - 1		Phase I Ecostudy	URS
	Tissue	2001					x								135, 144.5, 160	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2002				x	x		x			x			27.9, 49.7, 65.0, 77.5, 93.0, 108.7, 124.3, 144.5, 160.0	THg, MeHg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2003	x												27.9	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
						x									92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Spring Sampling)	VT
									x						92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Summer Sampling)	VT
												x			92.6	THg, MeHg	Uptake of Mercury and Relationships of Food Habits of Selected Species (Fall Sampling)	VT
		2005				x	x								27.9, 49.7, 65.0, 77.5, 93.0, 108.7, 124.3, 144.5	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
		2006					x			x					SFS - 1	THg, MeHg	Phase I Ecostudy: Forage Fish	URS
		2007			x	x									27.9, 49.7, 65.0, 77.5, 93.0, 108.7, 124.3, 144.5, 160.0	THg	VADEQ Fish Fillet Tissue Hg Monitoring	VADEQ
Herpetofauna																		
SFS	Tissue	2007					x								34.0	THg, MeHg	Mercury Bioaccumulation in Amphibians: Nondestructive Indices of Exposure, Maternal Transfer, and Reproductive Effects	VT
Birds																		
SFS	Blood	2005					x	x	x						NS	THg, MeHg	Examining the Fate and Effects of Mercury Contamination on Birds	WMU

NOTES:

The records presented in this table were obtained from the URS Master Database from 2000 to 2011 and from the South River Science Team Web Server (2006-2010). Research conducted by outside organizations was compiled to the fullest extent possible, however, some studies may not be represented. Relative River Miles (RRM) are determined by the streamline distance downstream (+), or distance upstream (-) of the footbridge located in downtown Waynesboro, VA. The locations reported are based on the coordinates or site descriptions provided in the source dataset and may not be fully comprehensive. For sites in the Middle River (MR) and North River (NR), no specific RRM is provided.

NS = Not Specified; SFS = South Fork Shenandoah River; *Analytes:* LOI = Loss on Ignition; MeHg = Methyl Mercury; δN15/ δC13 = Stable Isotopes; PAHs = Polyaromatic Hydrocarbons; PCBs = Polychlorinated Biphenyls; THg = Total Mercury; TOC = Total Organic Carbon; TSS = Total Suspended Solids; VOCs = Volatile Organic Compounds

DuPont = E. I. du Pont de Nemours and Company; EMU = Eastern Mennonite Univ.; JMU = James Madison Univ.; NOAA = National Oceanic and Atmospheric Admin.; RTG = Ralph Turner Geosciences; SITS = Stockton Infrared Thermographic Services; UD = Univ. of Delaware; UE = Unique Environmental

URS = URS Corporation; USEPA = US Environmental Protection Agency; USGS = US Geologic Survey; VADEQ = VA Dept. of Environmental Quality; VIMS = Virginia Institute of Marine Science; VT = Virginia Tech