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October 22, 2013

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Ms. Nancy S. Marks, Esq.
Natural Resources Defense Council
40 West 20th Street
New York, NY 10011

Final Remedial Proposal for the
South River and a Segment of the South Fork Shenandoah River, Virginia

Dear Dr. Livingston and Ms. Marks:

On behalf of E.I. du Pont de Nemours and Company (DuPont) and our consulting partners Anchor/QEA and URS Consultants, I am pleased to provide you with DuPont's final Remedial Proposal for the South River and a segment of the South Fork Shenandoah River, Virginia. The submission of this Remedial Proposal complies with Paragraph 44 of the Consent Decree and documents our intent to proceed with designing and implementing a remedial program for the South River and a segment of the South Fork Shenandoah River.

In addition to your review, a draft of this Remedial Proposal was also reviewed by members of the South River Science Team, the U.S. Environmental Protection Agency, the Virginia Department of Environmental Quality, and the U.S. Fish & Wildlife Service. All comments were considered when preparing this final proposal.

Over the nearly eight years we have worked closely with you, we have appreciated and benefitted from the technical suggestions and interactions in undertaking and completing both the Ecological Study and the Remedial Proposal. We look forward to moving ahead with the design and implementation of the remedial program.

If you have any questions about the enclosed information, please do not hesitate to call me at (302) 999-3733 or contact me via e-mail at Ralph.G.Stahl-Jr@dupont.com.

Regards,

Ralph G. Stahl, JR.

Ralph G. Stahl, Jr., Ph.D., D.A.B.T.
Principal Consultant
DuPont Corporate Remediation Group

REMEDIATION PROPOSAL
SOUTH RIVER AND A SEGMENT OF THE SOUTH FORK SHENANDOAH RIVER, VIRGINIA

Prepared by
Anchor QEA, LLC
URS Corporation
E. I. du Pont de Nemours and Company

October 2013

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LIST OF ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
%MeHg	percent of THg present as MeHg
µg/g	microgram per gram
BMA	bank management area
BMP	best management practice
CERCLA	Comprehensive Environmental Response, Liability and Compensation Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CMS	Corrective Measures Study
cm/yr	centimeters per year
CSM	conceptual site model
DuPont	E. I. du Pont de Nemours and Company
FDA	Food and Drug Administration
FGCM	fine-grained channel margin
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HRAD	Hg (mercury)-release age deposit
IHg	inorganic mercury
kg	kilogram
LiDAR	light detection and ranging
MeHg	methylmercury
mg/kg	milligrams per kilogram
mi^2	square miles
mi-yr	mile per year
mm	millimeters
MNR	monitored natural recovery
NCP	National Contingency Plan
NRDC	Natural Resources Defense Council
OSHA	Occupational Safety and Health Administration
RA	Release Assessment
RAO	remedial action objective

RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
ROPs	Remedial Options Program
RRM	relative river mile
SFS	South Fork Shenandoah
SRST	South River Science Team
SWMU	Solid Waste Management Unit
THg	total mercury
TMDL	total maximum daily load
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VADEQ	Virginia Department of Environmental Quality
VDH	Virginia Department of Health
YOY	young-of-year

EXECUTIVE SUMMARY

To comply with the final requirements of the 2005 Consent Decree between E. I. du Pont de Nemours and Company (DuPont) and the Virginia Chapter of the Sierra Club/Natural Resources Defense Council, a Remediation Proposal is hereby provided on behalf of DuPont that details the framework for undertaking remedial measures in the South River and a segment of the South Fork Shenandoah (SFS) River, Virginia. As part of the Consent Decree, DuPont previously submitted an Ecological Study, which concluded that the majority of mercury loading to the South River enters the channel beginning at the former DuPont facility in Waynesboro, subsiding approximately 10 to 12 miles downstream. The Ecological Study found that a primary mechanism for the continued loading to this South River segment is through the slow erosion of legacy mercury deposits that currently reside in riverbank soils. Approximately 40 to 60% of the mercury that currently cycles through the food web into smallmouth bass tissue likely originates from eroding bank soils.

This Remediation Proposal builds on the findings of the Ecological Study, presents a conceptual remediation action strategy, and develops site-specific short-term and long-term remedial action objectives (RAOs). Owing to the size, linear nature, complexity, and spatial variability of the South River system, remedial measures will be implemented utilizing an adaptive management approach. This type of approach requires that the river system be divided into manageable segments, addressing banks and adjacent in-channel bed sediments in a successive upstream-to-downstream sequence. Conducting work sequentially on discrete segments of the river system will allow the work to be performed both safely and expeditiously. Careful monitoring of the outcome of the first phase of remediation actions will help adjust the scope of subsequent remediation phases as part of an iterative learning process, recognizing the importance of natural variability in ecological systems and variability in measuring effectiveness of remedial measures.

The first phase of corrective actions will target the first 2 miles of the river adjacent to and downstream of the former DuPont facility in Waynesboro, targeting a construction season of 1 to 2 years to address banks that contribute material mercury loading to the river in this segment. Short-term RAOs are developed for Phase 1 and will be adjusted and applied to subsequent reaches and corrective action phases, as appropriate. Using a detailed monitoring

and adaptive management approach, in-channel sediments and biota will be evaluated after bank remediation has been completed in order to track and effectively integrate lessons learned. If monitoring results indicate that current remediation assumptions are inaccurate, adjustments to the remediation approach will be implemented for subsequent corrective action phases beyond the first 2-mile Phase 1.

This Remediation Proposal describes a range of technology options that will be used during Phase 1, including a number of proven bank stabilization remedies. Based on evaluations presented herein, compared to removal and land use control options, vegetative and/or structural stabilization of those banks that contribute disproportionately to mercury loading to the river will achieve greater protectiveness with far less short-term impact on the environment during remedy implementation, less impact on the community, and less impact on sustainability core elements. Thus, the primary Phase 1 corrective action technologies anticipated to be used in the South River include enhanced vegetative and structural stabilization of target banks to materially reduce mercury loading to the South River and accelerate natural recovery processes within channel areas. However, as detailed corrective action design proceeds for Phase 1 and subsequent phases, all promising technologies will be considered and integrated into comprehensive remedies for individual banks to maximize overall protectiveness and minimize disruption in an optimal balance.

Short-term and long-term monitoring plans are provided as part of this Remediation Proposal. As the monitoring plan is further developed and implemented, there will be frequent and open communication with those involved with the existing monitoring efforts to share data and experience and avoid duplication of effort where possible. The overall goal of the effort is to provide data to assess the efficacy of the remedy in addressing both migration and potential exposure pathways. Specific objectives of the monitoring are to provide data to:

- Monitor system responses to remedial measures
- Monitor the integrity of the remedial measures
- Monitor human and ecological exposures to mercury through aquatic and terrestrial food webs

- Provide input to the adaptive management framework and relative risk model to determine whether any aspect of the corrective action, monitoring strategy, design, or conceptual model needs to be modified

It is expected that once corrective actions have been implemented, the 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. The Ecological Study also noted an association between loading of mercury to the South River and its transfer to the terrestrial food web; it is expected that addressing mercury loading to the South River will not only reduce impacts in the aquatic environment, but also help to reduce transfer of mercury into the terrestrial food web.

DuPont will continue to work closely with the various state and federal governmental agencies to conduct education and other outreach efforts for the communities along the South River and SFS River. Examples of this education and outreach include continuing Promotores de Salud, an effective public health program for the Hispanic community, conducting angler surveys to monitor adherence to the existing fish consumption advisory, and communicating with local health clinics and physicians regarding prevention of potential human exposure to mercury in fish.

This Remediation Proposal will form the basis for more detailed work plans for design, construction, monitoring, and adaptive management in the South River and a segment of the SFS River, to be implemented in multiple phases of corrective actions. The remediation program will be performed under the Resource Conservation and Recovery Act (RCRA) regulatory framework with oversight by the Virginia Department of Environmental Quality (VADEQ) in collaboration with the U.S. Environmental Protection Agency (USEPA). During RCRA corrective measures design, more detailed investigations and evaluations will be performed to further assess which technologies are most appropriately tailored to a given bank based on landowner preferences, site characteristics, regulatory requirements, and other factors. As it did with the Ecological Study, DuPont intends to fully engage the South River Science Team in the design, implementation, monitoring, and adjustments to the remedy.

1 INTRODUCTION

This Remediation Proposal was prepared consistent with the requirements of a Consent Decree issued in July 2005 between E. I. du Pont de Nemours and Company (DuPont), the Natural Resources Defense Council (NRDC), and the Virginia Chapter of the Sierra Club (U.S. District Court 2005). It has been prepared with support from Anchor QEA, LLC, and URS Corporation (URS). An initial draft of this document was distributed to the South River Science Team (SRST) Remedial Options Program Work Group, the SRST Monitoring Task Team, the Virginia Department of Environmental Quality (VADEQ), the U.S. Environmental Protection Agency (USEPA), the U.S. Fish and Wildlife Service, the City of Waynesboro, and other interested parties for review and comment, in addition to submission to the NRDC and the Sierra Club.

The Consent Decree required that a 6-year Ecological Study be performed, followed by the submittal of a Remediation Proposal. The purpose of the Ecological Study was to compile results from a range of scientific disciplines and develop a coordinated, integrated, watershed-level approach to characterize mercury fate and transport in the South River and a segment of the South Fork Shenandoah (SFS) River, answer key site characterization questions, and inform remediation decisions.

This Remediation Proposal builds on the characterization of the nature and extent of mercury contamination in the South River and a segment of the SFS River as summarized in other documents, presents a conceptual remediation strategy, develops site-specific remedial action objectives (RAOs), and identifies and evaluates alternatives for achieving the RAOs. More detailed work plans for design, construction, monitoring, and adaptive management actions will be developed and implemented in multiple phases under the Resource Conservation and Recovery Act (RCRA) regulatory framework with oversight by VADEQ in collaboration with USEPA.

1.1 Background

From 1929 to 1950, DuPont used mercury compounds (e.g., mercuric sulfate) in the production of acetate flake and yarn at the former DuPont Waynesboro facility, which is currently owned and operated by INVISTA S. à r. l. This process generated mercury-

containing sludge that was conveyed to an on-site retort facility where the majority of the mercury was recovered. During that period, releases of mercury associated with the acetation process occurred 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 that drain these areas were found to be impacted by the former mercury operations and are currently the primary transport mechanism for mercury loading from the former DuPont Waynesboro facility to the South River. Beginning in 1998, DuPont began a Release Assessment and RCRA Facility Investigation (RA/RFI) at the Waynesboro facility. 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. Of the 20 units identified and fully characterized in the RA/RFI, three were recommended for a Corrective Measures Study (CMS) to characterize and prevent migration of mercury to the South River; these actions are discussed further in Section 1.3.

Comparisons of fish tissue data collected in summer and fall of 1999 with results from the 1980s and earlier indicated that mercury concentrations in tissue from a number of fish species remained steady or may have increased over time (URS 2012b). This finding prompted discussions between DuPont and VADEQ in 2000 on the need to reassess the legacy mercury issue in the South River and SFS River; these discussions led to the formation of the SRST in 2001. The SRST is composed of members from state and federal government, the academic community, local environmental groups, and DuPont. Chartered in February 2001, the SRST has been the focal point for data collection and evaluation, and outreach to local communities and the national scientific community (Stahl et al. 2013, in press).

In addition, and as noted in the Ecological Study (URS 2012b), DuPont intends to fully engage the SRST in the final design, implementation, and monitoring of remediation actions, with regulatory oversight. Various smaller teams have been established under the SRST to focus on remediation options (Remedial Options Program [ROPs] Work Group), monitoring (Monitoring Task Team), exposure of humans (Exposure Task Team), and communications and outreach (Communications Task Team). These teams, similar to the larger SRST, are composed of individuals representing various stakeholders on the South River and have been involved in the design and implementation of field work and research efforts over the past 6

years. With this background, it is expected that the final design, implementation, and monitoring of corrective actions will have substantive input from these important groups as well as other affected stakeholders and ultimately address requirements established by the regulatory agencies. This Remediation Proposal will be integrated into corrective action work plans that will be implemented under RCRA regulatory authorities with close oversight and review by VADEQ in collaboration with USEPA.

In September 2012, DuPont prepared the final report of the Ecological Study (URS 2012b), which demonstrated that 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 plant, 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. 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 and biomagnified by fish. In addition, the former DuPont Waynesboro facility continues to act as a point source of IHg to the system, an issue that is being addressed under an existing RCRA Corrective Action permit. Section 2 of this Remediation Proposal provides a more detailed description of the findings of the Ecological Study and the spatial distribution of mercury sources in the South River.

Based on the findings of the Ecological Study (URS 2012b) and the results of remediation pilot studies conducted in the South River and a segment of the SFS River, DuPont concluded there may be remediation options that are safe, effective, and reasonably necessary to address ecological and human health impacts that may be caused by mercury contamination in these systems. Accordingly, DuPont proceeded under paragraph 44 of the Consent Decree and prepared this Remediation Proposal. The submission of this Remediation Proposal to NRDC and Sierra Club hereby satisfies the condition in the Consent Decree that DuPont submit a Remediation Proposal within 1 year of the completion of the Ecological Study report. NRDC, in September 2013, agreed to an extension until late October 2013 for DuPont to submit a final Remediation Proposal.

1.2 Scope

This Remediation Proposal is being developed to satisfy requirements of the Consent Decree, and in consideration of RCRA and related Comprehensive Environmental Response, Liability and Compensation Act (CERCLA) guidelines. Consistent with USEPA guidance (see Section 1.5), ecological and human health impacts that may be caused by mercury contamination in the South River and a segment of the SFS River are best addressed by applying a comprehensive set of RAOs that integrate affected environmental media, transport mechanisms, and exposure pathways.

The scope of this Remediation Proposal addresses the remedial strategy for the aquatic portion of the South River and a portion of the SFS River. A floodplain risk assessment is currently being developed under regulatory agency oversight, and will include a conceptual site model (CSM) specific to potential ecological and human receptors and relevant exposure pathways associated with the floodplain. Remediation strategies for the floodplain continue to be investigated and, upon completion of the risk assessment for the floodplain, a RCRA corrective action approach will be developed and integrated into the adaptive management strategy for the South River and SFS River system. Preliminary human health and ecological exposure pathway diagrams are presented in Figures 1-1 and 1-2, respectively, and are discussed further in Section 1.3.1.

Owing to the size, linear nature, complexity, and spatial variability of the South River system, reduced exposure of humans and ecological receptors, and subsequent overall risk reduction, will be best achieved in the South River and ultimately the SFS River by conducting remedial measures in an adaptive management approach (e.g., NRC 2004). The adaptive management approach, described in more detail in Sections 1.6 and 4.3.4, requires making and implementing response decisions based on monitoring results and informing future response decisions by these results. This type of approach requires that the river system be divided into manageable segments, beginning with source controls at the former Waynesboro facility (currently being performed under RCRA), followed by addressing banks and adjacent in-channel bed sediments in a successive upstream-to-downstream remediation action sequence. Conducting work sequentially on discrete segments of the river system will allow the work to be performed both safely and expeditiously. Careful monitoring of the outcome of the first set of river remediation actions (Phase 1) will help adjust the scope of

subsequent phases as part of an iterative learning process, recognizing the importance of natural variability in ecological systems and variability in measures of effectiveness of remedial measures.

The above approach is also consistent with findings of the Ecological Study, which found that the sources of mercury are primarily observed in the first 12 miles of the South River, beginning at the former DuPont facility at relative river mile (RRM) 0. The main working hypothesis is that reducing or eliminating the loading of legacy IHg in the South River in a stepwise manner, beginning with source controls at the former DuPont facility, will result in improvements in and downstream of that segment. Further, due to the finding that loading of mercury to the South River is also linked to its transfer into the terrestrial food web, it is expected that reducing loading to the aquatic portion (South River) will not only reduce impacts in the river but will also result in reduced transfer to the semi-aquatic and terrestrial food webs. Efforts to identify approaches to address mercury in the floodplain and terrestrial food web are underway through the collaborative efforts of the SRST, and will be pursued in parallel with the implementation of this Remediation Proposal (see Section 1.3.1).

Following completion of source controls at the former Waynesboro facility, the first segment of the South River to be addressed by Phase 1 of this Remediation Proposal includes bank soils and in-channel sediments located immediately adjacent to, and downstream of, the former DuPont Waynesboro facility. As discussed in more detail in Section 2, this first segment includes eroding bank deposits that may transport legacy IHg 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 (see Section 2), as well as implementability, safety, and adaptive management considerations, targeting an initial Phase 1 remediation construction period of approximately 1 to 2 years.

However, as work progresses along the South River from upstream to downstream, and subject to the outcome of adaptive management decisions, it may be appropriate, in parallel with this approach, to advance remediation actions in certain areas out of sequence with the upstream-to-downstream remediation strategy. For example, riverbanks or floodplain areas with mercury concentrations that may pose a risk to humans and/or ecological health, as well as pilot tests of promising remediation technologies, may be addressed out of sequence.

In addition, ongoing monitoring may identify certain downstream banks that could contribute disproportionately large mercury loading to the South River. Such areas (e.g., a large mercury bank deposit in imminent danger of collapse) may also be addressed out of sequence. However, conducting most corrective action work sequentially through the river system will generally allow the work to be performed most safely and expeditiously.

1.3 Relationship to Other Actions

This Remediation Proposal is being conducted in parallel with other efforts that may have relevance for the scope of remediation actions. Ecological and human health risk assessments may identify other areas where remedial measures are necessary or that necessitate implementing remedies out of sequence. In addition, interim corrective actions performed at the former manufacturing facility may lead to improved source controls; it will be important to understand the effect of these actions on the short-term and long-term response of the South River. These actions are described in more detail in Section 1.3.2.

1.3.1 Ecological and Human Health Risk Assessments

The remediation for the aquatic portion of the South River, described in more detail in this Remediation Proposal, will run in parallel to ecological and off-site human health risk assessments. The results of these risk assessments may identify other potential sources of mercury or areas of elevated mercury concentrations in environmental media that will be addressed under the RCRA regulatory program and as part of the adaptive management process.

The ecological and human health risk assessments integrate physical, chemical, and biological data from the investigations conducted on the physical and biological media of the South River watershed. Consistent with USEPA guidance, the human health and ecological risk evaluations draw on accepted risk assessment concepts including planning, problem formulation, and the use of CSMs and research. The CSMs have been developed to address potential ecological and human exposure on-site at the Waynesboro facility as well as off-site along the South River and adjacent floodplains. These CSMs form the basis of the evaluation and are used to guide the development of the risk assessments.

The ecological risk assessment will characterize potential ecological risk to the range of ecological receptor types exposed to mercury in surface water, sediment, porewater, and soil in the South River. A screening-level evaluation of the data was performed in the Ecological Study, which identified mercury as the primary constituent of potential ecological concern (URS 2012b). A more in-depth ecological risk assessment will be performed under the oversight of VADEQ under the RCRA regulatory program. The ecological risk assessment will assess the risk to a wide range of ecological receptors via complete exposure pathways. The receptors and exposure pathways are shown in the preliminary ecological CSM (Figure 1-2). This model may be modified as a result of discussions with VADEQ. The potential risks will be determined by comparing the mercury dose received through the exposure pathways with conservative literature-derived benchmark doses, in consideration of South River-specific effects studies.

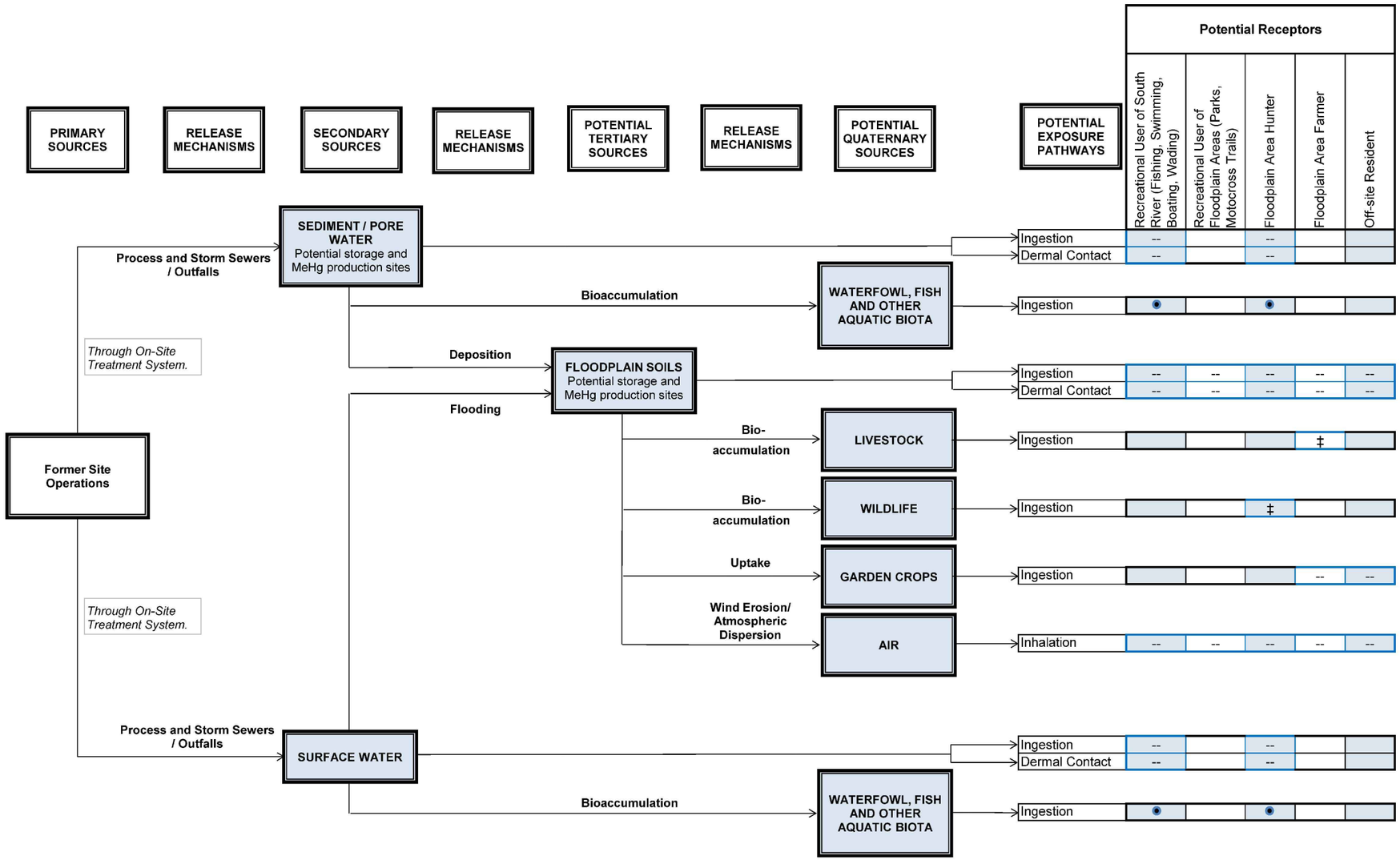
The human health assessment will focus on potential off-site exposures to mercury. On-site human health assessments are nearing completion through the RCRA process. Although the greatest potential for human exposure to mercury is through the consumption of fish tissue, several complete exposure pathways have been preliminarily identified; these are depicted in the CSM for exposure (Figure 1-1). These pathways include:

- Ingestion of livestock (e.g., beef)
- Ingestion of wildlife and small game (e.g., deer, muskrat, squirrel)
- Ingestion of waterfowl (ducks, geese), fish, and other animals (e.g., snapping turtles)
- Ingestion of garden crops grown on the floodplain
- Direct contact with floodplain soil, sediment, or surface water

The results of some of these analyses have been completed and published in peer-reviewed literature. For example, garden crops grown in the South River floodplain did not contain mercury concentrations at levels unsafe for human consumption (Berti et al. 2012). The other pathways will be evaluated following USEPA guidance under the oversight of VADEQ under the RCRA regulatory program.

The risk assessments may identify areas of unacceptable risks to ecological or human health that may require remediation actions. These areas could include media containing mercury concentrations that exceed risk-based criteria in floodplain soils, sediment, and/or dietary

items (for either humans or ecological receptors). As discussed above, such areas will be addressed under the RCRA regulatory program and as part of the adaptive management process.



Notes:

→ CONTAMINANT MIGRATION PATHWAY

-·→ LIMITED OR INSIGNIFICANT CONTAMINANT MIGRATION PATHWAY

● POTENTIALLY COMPLETE EXPOSURE PATHWAY

❍ SECONDARY EXPOSURE PATHWAY

-- EXPOSURE PATHWAY IS POTENTIALLY COMPLETE BUT INSIGNIFICANT

‡ EXPOSURE PATHWAY EVALUATION IS IN PROGRESS

BLANK = INCOMPLETE EXPOSURE PATHWAY

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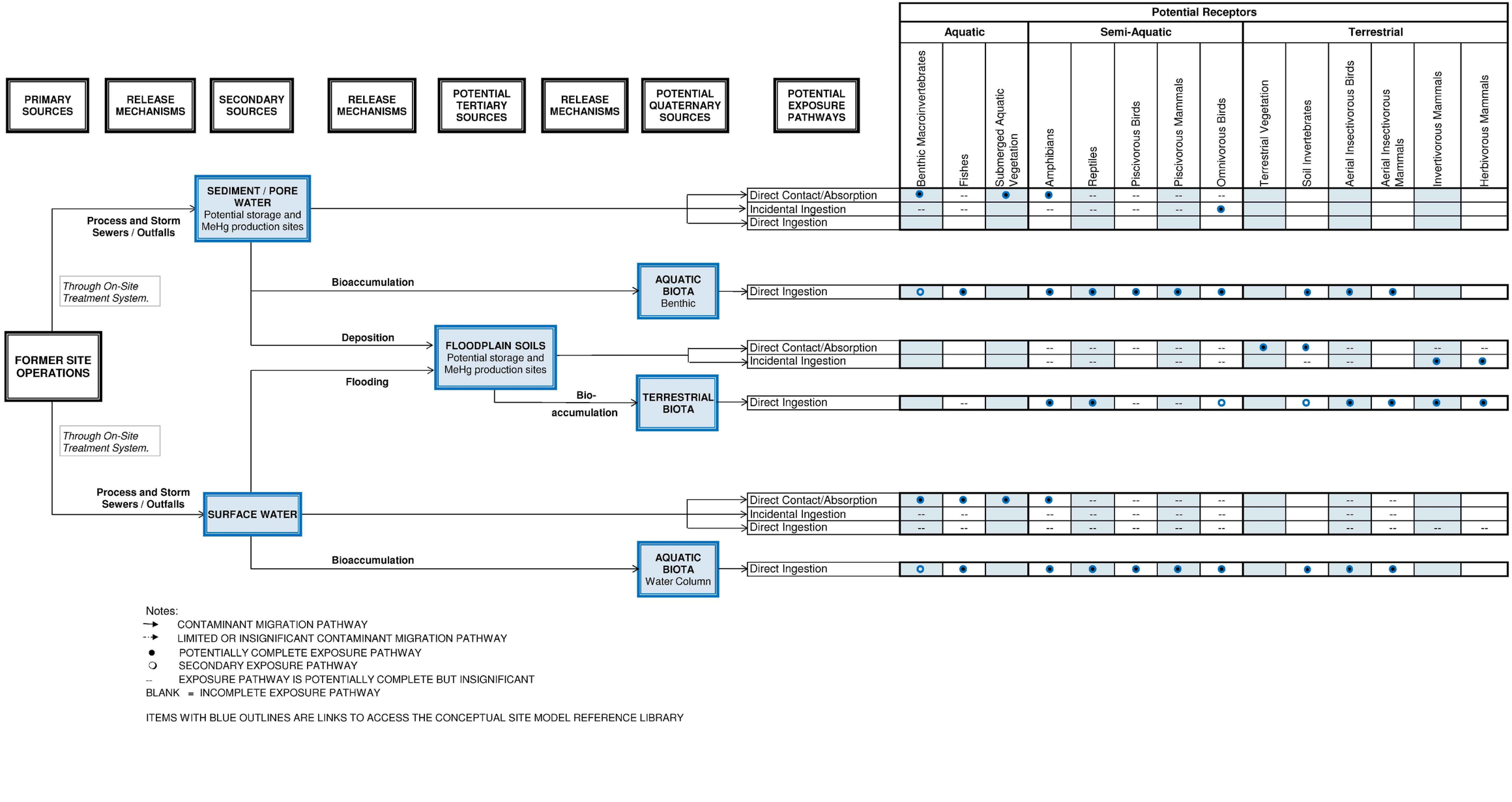
ANCHOR QEA URS

Figure 1-1
Human Health Conceptual Site Model
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River



Notes:

- → CONTAMINANT MIGRATION PATHWAY
- --→ LIMITED OR INSIGNIFICANT CONTAMINANT MIGRATION PATHWAY
- ● POTENTIALLY COMPLETE EXPOSURE PATHWAY
- ❍ SECONDARY EXPOSURE PATHWAY
- -- EXPOSURE PATHWAY IS POTENTIALLY COMPLETE BUT INSIGNIFICANT
- BLANK = INCOMPLETE EXPOSURE PATHWAY

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Figure 1-2
Ecological Exposure Conceptual Site Model
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

1.3.2 RCRA Corrective Actions at the Former Waynesboro Facility

In order to identify and characterize sources of contamination at the plant, DuPont conducted the RA/RFI under corrective action permit VAD003114832. The findings and recommendations of the RA/RFI, as submitted in the Comprehensive RFI Report (URS 2012a), identified the following three units for evaluation of corrective action alternatives in the CMS, which is currently under development:

- Former Mercury Recovery Area – Solid Waste Management Unit (SWMU) 1
- Former Incineration Area – SWMU 4
- Former Sludge Pond – SWMU 7

In addition, outfall discharges and groundwater beneath the former mercury area were identified for evaluation of corrective action alternatives in the CMS.

As part of the CMS for the former Waynesboro facility, DuPont is currently evaluating corrective action alternatives with input from VADEQ and USEPA to address remaining upland mercury sources at the facility, including impacted groundwater and mercury discharges in the plant outfalls. Until a final plan of corrective action is approved, DuPont is implementing interim corrective actions that have included cleaning impacted sewers and cutting off or removing drainage structures known to be conveying mercury to the sewer system. Additional interim measures will continue to be implemented at the former facility in conjunction with continued monitoring of groundwater and outfall discharges to ensure the effectiveness of corrective measures prior to implementing work in the river.

1.4 Mercury Remediation – Lessons Learned

This Remediation Proposal was developed in consideration of the difficulties experienced at other sites in successfully remediating mercury-impacted aquatic and terrestrial systems. These difficulties are largely due to the chemical nature of mercury and the complexity of mercury cycling. Several of these case histories are discussed in the following paragraphs and demonstrate the challenges and lessons learned for successful mercury remediation. It should also be noted that throughout the Ecological Study, and continuing today, DuPont and the SRST have routinely interacted with those groups undertaking investigation and remediation actions at other similar mercury cleanup sites (e.g., Oak Ridge National

Laboratory, Tennessee). Information and experience important to the development and potential implementation of this Remediation Proposal have been obtained in this manner and incorporated accordingly.

Mercury is a persistent contaminant; IHg does not degrade over time and is highly particle reactive; thus it accumulates in sediment and soil. The methylation of mercury by bacteria is a widespread process in the South River (Yu et al. 2011), and in other similar systems effective control of methylation has proven to be difficult. MeHg is much more readily bioaccumulated than IHg, such that small amounts of MeHg can lead to relatively high concentrations in biological tissue. For example, a study of more than 3,600 waterbodies in northeastern North America that receive mercury from atmospheric deposition found that 42% of yellow perch (*Perca flavescens*) in these systems had mercury concentrations greater than USEPA's fish tissue criterion for MeHg (0.3 micrograms per gram [µg/g] wet weight; Kamman et al. 2005).

Reviewing case studies of monitored natural recovery (MNR) from legacy mercury contamination reveals some important lessons for remediation efforts. In their comprehensive review, Munthe et al. (2007) found that although mercury in fish tissue is likely to decline after the control of mercury sources, the degree of recovery is highly site-specific and dependent on many factors, including how mercury originally entered the environment. In some systems where a single point source was responsible for mercury loading and completely remediated, there was often a rapid initial decline in tissue mercury concentrations followed by a longer period with lower rates of decline. There is some evidence that this has occurred in South River sediment; Skalak (2009) estimated that concentrations of total mercury (THg) in suspended sediment of the South River declined from approximately 1,200 µg/g during the peak release period (1929 to 1950) to approximately 10 to 30 µg/g observed today. Mercury concentrations in fish tissue were not characterized during the peak release period, so it is not known if fish tissue has undergone a similar recovery.

In some instances, rates of natural recovery have been accelerated by remediation, but were subsequently slowed by uncontrolled mercury loading sources. For example, an extensive mercury remediation project in Lavaca Bay (Texas), which included large-scale sediment

dredging and extraction and treatment of groundwater, resulted in smaller decreases in sediment mercury concentrations than predicted (USEPA 2011). The lower rate of decline has been attributed to ongoing mercury releases from sediment and soil in unremediated marshes and shorelines.

In addition to long recovery times, there are instances where other factors prevented a strong response in fish tissue after control of point source inputs. Mercury loading to the East Fork of Poplar Creek (Tennessee), a high-gradient stream generally similar to the South River, was reduced by approximately 80% between 1985 and 1996; however, mercury concentrations in fish did not decline and in some locations increased. The CSM developed for Poplar Creek suggests that changes in the chemical speciation of the mercury load enhanced the bioavailability of the mercury and prevented a decline in mercury methylation (Southworth et al. 2011).

Similarly, Onondaga Lake (New York) had no change in fish tissue concentrations after the original point source ceased discharging mercury, because of MeHg production from legacy sediment and geochemical characteristics of the lake (Effler 1996). However, recent increases in nitrate concentrations in the lake (through wastewater treatment upgrades and in-lake nitrate additions) have reduced MeHg production and resulted in declines in fish tissue mercury concentrations (Henry et al. 2013).

Some systems have responded positively to a cessation of sources and prolonged periods of natural recovery. In Bellingham Bay (Washington), reductions in mercury loading from a chlor-alkali facility in the 1970s and subsequent capping of secondary sources of contaminated sediment in 2000 and 2001, along with natural sedimentation and burial, led to reductions in surface sediment and crab tissue mercury concentrations, as well as reductions in sediment toxicity (Hilarides 2004). However, crab tissue MeHg concentrations did not begin declining until sediment IHg concentrations were reduced by more than 80%, when sediment IHg concentrations apparently began limiting MeHg production.

The case histories summarized above demonstrate some of the challenges and lessons learned for successful mercury remediation. A key finding is that methylation can convert relatively small amounts of IHg into MeHg, such that post-remediation fish concentrations often

remain above USEPA's tissue criterion for MeHg (0.3 µg/g wet weight). In addition, recovery from even a single point source may take decades, and the response to the mercury load reduction is highly site-specific. This may be particularly relevant to the South River, where there does not appear to be any readily identifiable discrete points of mercury loading or methylation other than the quantified, limited loading from the former facility. As a result, it is not clear what shape the recovery curve will take for the South River once this Remediation Proposal is implemented.

1.5 USEPA Contaminated Sediment Remediation Guidance

As discussed in more detail in Sections 2 and 3, bank soils represent a primary source of mercury to the South River and a portion of the SFS River. As such, this medium is prioritized in the risk management strategy described in this Remediation Proposal. USEPA's risk management principles were developed to provide guidance to managers in "making scientifically sound and nationally consistent risk management decisions at contaminated sediment sites" (USEPA 2002). While the risk management principles should be applied to all contaminated sediment sites, their "implementation at particular sites should be tailored to the size and complexity of the site, to the magnitude of site risks, and to the type of action contemplated." The USEPA principles apply to actions conducted under both the RCRA and CERCLA regulatory programs, and are equally relevant to bank soils and in-channel sediment in the South River and a portion of the SFS River. The following list briefly summarizes the 11 USEPA (2002) principles (*in italics*) and how they have been integrated into this Remediation Proposal:

1. *Control sources early* – All sediment and bank soil remediation actions included in this Remediation Proposal will be appropriately coordinated with the upstream source controls summarized in Section 1.3.2. Timely control of mercury sources from the Waynesboro plant has been the highest priority to date.
2. *Involve the community early and often* – Coordinated through the SRST, extensive community relations activities have been conducted to date to keep the local community informed and provide a mechanism for comments. Increased engagement with City of Waynesboro officials and local residents will occur during the design of Phase 1 corrective actions, including coordination with the City's goals and objectives for land use and development along the river corridor.

3. *Coordinate with states, local governments, tribes, and natural resource trustees* – Composed of representatives from the state and federal government, local academic institutions, and environmental groups, the SRST continues to be a central organization where studies on the South River and a portion of the SFS River are designed and implemented and results are analyzed and discussed, and through which communications are made both locally at the community level and nationally through scientific professional societies.
4. *Develop and refine a CSM that considers sediment stability* – As discussed in Sections 2 and 3, and described in more detail in the Ecological Study (URS 2012b), a CSM for the South River and SFS River aquatic system (i.e., banks and in-channel areas) has been developed based on a substantial data set generated from site-specific studies coordinated by the SRST. The extensive modeling and monitoring work conducted on the river provides a cohesive weight of evidence with regard to sediment and bank soil characteristics.
5. *Use an iterative approach in a risk-based framework* – As discussed in more detail in Sections 1.6 and 4.3.4, an adaptive management approach is appropriately incorporated into this Remediation Proposal. In addition, as discussed in Section 1.3.1, human health and ecological health risk assessments are being performed in parallel to this Remediation Proposal to provide input to identify remediation targets. Multiple pilot-scale studies have also been conducted in an effort to evaluate remediation technologies and make progress in remediation of the river. These pilot studies have provided valuable site-specific information.
6. *Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models* – As discussed in detail in the Ecological Study (URS 2012b), targeted data collection efforts have been used throughout the project to reduce uncertainty tied to both the CSM and the nature and extent of contamination.
7. *Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals* – This Remediation Proposal presents the results of the analysis of site-specific data, National Contingency Plan (NCP; 40 Code of Federal Regulations [CFR] 300.5) evaluation criteria, RAOs, and potential remediation alternatives. The recommended remedy (discussed in Section 6) was identified considering the most effective and efficient means by which to achieve risk-based goals while minimizing short-term impacts.

8. *Ensure that sediment cleanup levels are clearly tied to risk management goals* – Site-specific RAOs were developed to protect human and ecological receptors. Metrics tied to these RAOs were then used to evaluate potential remediation alternatives. As discussed in Section 1.3.1, human health and ecological health risk assessments are being performed in parallel to this Remediation Proposal to identify remediation targets.
9. *Maximize the effectiveness of institutional controls and recognize their limitations* – Institutional controls (i.e., fish consumption advisories) have been in place for the South River and SFS River since 1977 and would be maintained as part of the recommended remedy as long as necessary. An active outreach campaign to inform local English-speaking and non-English-speaking residents of the fish consumption advisory has been established, including Promotores de Salud, a public health program for the Hispanic community.
10. *Design remedies to minimize short-term risks while achieving long-term protection* – This Remediation Proposal evaluates short-term and long-term risks associated with each remediation alternative. The recommended remedy (identified in Section 6) is expected to provide the fewest short-term risks while achieving long-term protection.
11. *Monitor during and after sediment remediation to assess and document remedy effectiveness* – Monitoring during and following remediation, adaptive management, and long-term monitoring are all key elements of the recommended remedy (identified in Section 6).

The 11 risk management principles outlined above were expanded in USEPA's subsequent *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005). As with the USEPA (2002) risk management principles, the subsequent 2005 guidance is relevant both to bank soils and in-channel sediments within the South River and a portion of the SFS River. This guidance document embodies national USEPA policy on contaminated sediment, the focus of which is to reduce risks to human health and the environment posed by contaminated sediment sites. It also provides a risk management decision-making framework to assist with selecting appropriate remedies. There are six key principles in the 2005 guidance document, as outlined below.

First, and foremost, the focus of remediation should be on risk reduction, not simply on contaminant mass removal (USEPA 2005). This principle is based on the consideration that soils and contaminated sediment that are not bioavailable or bioaccessible and are reasonably stable—meaning that the contaminants are unlikely to be released from the sediment or bank soils in amounts that would contribute to unacceptable risk to human health and the environment—do not necessarily contribute to site risks. Mass removal, therefore, does not equal risk reduction (NRC 2007).

Second, a realistic, site-specific evaluation of the potential effectiveness of each sediment and bank soil management option, including removal, capping, in situ treatment, and MNR, should be incorporated into the selection of remedies at a site (USEPA 2005). The extensive series of pilot studies and related investigations conducted in the South River and discussed in the Ecological Study (URS 2012b) are consistent with this principle.

Third, as part of the remedy selection process, an appropriate evaluation of the comparative net risk reduction potential of the various management options, including a realistic evaluation of their respective advantages and site-specific limitations, should be conducted (USEPA 2005). This includes the risks introduced by implementing the remediation alternatives. Comparative net risk reduction will be addressed through the application of adaptive management (see Section 4.3.4), along with the relative risk modeling currently being performed by the SRST (see Section 3.1.1). These tools are expected to provide quantitative feedback on net risk reduction and net overall improvements (e.g., improved water quality and habitat functions) resulting from remediation actions.

Fourth, at large or complex sites, consideration of combinations of remedies may be appropriate (USEPA 2005). The recommended remedy for the South River (described in Section 6) is consistent with the combination remedy approach by combining source control, bank stabilization for bank soils, and in-channel MNR for sediments. The possibility of adding focused removals and an in situ treatment option represent additional remediation components.

Fifth, adaptive management concepts, which involve a stepwise approach to the implementation of remediation, should be applied (USEPA 2005). For the South River and a

portion of the SFS River, adaptive management has been utilized to date in the form of the pilot studies, and will be used going forward in an adaptive management approach (see Sections 1.6 and 4.3.4). As noted earlier, the adaptive management approach will be coupled with the relative risk model to provide quantitative feedback on the effectiveness of remediation actions to adjust future remedy decisions as part of an iterative learning process.

Sixth, comparing and contrasting the costs and benefits of the various remedies is part of the risk management decision-making framework (USEPA 2005). The analysis of risk reduction benefits versus project costs for the South River is provided in the comparative analysis of alternatives in Section 5.

The guidance concludes that these six principles, if applied appropriately, would lead to protective remedies that are also cost-effective and consistent with the NCP.

1.6 Adaptive Management Approach

Because of the South River's size and complexity, the inherent uncertainty associated with mercury cycling in this river system, and challenges noted from remediation of other mercury sites (Section 1.4), an adaptive management approach for implementing remedial measures has been integrated into this Remediation Proposal. 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. It has been used successfully in a range of natural resource management applications where there are significant uncertainties in the effectiveness, implementability, or cost of the alternative actions. The overall adaptive management objective is to develop a flexible decision-making process that can be adjusted as remediation action outcomes are better understood and as landowner and other stakeholder preferences are identified and possibly change over time.

Adaptive management promotes flexible decision-making in the face of uncertainty. It allows the identification of the most robust course of action, given a range of scenarios under consideration. Careful monitoring of the outcome of implemented actions advances understanding and helps adjust future remedy decisions as part of an iterative learning

process. 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
- An understanding of the processes and drivers that impact those objectives
- A range of potentially viable remediation alternatives
- Monitoring of key performance metrics

Adaptive management is particularly well suited to this Remediation Proposal, in part because remedial measures will be implemented sequentially over the next 5 to 10 years or more, providing an opportunity to effectively integrate lessons learned. It will facilitate testing and monitoring remediation actions, particularly where there is a need to assess effectiveness prior to undertaking additional actions, as is the situation on the South River. Where actions do not result in measureable improvements, changes in technologies or applications may be required. Implementation of corrective actions in the South River will also require landowner acceptance and flexibility to consider other stakeholder needs. Although the priorities and values of different landowners and other stakeholders can be considered through their reviews of suggested approaches, they can also be directly incorporated into the evaluation of remediation options.

Use of the adaptive management learning approach, described in more detail in Section 4.3.4, along with relative risk modeling currently being performed by the SRST (see Section 3.1.1), is expected to provide quantitative feedback on net environmental improvements resulting from implementation of remedial measures, providing benefits to this Remediation Proposal.

1.7 Remediation Proposal Organization

Subsequent sections of this Remediation Proposal are organized as follows:

- Section 2 – South River Characteristics
- Section 3 – Basis for Remediation
- Section 4 – Phase 1 Remediation Alternatives
- Section 5 – Phase 1 Remediation Alternative Evaluation Criteria

- Section 6 – South River Remediation Proposal
- Section 7 – Preliminary Monitoring and Community Outreach Plan
- Section 8 – Implementation and Management
- Section 9 – References

The following appendices are attached to this Remediation Proposal:

- Appendix A – Bank Stabilization Pilot and Treatment Pilot Technical Briefing Papers
- Appendix B – Integrating Green and Sustainable Remediation Practices
- Appendix C – 2012 and 2013 Bank Sampling Data
- Appendix D – Monitoring Protocols

2 SOUTH RIVER CHARACTERISTICS

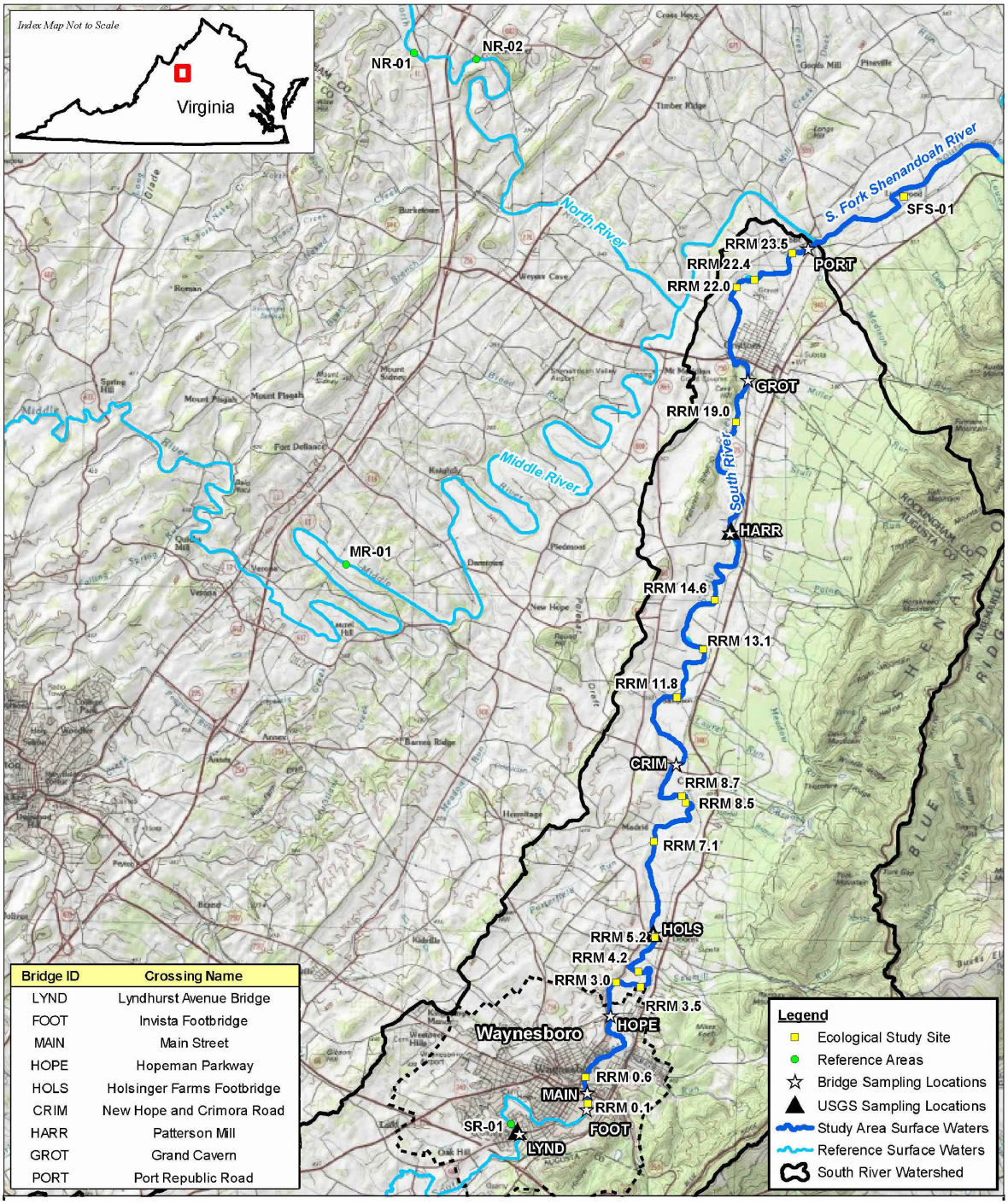
Sections 2.1 through 2.5 describe the physical, geologic and geomorphological, chemical, and biological characteristics of the South River, summarizing the findings of the Ecological Study (more detailed discussion of this information is provided in URS 2012b). Although a portion of the SFS River is also included in the Consent Decree and this Remediation Proposal, the phased nature of the planned remediation necessitates an initial focus on the upper segment of the South River (i.e., RRMs 0 to 2; RRMs 2 to 4, etc., see below). The features of the lower segment of the South River and a portion of the SFS River are discussed in Section 2.6.

2.1 Physical Location and Features

The South River is located in the Blue Ridge Mountains of the Appalachian chain. It is a fourth-order, high-gradient, cool-water, gravel-bed bedrock river (Turowski et al. 2008), and joins the North River at Port Republic to form the SFS River (Figure 2-1). The South River has drainage basin areas of approximately 127 square miles (mi^2) at Waynesboro, Virginia, and 212 mi^2 at Harriston, Virginia (USGS 2007; Figure 2-1). Although several tributaries join the South River throughout its length, these tributaries are generally first-order streams and most are intermittent during periods of low precipitation.

The bed of the South River is primarily composed of boulders, cobbles, and gravel, with frequent bedrock exposures along the channel perimeter. Pools and riffles are typical features of the longitudinal profile of the channel, as are long pools created by bedrock exposures and coarse-grained tributary confluence bars. Between RRMs 0 and 12, approximately 13% of the total stream bed area is composed of relatively fine-grained sediments (silts, clays, or fine sands; URS 2012b). The bankfull width of the channel ranges between approximately 60 and 100 feet, and the bankfull depth is approximately 6 to 10 feet.

The South River mostly flows through pastures and farm fields with a narrow border of trees along the banks, although riparian forests cover some areas of the South River valley. The current land use composition of the watershed is approximately 33% agricultural, 56% forested, and 11% developed. Wetlands cover only 0.01% of the watershed, less than the coverage of open water (0.6%) or barren lands (0.05%; Fry et al. 2009).



SOURCE: USGS Quad 100k Topo Quad.

NOTE: RRM = Relative River Mile

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Figure 2-1
Sampling Locations Overview Map
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

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2.2 Geologic and Geomorphological Characteristics

The South River between Waynesboro and Port Republic can be described as three relatively distinct reaches with different geomorphic characteristics and distributions of mercury concentrations (Figure 2-2). Mercury distributions within the South River are briefly summarized below; mercury concentration data are discussed in more detail in Section 2.3 and in the Ecological Study (URS 2012b).

2.2.1 Geologic and Geomorphological Characteristics: RRMs 0 to 3

The first geomorphologic reach of the South River below the former DuPont Waynesboro facility extends from approximately RRMs 0 to 3 and incorporates the region around the facility and the city of Waynesboro. This reach is characterized by a narrow floodplain and low percentage of fine-grained sediment deposits, owing to the steeper slope of the river. However, the downstream portion of this reach (approximately RRMs 2.3 to 3) has a higher percentage of fine-grained sediment in the channel margins. Land uses in this area are primarily developed. This reach receives mercury loads from the upstream watershed and the outfalls at the former DuPont Waynesboro facility. The concentrations of mercury in floodplain and riverbank soils are higher in this area compared with other reaches of the South River. Based on comprehensive sampling of the South River, THg concentrations in floodplain soils generally decline with distance downstream of the former facility (URS 2012b). In the vicinity of the former facility, mercury concentrations in surface water and sediment are relatively low in comparison with downstream reaches of the South River due to dilution by upstream inputs, except for sediment in locations adjacent to eroding banks. In this reach, the concentrations of mercury in all media increase with distance downstream of the former facility.

2.2.2 Geologic and Geomorphological Characteristics: RRMs 3 to 12

The second geomorphologic reach is located between approximately RRMs 3 and 12 and is characterized by a series of low-gradient pools. Surrounding land uses are primarily pasture and agricultural.

Compared to other reaches of the South River, a higher proportion of eroding banks with elevated mercury concentrations occur along this reach, and areas of fine-grained sediment

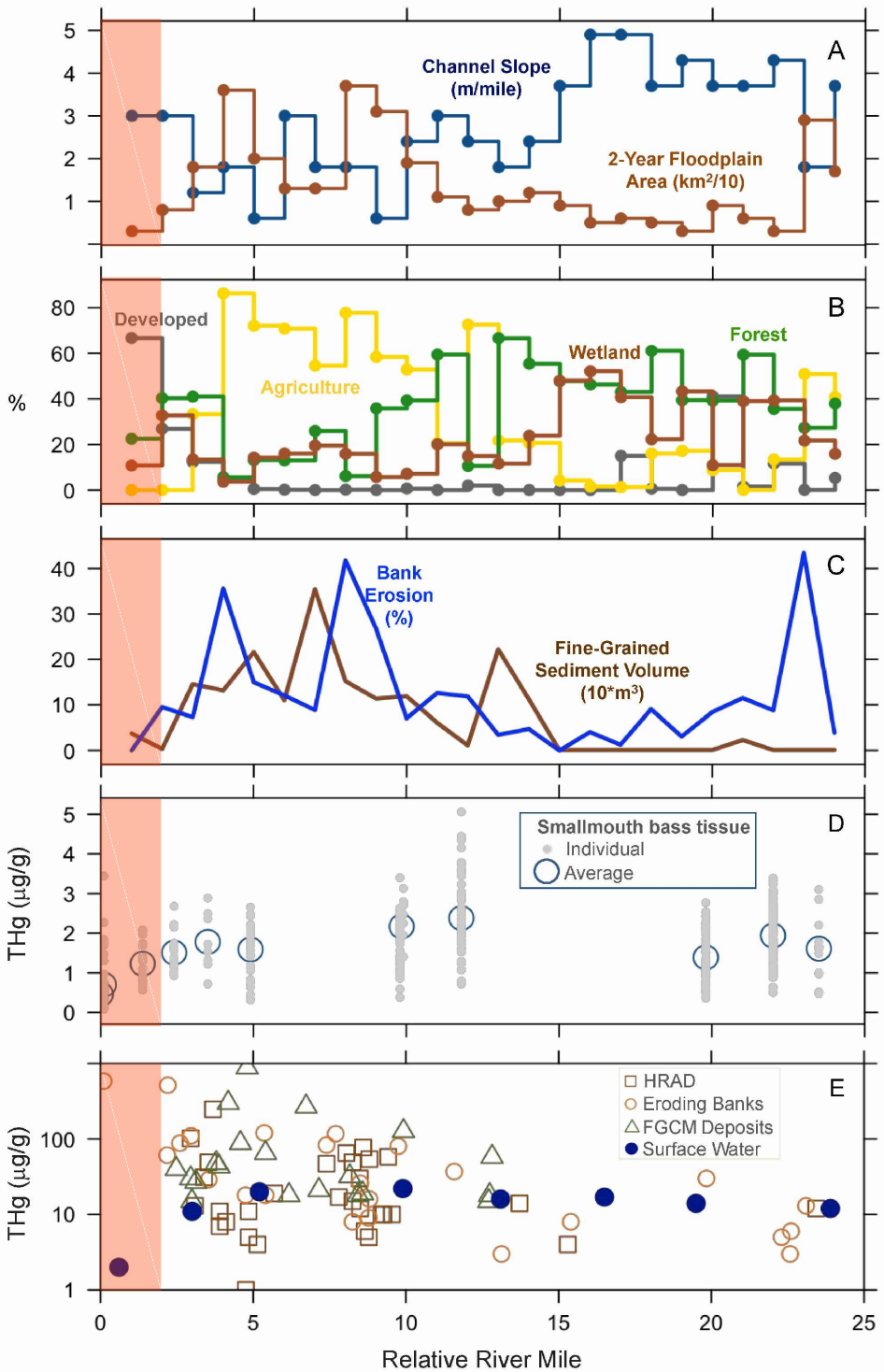
deposits occur on the channel margins, particularly behind downed trees (URS 2012b). In addition to the erosion of floodplain soils, other potentially important sources of mercury to the river are found in this reach. Historic near-channel deposits, referred to as "Hg-release age deposits" (HRADs), may contain soils with elevated concentrations of mercury deposited from 1929 to 1950 when mercury was in use at the facility. Fine-grained channel margin (FGCM) deposits also serve as areas of THg storage and release to the river water column through resuspension and diffusion. Geomorphic characterization of these features as well as in-river storage areas of FGCM deposits indicate that the majority of HRADs, eroding alluvial riverbanks, and FGCM deposits are located in the upper 10 to 12 miles of the South River.

The concentrations of mercury in physical and biological media in this reach generally increase linearly with distance. Incremental loading rates for THg and MeHg are highest in this reach (Flanders et al. 2010; Hydroqual 2009). Surface water samples collected over short distance intervals in this reach showed steady increases in THg concentrations with increasing distance downstream, suggesting a diffuse primary source (Turner and Jensen 2005).

2.2.3 Geologic and Geomorphological Characteristics: RRMs 12 to 25

The third geomorphologic reach includes the remainder of the South River, from RRM 12 to the confluence with the North River at RRM 25. In addition, this reach includes the upper segment of the SFS River that is the northern boundary of the Ecological Study Area as noted in the Consent Decree. The slope of the river is higher in this area, and there are few, if any, fine-grained sediment deposits. This reach is characterized by relatively higher concentrations of THg and MeHg in surface water (i.e., similar to or higher than in the reach immediately upstream), but declining concentrations in sediment and soil. The 2-year floodplain in this reach is mostly forested. Although the South River watershed in general has few wetlands (Section 2.1), this reach has a relatively higher proportion of wetlands. This is due to the classification of several segments of the river channel as riverine wetlands and the presence of many small palustrine, forested wetlands in the 2-year floodplain (USFWS 2012). Although bank erosion rates are relatively high in this reach, soil concentrations are lower than in the first two reaches. Incremental loading rates of IHg in this reach tend to be relatively low in comparison with the other two remediation reaches,

suggesting that there are few active sources of IHg in this reach (Flanders et al. 2010). However, the concentrations of MeHg in sediment, surface water, and aquatic biota (e.g., fish) in this reach are often the highest measured in the South River (URS 2012b). This suggests that while loading of mercury is concentrated in the first 10 to 12 miles of the South River, methylation of mercury is a widespread process in the South River and transport of IHg from upstream sources can support the methylation process.



Note: Selected results of the habitat stratification process showing the different characteristics of three reaches of the South River. (A) Channel slope (the change in elevation in meters per river mile) and area of the floodplain (km^2/10). (B) The percent coverage of land use within the 2-year floodplain. (C) The percent of river banks observed to be eroding and the volume of fine-grained sediment deposits ($10*m^3$). (D) The concentration of THg in smallmouth bass, reported as wet weight. (E) The concentrations of THg in historic release age deposits (HRAD), eroding bank soils, fine-grained channel margin deposits (FGCM) and on particles in surface water (THg_P), in units of dry weight.

Prospective Phase 1 Remediation Area (RRM 0 to 2; see text)

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Figure 2-2
Habitat Stratification Metrics
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

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2.3 Mercury Concentration Distributions

2.3.1 Floodplain Soils

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 2012b) 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 2- and 5-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

Field-based, tributary loading studies conducted during storm events in the Ecological Study show that runoff from the floodplain is a relatively small source of THg and MeHg to the South River (URS 2012b). In addition, the South River mercury total maximum daily loading (TMDL) study (Eggleston 2009) found that the floodplain runoff accounts for a relatively small portion of the THg load. Likewise, low THg concentrations in alluvial groundwater samples collected from the floodplain do not indicate that groundwater is a major source. However, other interactions between water and floodplain soil (e.g., erosion and leaching) are important sources of THg (URS 2012b).

The floodplain may have areas of elevated THg exposure to terrestrial ecological receptors, which is currently being evaluated as part of an ongoing ecological risk assessment. The results of the ongoing risk assessment (see Section 1.3.1) may necessitate consideration of additional ecological-based RAOs as part of the adaptive management process.

Groundwater provides a potential transport pathway for mercury from floodplain soils to the South River. There are three categories of groundwater flow: regional groundwater flow through bedrock, groundwater flow through alluvial (floodplain) soil, and localized groundwater-surface water interactions in the hyporheic zone (Hinkle and Sterrett 1978).

The groundwater contribution (encompassing both alluvial groundwater flow and bedrock flow) to the flow volume in the South River is estimated to range from 25% to 70% (Grosso 2006) and varies seasonally. A number of groundwater quality studies have been conducted within the South River that show low concentrations of dissolved mercury in groundwater. Based on these studies, mercury loading from alluvial groundwater appears to contribute less than 2% of the mercury loading to the river.

While alluvial groundwater does not account for material loading, near-bank HRADs may be more susceptible to mercury leaching owing to the dynamic nature of stream hydraulics and the soil chemistry of the HRADs. Currently, a study is being conducted by the University of Delaware with support from the University of Texas at Austin and the University of Waterloo. The primary goal of this study is to investigate the processes that govern biogeochemical transformation and mobilization of mercury from HRADs in the form of colloidal or dissolved IHg that may result in material loading of mercury to the river, potentially through the hyporheic zone adjacent to the bank. The results of this study will be used to refine the CSM as part of the adaptive management process (see Section 4.3.4).

2.3.2 Bank Soils

Bank deposits include soils and sediments that have been deposited on the riverbank that vary in mercury concentration and HRADs, which are areas of higher mercury concentrations. A large data set has been developed for the South River, detailing mercury concentrations in eroding bank soils. A total of 207 riverbank transects have been sampled from RRMs 0.1 to 23.5. The vertically averaged THg concentration in the riverbank transects range from approximately 0.08 to 270 µg/g.

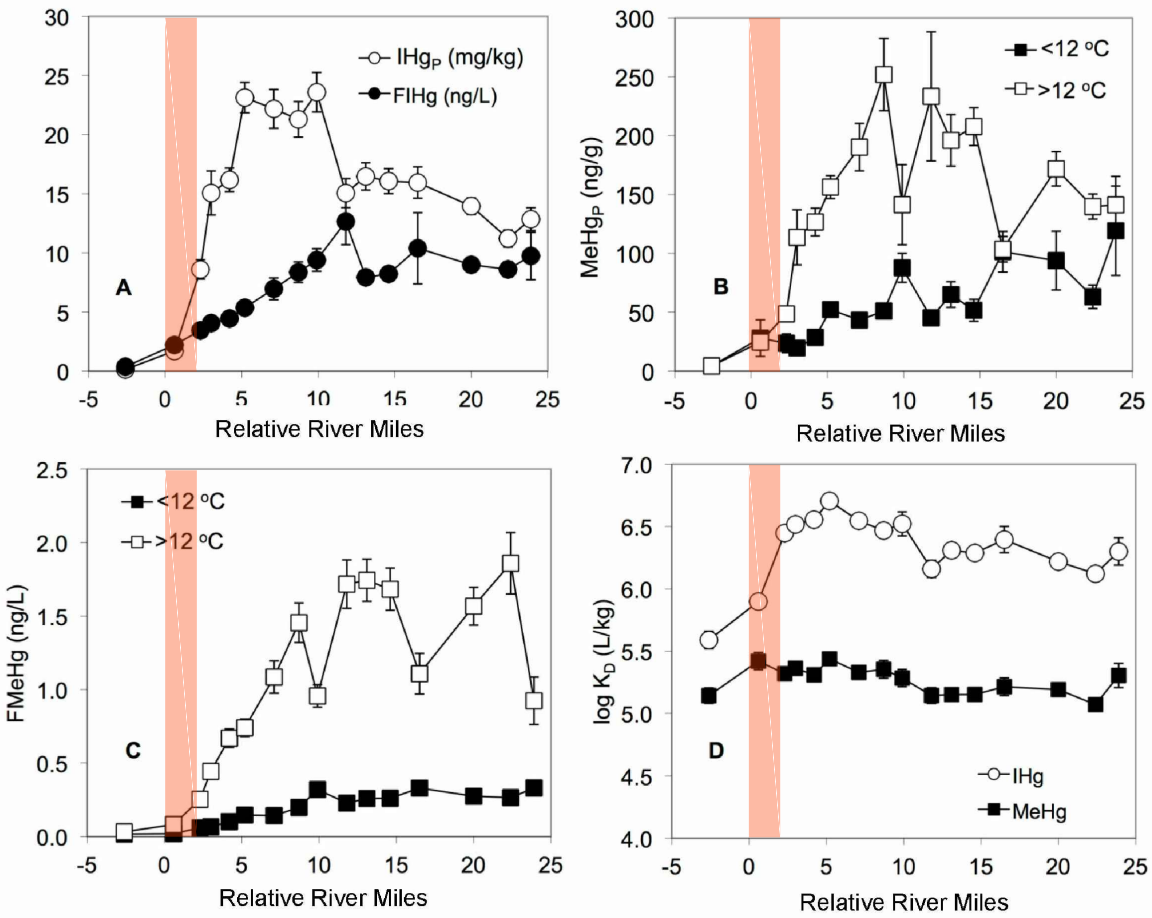
As discussed above, HRADs are near-channel deposits that contain mercury that was released from the facility during the time of mercury use (from 1929 to 1950). HRADs are found throughout the South River. A total of 47 of these deposits have been delineated between RRMs 0.1 and 23.9, but the majority (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 (ten 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 and 270 µg/g.

2.3.3 Surface Water

Under baseline flow (i.e., non-storm) conditions as defined in URS 2012b, 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 (Figure 2-3). Particulate IHg concentrations remain somewhat constant (approximately 25 µg/g) until they decline at approximately RRM 12. This suggests that particulate IHg is being diluted by cleaner solids from soils in the reach between RRMs 12 and 25. Dissolved (filter-passing) IHg concentrations in surface water of the South River increase from RRM 0 to approximately RRM 12.

The areas with the highest surface water MeHg concentrations tend to be more widely dispersed (Figure 2-2), 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 degrees Celsius (°C) (Figure 2-3); concentrations do not necessarily increase with temperature throughout the late summer (URS 2012b). 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 former facility (Figure 2-4).



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 (IHg_P, 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 ($MeHg_P$, 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 (K_D; Panel D) for IHg and MeHg.

Prospective Phase 1 Remediation Area (RRM 0 to 2; see text)

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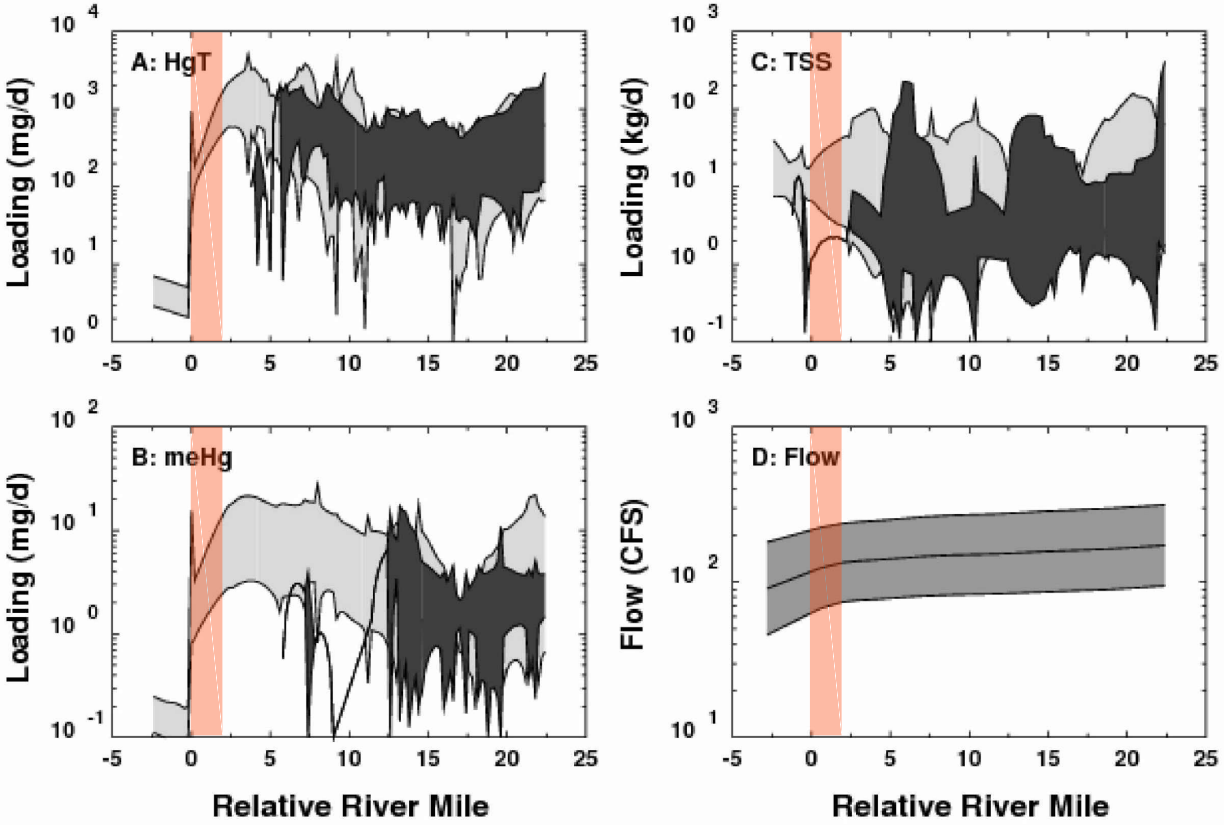
Figure 2-3
Mercury Concentrations in Surface Water
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River



Spatial profiles of incremental loads of HgT (A), meHg (B), and TSS (C) to the water column at low flow. Light shaded polygons are positive incremental loads and dark shaded areas are negative loads. The range of the polygon represents one standard deviation across all months that were evaluated in this study. The flow (D) is plotted as the median and one standard deviation for all months included in this analysis.

Prospective Phase 1 Remediation Area (RRM 0 to 2; see text)

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Figure 2-4
Incremental Mercury Loading to the South River - HydroQual (unpublished)
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

2.3.4 In-Channel Sediments

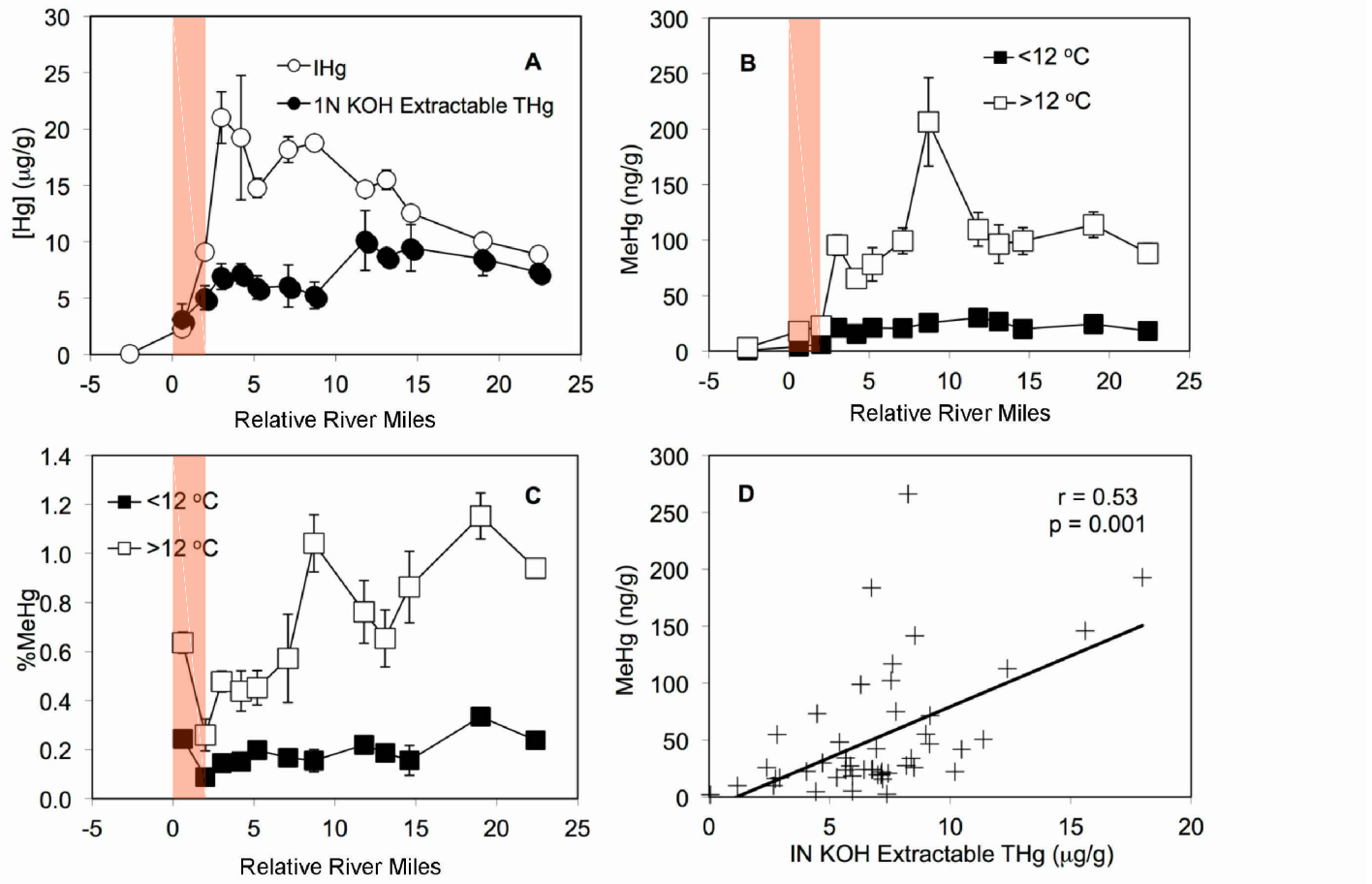
In the South River, fine-grained sediment occurs primarily in FGCM deposits and as interstitial sediment within the coarser substrates of the stream bed. The areal extent of FGCM deposits is much smaller than the coarse-grained stream bed and is generally restricted to low-velocity areas near the channel margins and downstream of obstructions in some discrete river segments.

THg concentrations are highly variable in FGCM deposits, ranging from approximately 0.1 to 880 µg/g (URS 2012b). Higher THg concentrations in FGCM deposits are found at depth, buried below fine sediment with more moderate concentrations in the range of tens of µg/g. The concentrations of IHg in interstitial sediment increase rapidly between RRMs 0 and 8.7 reaching a maximum of around 30 µg/g before declining farther downstream (Figure 2-5).

Concentrations of IHg in interstitial sediment have been relatively consistent over the period of study (URS 2012b). Areas with higher MeHg concentration 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°C (Figure 2-5). 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 (Figure 2-5, Panel C). The %MeHg data also suggest that methylation occurs in the interstitial sediment at all stations between RRM 0 and RRM 25.

Further sediment sampling was conducted in the full range of sediment environments in the South River to determine if any served as methylation 'hot spots.' Samples were collected on a bimonthly basis from floodplain wetlands, millraces, FGCM deposits, embedded gravels, and less embedded toe-of-pool areas that were sampled in Phase 1 (Figure 2-5). FGCM deposits and gravels embedded with fine-grained sediment generally contained higher MeHg concentrations than other sediment types, including floodplain wetlands. The results were reported in Table 4-2 of the Ecological Study report (URS 2012b). Similarly, the %MeHg was highest in FGCM deposits, embedded gravels, and the toe-of-pool areas. The areas with wetland or backwater characteristics consistently had lower MeHg concentrations and %MeHg.

The finding that methylation is not confined to certain areas or sediment environments in the South River was further supported by the work of Yu et al. (2011). This study used radiolabeled THg to measure mercury methylation potential and used genetic techniques to identify potential methylating bacteria sediment. Sediment samples were collected from the range of sediment types described above. The potential for mercury methylation was highest in FGCM deposits and embedded substrates, but positive net methylation rates were observed in all sediment samples tested from the South River. A diverse group of iron- and sulfate-reducing bacteria capable of mercury methylation were identified in South River sediment, suggesting that mercury can be methylated under a variety of geochemical conditions.



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).

Prospective Phase 1 Remediation Area (RRM 0 to 2; see text)

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Figure 2-5
Mercury Concentrations in Channel Sediment
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

2.3.5 Biological Tissues

Extensive sampling and analysis of biological tissues across the range of trophic levels has been performed in the South River, including a variety of fish and shellfish, benthic invertebrates, and periphyton (URS 2012b). This section focuses on the distribution of mercury concentrations in two key species of the South River system at different trophic levels: smallmouth bass (*Micropterus dolomieui*) and Asiatic clam (*Corbicula fluminea*), as well as in periphyton. Additional discussion of biological tissue monitoring is provided in Section 7.

Smallmouth bass are an important local sport fish (catch and release). Because they are a high trophic level piscivore, bass generally have high THg concentrations compared with other fish species. THg concentrations in smallmouth bass are highest in the reach between RRMs 6 and 13 (Figure 2-6).

Asiatic clam is an invasive bivalve species of the South River that has proven useful for monitoring relatively small-scale spatial patterns and also temporal trends, including the effectiveness of source control actions at the former Waynesboro facility and the bank stabilization field pilot demonstration (see Section 4.3.1). Resident Asiatic clams have been collected from within the surface of embedded gravels and analyzed for THg and MeHg (Figure 2-7). Concentrations of THg and MeHg in resident Asiatic clam tissue increase rapidly between RRMs 0 and 5, consistent with increases in mercury concentrations in surface water, sediment, and porewater. A summary of the results of Asiatic clam tissue analyses for the bank stabilization pilot project is provided in Appendix A.

The results of Asiatic clam tissue analyses performed for the pilot project show promise in the use of these organisms for future monitoring of the aquatic system. Although there is considerable variability in THg and MeHg concentrations in resident Asiatic clam tissue throughout the river system, transplanted Asiatic clams deployed in specific habitats to measure mercury uptake show reduced variability in tissue concentrations, resulting in a more robust monitoring tool to inform adaptive management remediation decision-making.

Since periphyton is the base of the South River aquatic food web, mercury uptake by periphyton is also the primary linkage between abiotic mercury and biotic mercury.

Tom et al. (2010) demonstrated that mercury levels in South River biota from periphyton to top predators fit trophic models for biomagnification. Moreover, Brent (2010) demonstrated that MeHg accumulation in periphyton can provide a rapid indicator of changes in MeHg uptake in the South River. Thus, periphyton sampling may also provide a useful performance monitoring tool to inform adaptive management remediation decision-making.

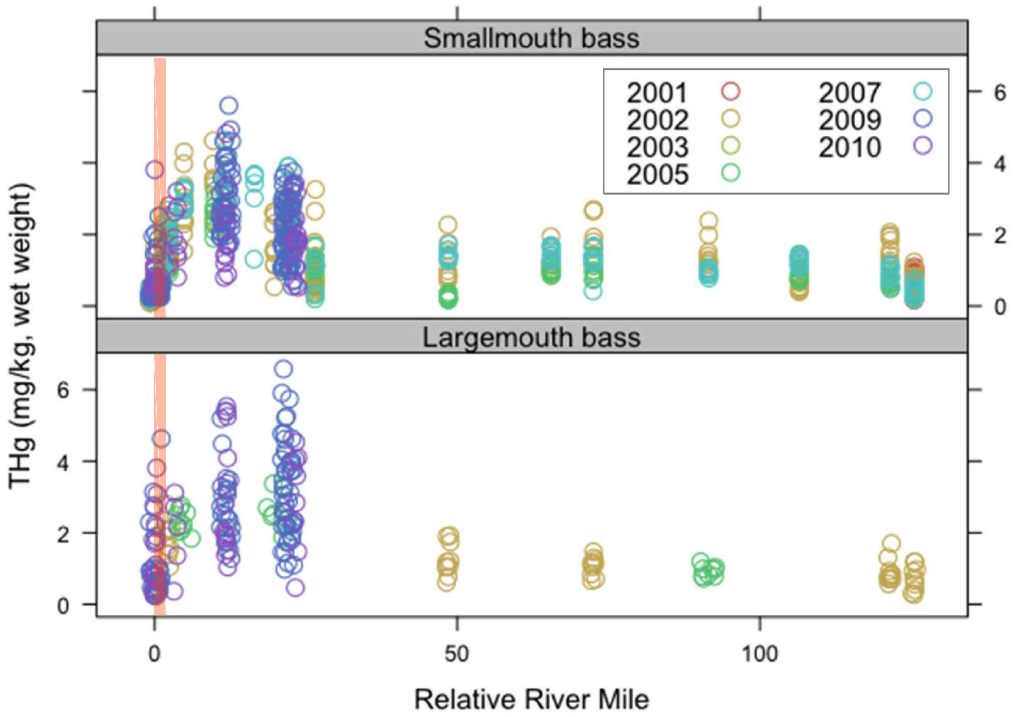

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Figure 2-6
Mercury Concentrations in Fish Tissue
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

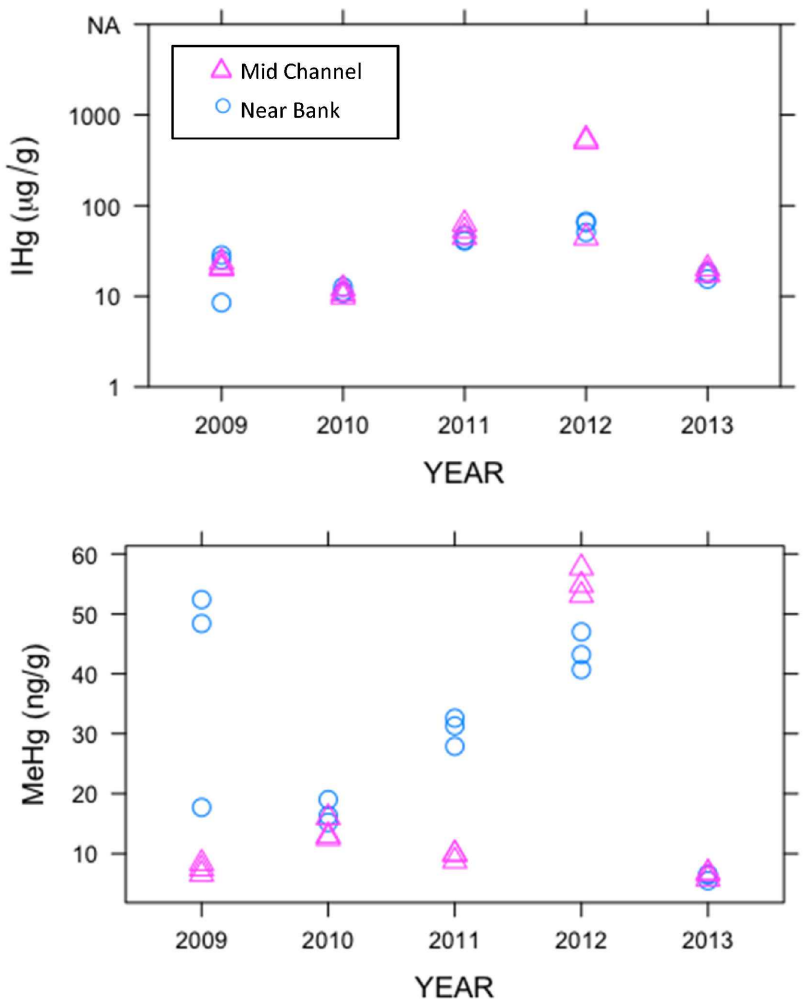


Figure 2-7
Mercury Concentrations in Corbicula Tissue
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

2.4 Sediment and Mercury Transport

Because mercury is strongly adsorbed to suspended organic matter in aquatic systems (Meili 1997; Gill and Bruland 1990), the transport and storage of organic material is an important variable controlling mercury cycling in aquatic systems. Detailed sediment and mercury transport analyses of the South River are presented in the Ecological Study (URS 2012b) and summarized below.

At RRM 0, the South River carries an estimated 54 to 92 megagrams of suspended sediment per year (an average long-term value that varies widely from year to year; URS 2012b). As suspended sediment is carried downstream, an average of approximately 6% of the annual load is deposited per mile on the floodplain. In addition to floodplain deposits, approximately 3% of the annual sediment load is deposited as FGCM deposits in quiescent areas near the banks. FGCM deposits occur immediately downstream of riparian trees that have fallen into the river (large woody debris) and bank obstructions, such as living trees. FGCM deposits also tend to occur where the river slope is less than about 0.25% (Skalak and Pizzuto 2010). Additions to and deposits from the suspended sediment load are continuous, but after a distance of 9 to 25 miles, the entire sediment load has generally been deposited and replaced by new sediment. The new sediment originates mostly from the eroded banks but also from resuspended surficial sediments of FGCM deposits. Soil erosion is a relatively small portion of the total sediment budget, but is disproportionately important for mercury transport. For example, a reduction in soil erosion between RRMs 0 and 10 would have a negligible effect on overall sedimentation rates in the South River, but could materially reduce the transport of mercury from the eroded riverbanks into the aquatic system.

Rates of sediment deposition in the system are low relative to the sediment budget for the South River. Floodplain deposition rates average approximately 0.04 centimeters per year (cm/yr), although higher rates may occur closer to the channel and in forested areas. Interstitial sediment, which is fine-grained sediment stored in the gravel matrix of the river bed, is deposited and released from the river bed during periods of fill and scour, respectively.

2.4.1 In-Channel Bed Stability

In-channel bed stability in the South River has been characterized through scour chain and other monitoring methods. Monitoring data collected over a period of about 2 years suggest that the South River bed is stable with no discernible scour. For example, following four 1-year recurrence interval discharges (approximately 2,000 cubic feet per second [cfs] at Waynesboro, Virginia), Pizzuto et al. (2011) measured no detectable scour using scour chains at RRM 4.3 (minor changes in bed elevations were within measurement errors). Scour data are not available for the river as a whole, but the conditions at RRM 4.3 are likely applicable to most of the reach between RRMs 0 and 13, before river slope increases.

The residence time of interstitial sediments in the gravel bed was evaluated using radionuclide age-dating methods. Approximately 80% of the stored sediment is less than 50 years old and the median age of stored sediment is about 32 years old. The uncertainty of the age estimates is approximately 50% or more (Pomraning 2011).

2.4.2 Bank Erosion

Bank erosion rates on the South River have also been characterized, averaging approximately 4 cm/yr throughout the system (Rhoades et al. 2009; this is an average long-term value that varies widely from year to year and between banks). Removal of small mill dams on the South River is estimated to have increased bank erosion rates two- to three-fold after approximately 1957, compared to earlier periods (Pizzuto and O'Neal 2009). Present-day bank erosion rates tend to be higher near islands and at migrating bends. Animals do not materially contribute to the total volume of bank erosion in the South River, although they may affect certain localized areas in important ways, especially from livestock grazing.

2.4.3 Mercury Mass Balance

A present-day mass balance for mercury was developed for the first 10 river miles of the South River and is summarized in the Ecological Study (URS 2012b). Several different lines of evidence—including incremental loading rates and concentration gradients in surface water, sediment, and porewater—strongly suggest that non-channel (e.g., bank) sources of THg are limited to the first 10 to 12 river miles of the South River.

Eroding banks are the largest current single source of THg loading to RRMs 0 to 10 of the South River, accounting for 40 to 60% of the THg loading to the river channel system (URS 2012b). Controlling bank erosion is thus a primary focus of this Remediation Proposal. However, there are other mechanisms by which THg stored in banks could potentially be transported to the water column, such as soil particle dispersion and colloidal transport, or soil-water and other biogeochemical interaction within the bank. Mercury loading rates from these potential transport pathways have proven difficult to quantify, and may need to be addressed as part of an adaptive management approach. Ongoing SRST studies continue to assess these mechanisms. In addition, mercury is loaded to the watershed by atmospheric deposition, which is a relatively small source (Eggleston 2009).

The facility outfalls continue to be a source of mercury to the South River (URS 2012b). Unintended mercury releases through the facility outfalls have also recently occurred as a result of on-site remediation actions, including sewer cleaning. As discussed in Section 1.3, DuPont is evaluating alternatives jointly with USEPA for the remediation of upland mercury sources, including impacted groundwater and mercury discharges in the plant outfalls; these actions will be coordinated with this Remediation Proposal.

In-channel sediments in RRMs 0 to 12 are both a potential exposure medium and a source of MeHg to the South River. Mercury is distributed throughout the channel bed: in deposits along the channel margin and behind obstructions and mixed within the gravel matrix of the streambed. THg and MeHg enter the water column through advection and diffusion from these in-channel deposits. Although a relatively small source of THg to the South River, in-channel sediment currently accounts for approximately 74% of the MeHg loading between RRMs 0 and 2.7 (URS 2012b). THg concentrations in finer sediment deposits along the channel margin and THg attached to fine sediment that occurs within the interstices of the gravel-cobble matrix are sufficient to maintain ongoing methylation of THg throughout the system.

There are uncertainties associated with the quantitative mercury mass balance summarized above that may be refined as part of an adaptive management approach to remediation. The primary uncertainty is due to the variability in the mercury load in the water column measured from year to year. The total mass of mercury loaded between RRMs 0 and 12, for example, can be much higher than the sum of the sources identified and described above

(e.g., riverbanks, outfalls). Although this may suggest that there is an unquantified source of mercury measured in the water column, it is more likely due to the difficulty of accurately measuring sediment resuspension, which was estimated by Eggleston (2009) using a river basin-scale hydrologic model. Pizzuto et al. (2011) noted that predicting the pathways and rates of sediment transport in alluvial valleys is challenging; thus, the current sediment resuspension estimates may not be accurate.

2.5 Biological Conditions

The South River is a generally high-quality ecological system supporting diverse land types and biological communities. These characteristics would be preserved or enhanced with the recommended remedy discussed in Section 6. Sections 2.5.1 and 2.5.2 describe the salient features of the biological communities in the South River.

2.5.1 Benthic Community

The South River supports benthic and epibenthic communities that vary in quality in response to the physical and chemical characteristics of the habitat present. The Ecological Study (URS 2012b) documented that the composition of the communities varies spatially and temporally, and is influenced more by natural variation in physicochemical variables, grain size, organic carbon content, and other abiotic factors than by mercury concentrations. The Ecological Study provided more detail on the structure and characteristics of the benthic invertebrate communities (URS 2012b).

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 (VADEQ 2009). The most probable stressors causing the impairment are loadings of sediment and phosphorus from point and non-point sources. 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. High densities of the aquatic invertebrate chironomids and hydropsychids, which thrive in poor quality habitat, are further evidence of this impairment.

Benthic and epibenthic communities play a pivotal role in the food web of the South River, including nutrient and mercury cycling throughout the system. One of the more important identified impairments to the South River benthic and epibenthic communities is increased embeddedness of in-channel habitats due to historic sediment loading from land uses such as agricultural activities in the upstream South River watershed. Bank stabilization associated with the recommended remedy will reduce sediment loading to the system, decreasing embeddedness and improving available habitat for benthic and epibenthic invertebrates.

2.5.2 Bank Habitat

Riverbanks and the surrounding riparian zones also represent ecologically important habitats of the South River. These areas provide foraging, nesting/burrowing, and refugia opportunities for numerous species of songbirds, piscivorous birds, small mammals, and reptiles/amphibians. The extent and quality of bank and riparian habitats of the South River vary extensively with surrounding land use. For example, the first 2 miles of the river are mostly surrounded by a mixture of commercial, industrial, and residential land uses with minimal riparian habitats. From approximately RRMs 2.5 to 12, the dominant land use is agricultural, including pasture hay and row crop mixed with limited stands of hardwood forest. While the riparian corridor is fairly narrow (less than 60 feet) in most locations, it is relatively undisturbed, with the exception of livestock grazing areas, and provides some level of ecological function.

2.6 Lower South River and South Fork Shenandoah River

One of the key findings of the Ecological Study (URS 2012b) is that areas with relatively high MeHg concentrations in environmental media (e.g., surface water) and biological tissue (e.g., fish) are observed in the downstream reach (e.g., at distances greater than approximately 12 miles from the former DuPont Waynesboro facility). This finding is particularly significant with respect to development of an overall remediation strategy for the South River and a portion of the SFS River. As described in Section 2.3, several lines of evidence indicate that the primary sources of IHg entering the system (i.e., eroding banks and facility outfalls) are largely constrained to the first 12 miles of the South River downstream of the former facility. However, relatively high tissue concentrations of MeHg also occur in downstream reaches of the South River and SFS River.

There are three potential causes for this spatial offset between mercury sources and evidence of exposure. First, the more downstream points may reflect the accumulated mercury load from many diffuse non-point sources. Second, mercury methylation is a widely distributed process in South River sediment (Yu et al. 2011). Finally, IHg is highly persistent over time. This may be the case especially in the South River, where soil-water interactions and soil wetting and drying may lead to a prolonged ability for soil to release IHg (Ptacek 2011).

The offset between mercury sources and exposure provides further support for a remediation strategy that will address the system in manageable segments from upstream to downstream, in an adaptive management framework. For example, there are few, if any, external sources of THg in the reach between RRMs 12 and 25. Under current conditions, most of the mercury load in this downstream reach entered the South River from RRMs 0 to 12. This suggests that remediation of upstream reaches should be appropriately sequenced early to reduce the loading to this downstream reach and reduce exposure. It is also possible that remediation of all sources within RRMs 0 to 12 will not immediately reduce MeHg exposure in any reach of the South River, as the IHg distributed in sediment will likely continue to contribute to elevated methylation rates for an unknown timeframe.

2.7 Summary

The sections above summarized the findings of the extensive characterization of the physical, geologic and geomorphological, chemical, and biological characteristics of the South River (from URS 2012b), and discussed features of the lower segment of the South River and a portion of the SFS River. The major findings are that the largest mercury sources (riverbanks, outfalls from the former Waynesboro facility, and sediment) primarily occur in the first 12 river miles. This necessitates that remediation begin in these areas and in the direction of flow. Remediating isolated downstream areas could result in recontamination from upstream sources, and declines in mercury concentrations or loads could be obscured by upstream loading.

The other important finding is that although the South River downstream of RRM 12 and the upper segment of the SFS River contain relatively few sources (i.e., few riverbanks with high THg concentrations), these areas have elevated mercury concentrations in some media

(e.g., fish and birds). The majority of mercury loaded to these reaches comes from the first 12 river miles (Figure 2-4).

3 BASIS FOR REMEDIATION

As described in previous sections, the basis for remediation in the South River and a segment of the SFS River is founded on the extensive characterization of mercury fate and transport within the South River watershed (URS 2012b). Based on the distribution of sources in the South River, remediation efforts will initially focus on the first 2 river miles of the South River below the former Waynesboro facility. This section provides the basis for remediation in the South River as directed by the CSM, risk management goals, and RAOs.

3.1 Basis for Remediation Conceptual Site Model

Consistent with USEPA (2005) guidance, RAOs for the South River were developed based on an understanding of the media, exposure pathways, and receptors that may be impacted. The site-specific basis for remediation CSM discussion in this section summarizes sources and the status of source control; summarizes the nature, extent, fate, and transport characteristics of mercury in the system; and identifies potential exposure pathways that may contribute to unacceptable risks to humans and the environment. This CSM in turn informs the development of South River-specific RAOs.

This Remediation Proposal focuses on bank soils associated with riverbanks, and to a lesser degree, in-channel sediments within the upper 12 miles of the South River. These bank soils are the primary media of concern in the basis for remediation CSM (discussed in more detail in Section 3.1.2) for the first phases of the remedy. The erosion of bank soils is a transport or migration pathway for mercury to enter the river and contribute to the mass of mercury in sediment and surface water. Contact between in-channel sediment, surface water, aquatic biota, and wildlife or humans determines whether complete exposure pathways exist (e.g., human consumption of fish) such that sufficient risk is concluded to potentially warrant remediation.

3.1.1 Exposure Pathways that Contribute to Potential Mercury Risks

As discussed in Section 1.3.1, on-site and off-site human health and ecological risk assessments are being prepared by DuPont for submittal to, and with input from, VADEQ and USEPA. The on-site risk assessment addresses the potential for human or ecological risk on the former DuPont Waynesboro facility upland areas, and the off-site risk assessment

addresses aquatic and floodplain areas of the South River. Diagrams showing preliminary human health and ecological exposure pathways are provided in Figures 1-1 and 1-2, respectively, in Section 1.3.1.

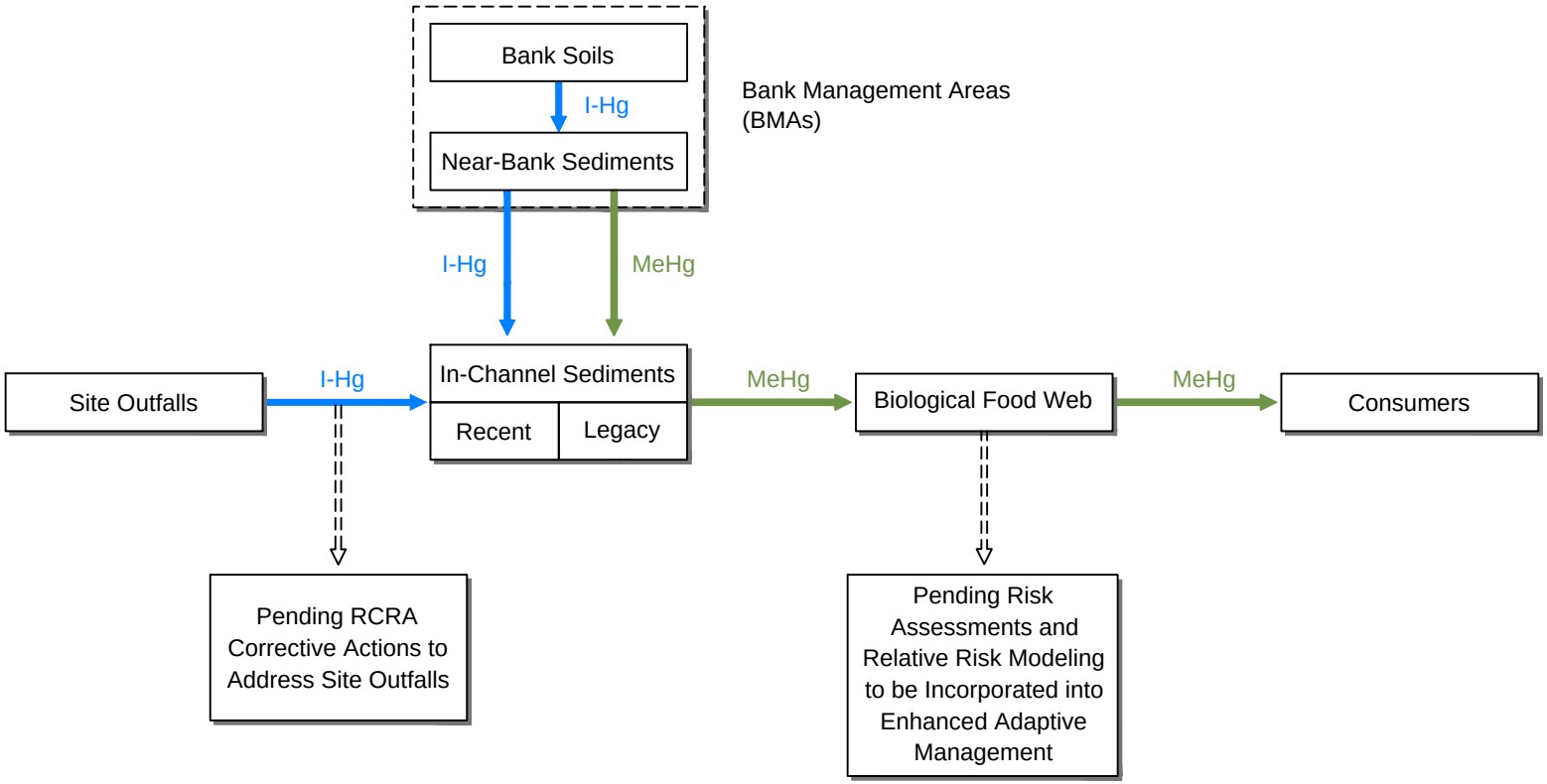
The findings of the risk assessments will be incorporated into the adaptive management framework that will be used for remediation decision-making, as appropriate for the site, river, and floodplain areas. Exposure of humans to contaminated fish is currently one of the focus areas for potential remediation activities in the South River; however, it is important to note that a fish consumption advisory that addresses this pathway has been in place since 1977. As other human and ecological risk evaluations are completed, additional pathways could be considered for remediation. Currently, the following human and ecological exposure pathways are considered potentially complete, and are being evaluated for their potential to pose unacceptable risk:

- Exposure of humans to mercury in fish tissue (and potentially also turtles and waterfowl; see Section 7)
- Exposure of semi-aquatic and terrestrial ecological receptors to mercury in floodplain soil
- Exposure of aquatic and semi-aquatic ecological receptors to mercury in surface water, sediment, and porewater
- Exposure of aquatic, semi-aquatic, and some terrestrial receptors to mercury in biological tissue

While not a regulatory requirement, DuPont has funded development of a relative risk model for the South River and a segment of the SFS River by Dr. Wayne Landis, Western Washington University, and his students. A major portion of this SRST project is expected to be completed in December 2013 and the final results will be provided in a manuscript suitable for publication in 2014. Additional work by Dr. Landis on relative risks to humans and ecological receptors exposed to mercury is being discussed, but would not be undertaken until early 2014. Because the outputs from the relative risk model can be applicable to understanding net risk reduction from the implementation of a remediation action, it will be coupled with the adaptive management process to provide a more holistic view of the benefits from implementing specific elements of the Remediation Proposal.

3.1.2 Basis for Phase 1 Remediation

The first phase of corrective actions will target the first 2 miles of the river adjacent to and downstream of the former DuPont facility in Waynesboro, targeting a construction season of 1 to 2 years to address banks that contribute material mercury loading to the river in this segment. Figure 3-1 shows the South River CSM developed to evaluate the basis for Phase 1 remediation actions. This CSM will be expanded upon as additional data are collected and the corrective action program moves forward toward downstream areas and the floodplain. The Phase 1 CSM focuses on the three pathways relevant to understanding the need for a response action: 1) the source of mercury to the South River and the extent to which sources are controlled; 2) the mercury-impacted media—in this case, bank soils and in-channel sediments; and 3) potential receptors. The potential for mercury exposure between sediments and fish and between fish and consumers of fish is depicted in the CSM. Fish (and potentially turtles and other animals; see Section 7) can bioaccumulate mercury through the food chain insofar as food chain pathways are connected to the sediment bed. Consistent with USEPA (2005) guidance, and as described above, the basis for remediation CSM will be expanded upon and updated to include downstream and floodplain areas as appropriate during adaptive management and based on the findings of the risk assessments.



NOTE:
A floodplan risk evaluation is currently underway. The adaptive management plan described in this Remediation Proposal will be augmented as needed to address potential upland exposures as indicated by the risk assessment.

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Figure 3-1
Basis for Remediation Conceptual Site Model
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

3.2 Risk Management Goals

The objective of this Remediation Proposal is to describe a program that targets reduction of risks to humans and ecological receptors as a result of exposure to mercury. A key link between the risk assessment and remediation planning processes is the definition of risk management goals; they are a key step in the problem definition stage and help guide the risk analysis process. They may be refined based on the feasibility of remediation (PCCRAM 1997). The preliminary risk management goals are defined as follows:

- Materially reduce THg and MeHg concentrations in surface water and fish tissue in the South River and SFS River
- Reduce exposure of ecological receptors to MeHg in the South River and SFS River
- To the extent practicable, relax or eliminate fish consumption advisories in the South River and SFS River through the reduction in fish mercury body burden
- Improve habitat conditions to enhance ecological functions in the South River channel

3.3 South River Remedial Action Objectives

RAOs 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 remediation alternative evaluation process determines the feasibility, implementability, and sustainability of remedial measure alternatives, while determining the extent to which remedies are expected to achieve the RAOs. As noted in USEPA's (2005) guidance, RAOs should reflect objectives that are achievable through remediation. RAOs are media-specific and consist of the following:

- General response objectives
- Performance objectives
- Measurable metrics

General response objectives identify the exposure pathway to be addressed in order to address potential risks to human health and the environment. Performance objectives identify specific media targets intended to fulfill the general response objective. Measurable

metrics consist of quantitative criteria that establish whether performance objectives have been met. A combination of some or all of these objectives is developed as part of the remedy.

3.3.1 Bioaccumulation and Food Web Exposure RAOs

As discussed in Section 1, remediation of the South River and a segment of the SFS River will generally be performed in an upstream-to-downstream sequence within an adaptive management framework. The first segment of the South River to be addressed by this Remediation Proposal includes bank soils within the first 2 miles downstream of the former DuPont Waynesboro facility. The length of this Phase 1 segment was preliminarily determined based on reach characteristics (see Section 2), as well as implementability, safety, and adaptive management considerations, targeting an initial Phase 1 construction period of approximately 1 to 2 years. Based on preliminary evaluations described in this Remediation Proposal, the RRMs 0 to 2 reach is currently targeted for initial bank remediation actions, subject to refinement during detailed design. The process will generally proceed in an upstream-to-downstream direction as additional data are collected as input to the remediation decision-making process using an adaptive management approach.

Both short- and long-term RAOs are appropriate to address bioaccumulation and food web exposures in this Remediation Proposal. Short-term RAOs are expected to be met following remedial measure construction, while long-term RAOs may require additional remediation in other segments or throughout the South River before they are attained. Preliminary RAOs developed for this Remediation Proposal will be subject to refinement during remediation planning (e.g., corrective action design and development of detailed monitoring plans) as well as follow-on adaptive management. It is also likely that some or all of these RAOs will also apply to other river segments during Phase 2 and beyond. 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 mercury transport and exposure and improve bank habitat functions within the upper 2 miles of the South River

  - *Performance objectives*: Conduct and/or maintain bank remediation actions in the upper 2 miles of the South River to achieve sustainable reductions in mercury concentrations and improve water quality and bank habitat functions within this reach
  - *Measurable metrics:* Bank erosion rates, measured using detailed topographic surveys, erosion pins, and/or root analysis; establishment of bank vegetation; and mercury concentrations in physical media and biological tissues (see Section 7)

- 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 7)

Section 7 of this Remediation Proposal presents a preliminary monitoring plan for the recommended remedy including preliminary measureable metrics. Under regulatory agency oversight and in collaboration with the SRST, the measureable metrics will be developed in more detail in future work plans and corrective action design documents that will more specifically describe the selected remedy to be applied to the South River. The measureable metrics will account for the existence or need for an adequate baseline data set and use standard operating procedures that are consistent with SRST data.

3.3.2 Weight-of-Evidence Prioritization of Bank Management Areas

As generally summarized in the basis for remediation CSM depicted in Figure 3-1 and discussed in Section 3.1, eroding banks are the largest current single source of mercury loading to the upper reaches of the South River. Controlling bank erosion is thus a primary focus of this Remediation Proposal. Potential Phase 1 bank management areas (BMAs) within RRMs 0 to 2 of the South River were identified and prioritized for this Remediation Proposal using multiple lines of evidence that integrated the following data sets and considerations:

- Average THg concentrations in bank soils (see Section 3.3.2.1)
- Bank erosion and mercury loading estimates from Pizzuto et al. (2011), though estimates were only developed for the approximately 20% of the area in RRMs 0 to 2 that was not affected by urban or anthropogenic alterations to the banks (see Section 3.3.2.2; note that subsequent bank characterization in 2012 and 2013 has been comprehensive; see Section 3.3.2.3.)
- Bank stability evaluations, including bank angles, root depth to bank height ratios, weighted root densities, and other metrics (see Section 3.3.2.3)
- Near-bank fine-grained sediment deposits (see Section 3.3.2.4)

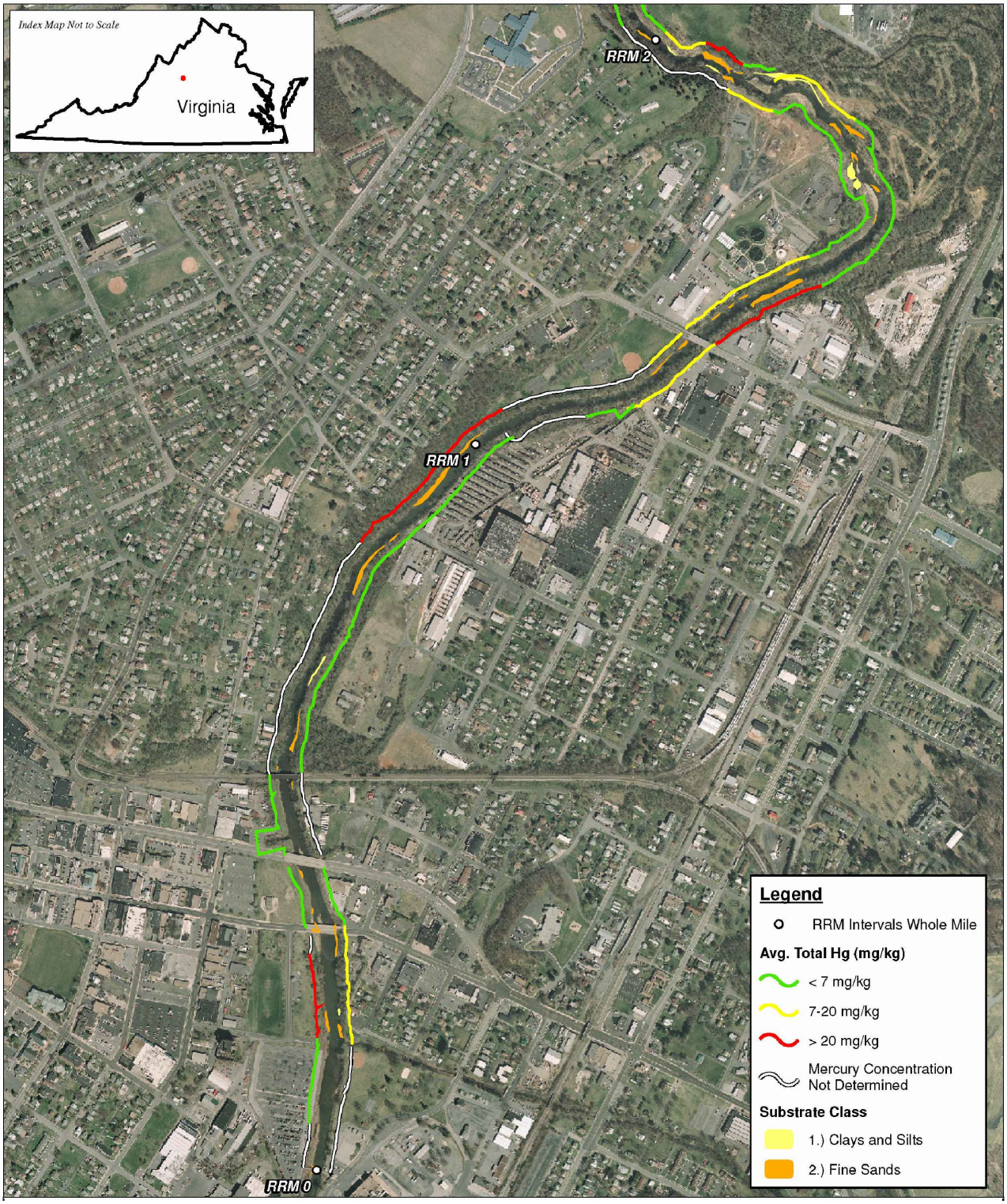
This Remediation Proposal identifies preliminary Phase 1 BMAs for RRMs 0 to 2 that will likely be addressed during the first and second construction seasons of remediation and sequenced to follow outfall source controls and monitoring at the former DuPont Waynesboro facility. Additional data collection will be performed during corrective action design to refine the Phase 1 BMAs. Concurrent with implementation of the RRMs 0 to 2 bank remediation actions during Phase 1, and as further data become available, additional BMAs are anticipated to be identified in reaches addressed during Phase 2 and beyond downstream of RRM 2 following a similar selection process as is outlined in Sections 3.3.2.1 through 3.3.2.5. The BMA identification and prioritization process will follow the overall adaptive management process and may be modified as additional data become available.

3.3.2.1 Average THg Concentration of Bank Soils

South River bank soils have been evaluated by the SRST over the past 10 years. These studies were primarily aimed at determining the fundamental dynamics of geomorphology and mercury fate and transport within the South River. In 2012 and early 2013, URS completed a supplemental bank soil sampling program to characterize the distribution and concentration of mercury in bank soils in the South River from RRMs 0 to 5. Banks were categorized into unique segments based upon geomorphic characteristics previously identified by the University of Delaware (Pizzuto et al. 2011). Composite surficial (0- to 2-inch depth) soil samples were collected at randomly located transects within selected bank segments. Composite samples were collected continuously along the bank face, such that each composite was between 1 to 2 feet in length. An average of six samples per bank was

collected, although the number of composite samples per bank varied with bank height. Samples were analyzed for THg (primarily composed of IHg) and percent moisture. The 2012 and 2013 bank sampling data are presented in Appendix C.

Arithmetic average THg concentrations were calculated for each individual transect, as well as for each bank segment. Average bank segment concentrations ranged from 0.08 to 270 µg/g. Average THg concentrations in bank soils from RRMs 0 to 2 are presented in Figure 3-2, using THg concentration ranges from previous modeling conducted by the University of Delaware (i.e., low: less than 7 µg/g; medium: 7 to 20 µg/g; and high: greater than 20 µg/g). Similar bank soil mercury concentrations occur in the next downstream reach, from RRMs 2 to 5 (Figure 3-3).



SOURCE: VBMP 2007 Aerial Imagery.

NOTE: RRM = Relative River Mile

0 1000
Scale in Feet

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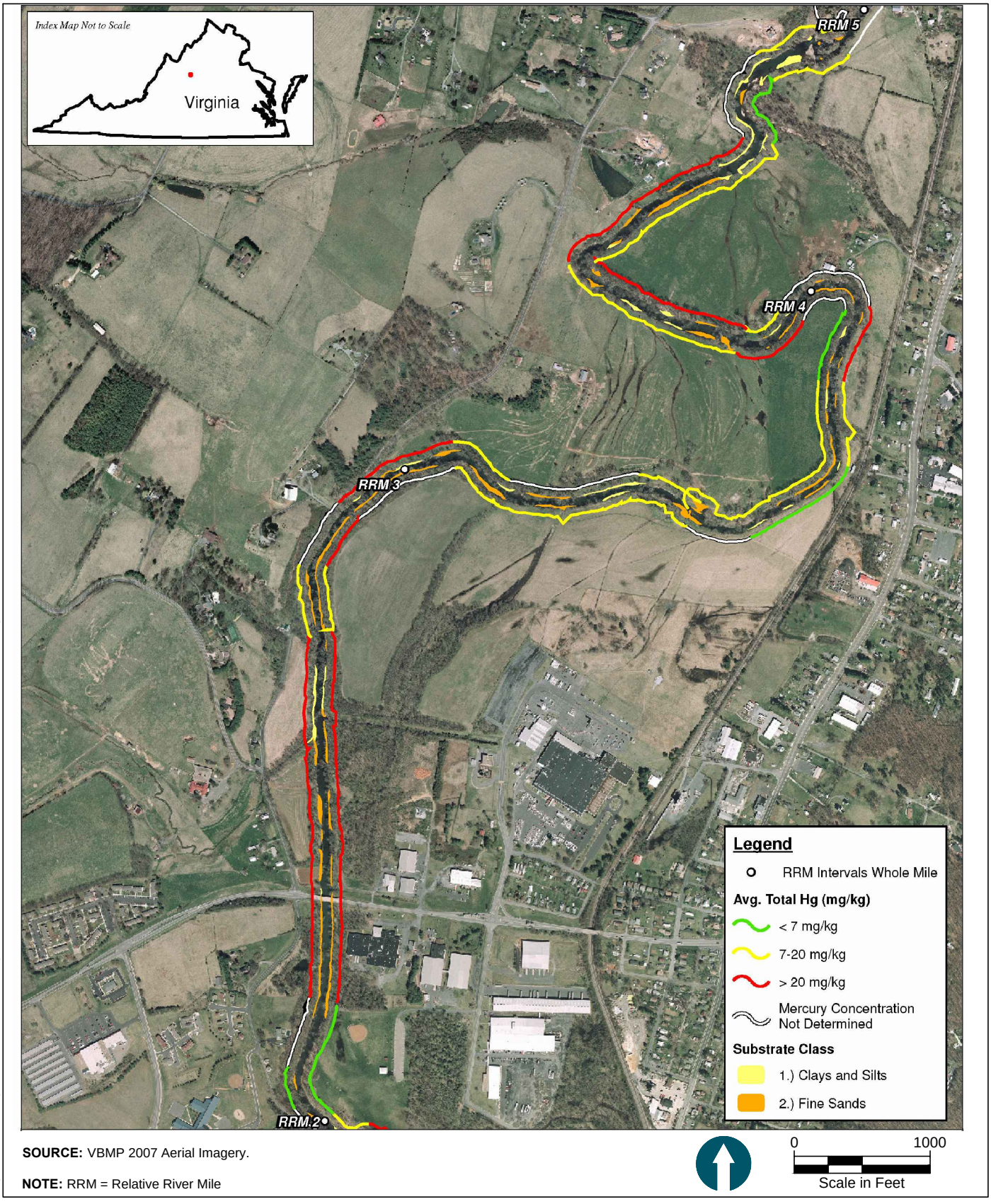
Figure 3-2
Mercury Concentrations in Bank Soils - RRM 0 to 2
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

ANCHOR QEA URS



SOURCE: VBMP 2007 Aerial Imagery.

NOTE: RRM = Relative River Mile

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Figure 3-3
Mercury Concentrations in Bank Soils - RRM 2 to 5
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

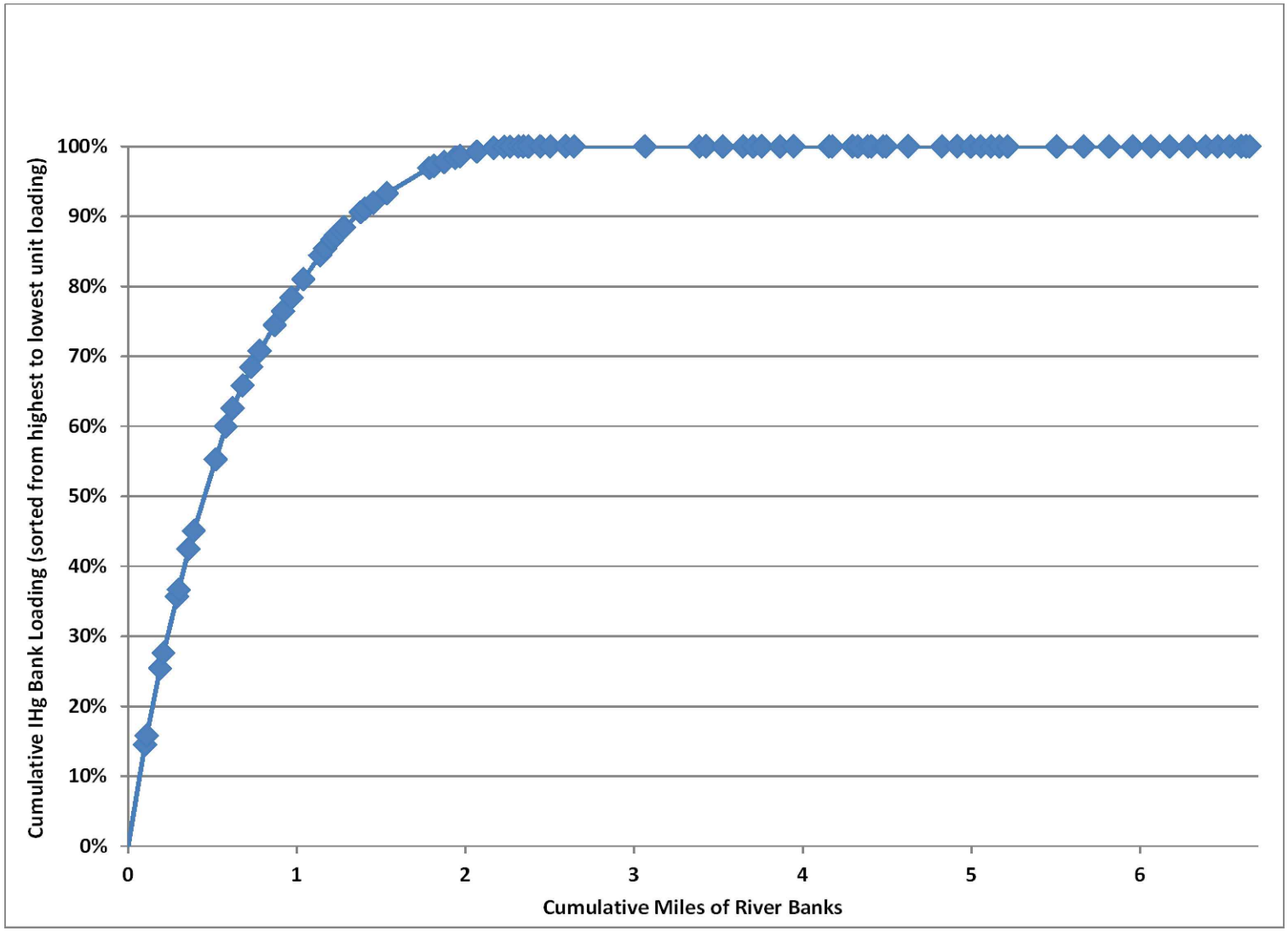
ANCHOR QEA

URS

3.3.2.2 Bank Erosion and Mercury Loading Estimates

Initial estimates of bank erosion were determined by the University of Delaware through various methods including aerial photograph interpretation, side-scan light detection and ranging (LiDAR), analysis of exposed tree roots, and bank pins. These measurements of erosion were coupled with modeled and measured mercury concentrations in bank and nearby floodplain soils to calculate IHg loading to the South River from eroding banks. Although only approximately 20% of the banks within RRMs 0 to 2 were evaluated by the University of Delaware due to urban or other anthropogenic alterations, IHg loading rates were estimated for most of the banks between RRMs 2 and 5 (Pizzuto et al. 2011).

For the approximately 5.2 miles of non-anthropogenically modified banks in RRMs 0 to 5 evaluated by the University of Delaware (of the total 10 miles on both sides of the river), total IHg loading was found to be disproportionately attributable to a relatively small number of banks. Sorting each bank from highest to lowest unit loading (i.e., by kilograms IHg per mile per year [kg IHg/mi-yr]), the cumulative IHg loading is compared with the cumulative bank length in Figure 3-4, illustrating this loading disproportionality. For example, approximately 75% of the total IHg loading to RRMs 0 to 5 from non-anthropogenically modified banks comes from roughly 15% of these banks, corresponding to banks with an estimated unit loading greater than roughly 1 kg IHg/mi-yr. For the purpose of this Remediation Proposal, the 1 kg IHg/mi-yr unit loading rate was used as an initial BMA screening level, identifying approximately 0.3 mile of banks not affected by urban or other anthropogenic alterations in RRMs 0 to 2 as preliminary BMAs; these BMAs appear to contribute disproportionately to loading (Figure 3-5 and Table 3-1). Because the University of Delaware studies focused on natural forces and natural conditions that affect bank erosion, roughly 80% of the banks within RRMs 0 to 2 were not evaluated due to anthropogenic modifications. To account for those banks not evaluated by the University of Delaware, an additional weight-of-evidence evaluation that focused on bank stability metrics was used to identity other preliminary BMAs in RRMs 0 to 2, as discussed in Section 3.3.2.3.



SOURCE: From Pizzutto et al. (2011), excluding Anthropogenically Altered Banks.

ANCHOR QEA URS

Figure 3-4
Estimated Cumulative IHg Bank Loading, RRM 0 to 5
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

Table 3-1

Bank Management Area Weight-of-Evidence Metrics

Bank Location			Bank Stability				Mercury Concentration/Loading			Preliminary BMAs
Station	RRM Start	RRM End	Bank Angle (degrees)	Root Depth/Bank Height Ratio	Weighted Root Density (%)	Weight-of-Evidence Relative Bank Stability Ranking	Average IHg (µg/g)	IHg Unit Loading (kg IHg/mi-yr)	Attached FGCM	Preliminary BMA Prioritization
LBH-01	0.00	0.04	20	1.00	75	High			Yes	No Further Action
LBH-02	0.04	0.06	10	1.00	75	High				No Further Action
LBH-03	0.06	0.17	40	1.00	75	High	1.0			No Further Action
LBH-04	0.17	0.27	40	1.00	65	High	123.8		Yes	Further Evaluation
LBH-05	0.27	0.30	10	0.20	16	Moderate			Yes	Further Evaluation
LBH-06	0.32	0.39	40	1.00	50	High	0.5		Yes	No Further Action
LBH-07	0.41	0.51	80	0.10	9	Low	5.2			Further Evaluation
LBH-08	0.51	0.55	70	1.00	25	Moderate				Further Evaluation
LBH-09	0.55	0.62	75	1.00	70	High				No Further Action
LBH-10	0.62	0.81	65	1.00	50	Moderate				Further Evaluation
LBH-11	0.81	1.05	80	1.00	70	Moderate	30.54		Yes	Preliminary BMA
LBH-12	1.05	1.25	45	1.00	80	High				No Further Action
LBH-13	1.25	1.31	60	0.75	56	Low	12.9			Preliminary BMA
LBH-14	1.32	1.49	85	0.80	56	Low	19.7	0.34	Yes	Preliminary BMA
LBH-15	1.49	1.60	90	0.60	30	Low	5.8		Yes	Further Evaluation
LBH-16	1.60	1.65	15	0.80	56	Moderate	2.4			No Further Action
LBH-17	1.65	1.69	85	0.80	32	Low	2.0	3.97	Yes	Preliminary BMA
LBH-18	1.69	1.83	5	1.00	60	High	2.0		Yes	No Further Action
LBH-19	1.83	1.89	85	0.90	63	Low	7.6		Yes	Preliminary BMA
LBH-20	1.89	2.04	75	1.00	50	Moderate			Yes	Further Evaluation
RBH-01	0.04	0.11	45	1.00	50	High				No Further Action
RBH-02	0.11	0.16	45	1.00	45	High (post-pilot)	25.0			Bank Stabilization Pilot

Bank Location			Bank Stability				Mercury Concentration/Loading			Preliminary BMAs
Station	RRM Start	RRM End	Bank Angle (degrees)	Root Depth/Bank Height Ratio	Weighted Root Density (%)	Weight-of-Evidence Relative Bank Stability Ranking	Average IHg (µg/g)	IHg Unit Loading (kg IHg/mi-yr)	Attached FGCM	Preliminary BMA Prioritization
RBH-03	0.16	0.31	45	0.90	59	Moderate	10.6		Yes	Further Evaluation
RBH-04	0.31	0.38	70	1.00	20	Moderate	2.2			No Further Action
RBH-05	0.40	0.51	65	1.00	70	High				No Further Action
RBH-06	0.51	0.81	45	1.00	80	High	3.8		Yes	No Further Action
RBH-07	0.81	0.92	90	0.90	45	Low	5.2		Yes	Further Evaluation
RBH-08	0.92	1.05	45	1.00	80	High	1.8			No Further Action
RBH-09	1.05	1.15	30	0.90	63	Moderate				Further Evaluation
RBH-10	1.15	1.20	20	1.00	70	High	0.8			No Further Action
RBH-11	1.20	1.33	65	0.80	60	Moderate	8.3			Further Evaluation
RBH-12	1.33	1.41	90	1.00	80	Moderate	31.1			Preliminary BMA
RBH-13	1.41	1.49	110	0.70	49	Low	180.5		Yes	Preliminary BMA
RBH-14	1.49	1.58	60	0.60	36	Low	3.6	<0.01		Further Evaluation
RBH-15	1.58	1.62	90	0.70	35	Low	0.9	1.34		Preliminary BMA
RBH-16	1.62	1.65	90	0.80	32	Low	1.5	1.84	Yes	Preliminary BMA
RBH-17	1.65	1.72	30	1.00	70	High	2.0	<0.01	Yes	No Further Action
RBH-18	1.72	1.82	90	0.30	18	Low	7.96	2.53	Yes	Preliminary BMA
RBH-19	1.82	1.88	35	0.90	72	Moderate	3.91	<0.01	Yes	No Further Action
RBH-20	1.88	1.93	80	0.80	44	Low	23.87	0.72	Yes	Preliminary BMA
RBH-21	1.93	2.00	50	0.75	45	Low	10.87		Yes	Preliminary BMA

Notes:
Blank cells denote that data are not available for this bank; additional data collection will be performed during corrective action design

Green shading denotes a high stability and/or low concentration bank characteristic
Yellow shading denotes a moderate stability and/or moderate concentration bank characteristic
Orange shading denotes a low stability and/or high concentration bank characteristic
Blue shading denotes the bank stabilization pilot area (see Appendix A)

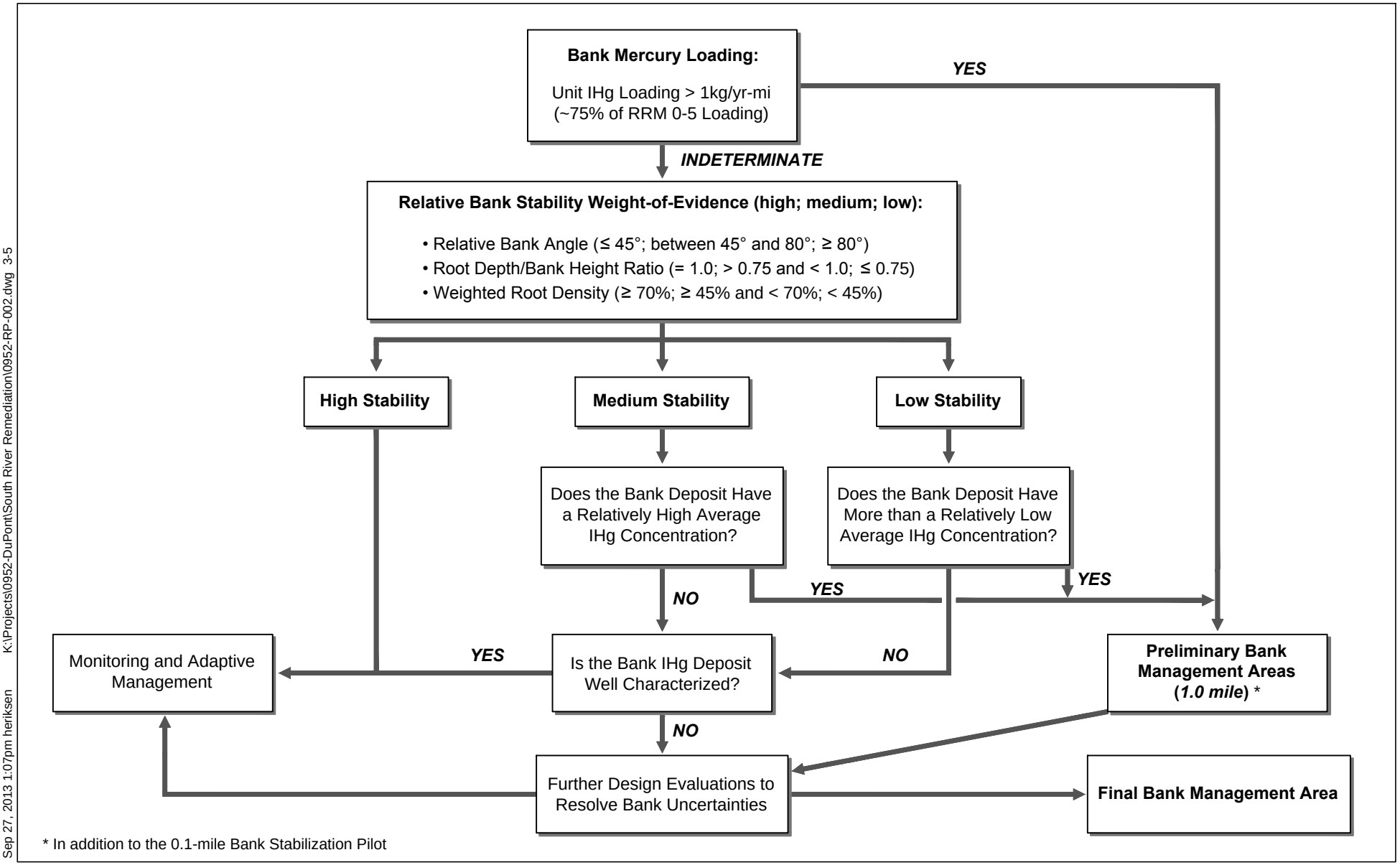


Figure 3-5
RRM 0 to 2 Bank Management Area Weight-of-Evidence Flow Chart
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

3.3.2.3 Bank Stability Evaluations

An independent evaluation of bank stability within RRMs 0 to 2 of the South River was performed by URS and Anchor QEA in 2012 and 2013 using a modified approach to the Bank Erosion Hazard Index originally developed by Rosgen (2006). A range of field metrics that collectively determine the susceptibility of an individual bank (or portion of a bank) to erosion were evaluated. The bank stability evaluations included comparisons with bank erosion estimates determined by the University of Delaware in RRMs 0 to 5 as outlined in Section 3.3.2.2, along with evaluations of bank erosion in other similar river systems (e.g., Tittabawassee River in Michigan, and Housatonic River in Massachusetts; Anchor QEA unpublished data). Based on these evaluations, the primary metrics utilized in bank stability evaluations for this Remediation Proposal—along with corresponding categorization of specific banks on a relative basis into high, moderate, and low stability categories—are as follows:

- Relative bank angle:
  - High stability: less than or equal to 45°
  - Moderate stability: between 45° and 80°
  - Low stability: greater than or equal to 80°
- Root depth to bank height ratio:
  - High stability: 1.0
  - Moderate stability: greater than 0.75 and less than 1.0
  - Low stability: less than or equal to 0.75
- Weighted root densities:
  - High stability: greater than or equal to 70%
  - Moderate stability: greater than or equal to 45% and less than 70%
  - Low stability: less than 45%

Based on these metrics, the overall weight of evidence of the stability of individual banks in RRMs 0 to 2 is summarized in Figure 3-5 and Table 3-1. The bank must be categorized as high stability for at least two of the three lines of evidence to be considered to have high stability overall. Combining this bank stability evaluation with data on average IHg concentrations in each bank, using concentration ranges developed by the University of

Delaware (i.e., low: less than 7 µg/g; medium: 7 to 20 µg/g; and high: greater than 20 µg/g), 0.7 mile of banks in RRMs 0 to 2 were identified as preliminary BMAs, in addition to the 0.3 mile of banks identified in Section 3.3.2.2 based on mercury loading (Figure 3-5 and Table 3-1).

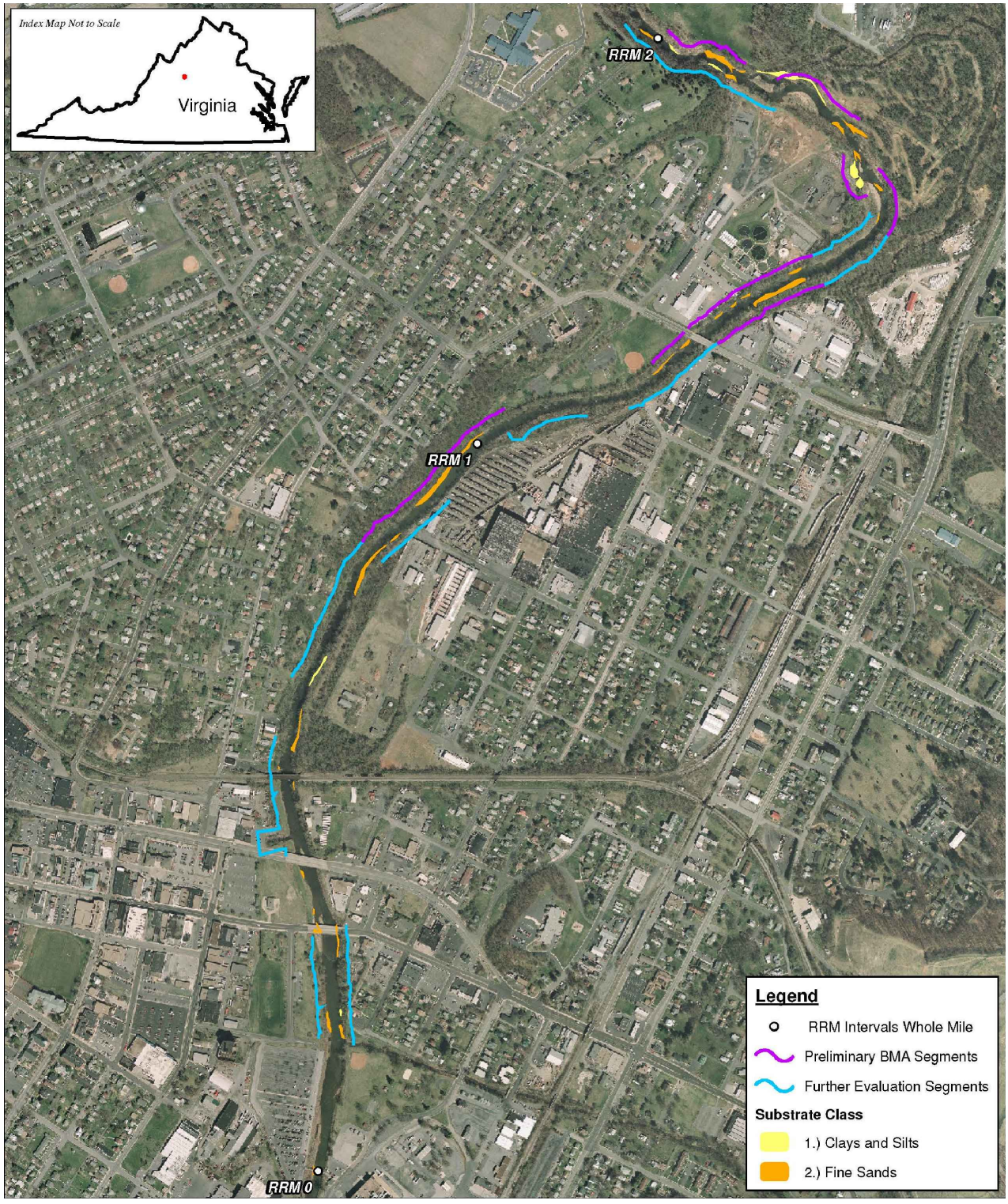
3.3.2.4 Fine-Grained Channel Margin Deposits

FGCM deposits consisting of silts, clays, and fine sands, which tend to have higher average THg concentrations (54 µg/g) than the surrounding embedded gravel beds (15 µg/g), have been delineated throughout RRMs 0 to 2 and in other areas of the South River, as depicted on Figures 3-2 and 3-3. These FGCM deposits may reflect recent bank erosion from adjacent or upstream areas. To the extent that FGCM deposits are located adjacent to preliminary BMAs identified based on relatively higher average mercury concentrations and/or lower stability as outlined above, these deposits provide further evidence corroborating a higher priority BMA to be addressed in this Remediation Proposal (Table 3-1).

3.3.2.5 Preliminary BMA Identification

Combining the 0.3 mile of banks identified in the Section 3.3.2.2 loading analysis with the 0.7 mile of banks identified in the Section 3.3.2.3 bank stability evaluation results in a total of 1.0 mile of banks that are carried forward in this Remediation Proposal as preliminary BMAs. (Note that the 0.3 mile of bank identified through the University of Delaware study was also assessed using other bank stability metrics, and did not alter the BMA identification.) These banks, along with an additional 1.5 miles of banks, will be evaluated further during corrective action design to identify final BMAs in RRMs 0 to 2 (Figure 3-5 and Table 3-1).

For the purpose of this Remediation Proposal, preliminary delineation of the extent of individual BMAs was performed using the sampling and survey data described in the sections above. In addition, FGCM deposits located immediately adjacent to a given BMA were also incorporated into the delineation to provide an efficient remediation approach. Preliminary BMAs in RRMs 0 to 2 are depicted in Figure 3-6. As discussed above, final BMA delineations in RRMs 0 to 2 will be performed during corrective action design through additional IHg concentration and stability characterization.



SOURCE: VBMP 2007 Aerial Imagery.

NOTE: RRM = Relative River Mile

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Figure 3-6
Preliminary Bank Management Areas - RRM 0 to 2
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

ANCHOR QEA URS

3.4 Relationship of South River BMAs to In-Channel Sediment Deposits

The majority of the channel substrate in the South River consists of gravel and cobble-sized materials with very few muddy, soft-bottomed areas containing fine-grained sediment. However, fine-grained sediment consisting of fine sand, silt, and clay is located within the gravel matrix of the river bed (interstitial sediment). Spatially, embedded gravel deposits occupy approximately 85% of the river bed within the wetted perimeter of the South River. The remaining 15% is either bedrock or fine-grained sediment deposits, with most of the latter occurring as FGCM deposits. Given the spatial extent and the lower IHg concentration associated with interstitial sediments, the focus of in-channel sediment remediation will be on FGCM deposits that are associated with BMAs as described above. Utilizing the adaptive management approach, embedded gravel sediment deposits will be evaluated after BMA remediation has been completed and monitoring data become available.

3.5 Regulatory Requirements

Any corrective action implemented in the South River must comply with the requirements of federal, state, and local environmental laws. Key regulatory requirements for corrective actions in the South River are outlined in Sections 3.5.1 through 3.5.3.

3.5.1 Potential Chemical-Specific Requirements

3.5.1.1 Water Quality Standards

Federal water quality standards are the foundation of the water quality-based pollution control program mandated by Section 303 of the Clean Water Act. Water standards are provisions of state, tribal, or federal law that define the water quality goals of a waterbody, or segment thereof, by designating the use or uses to be made of the waterbody, establishing criteria based on sound science that are protective of applicable uses, and protecting water quality through antidegradation requirements (see 40 CFR Part 131). States and tribes adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. These standards may be requirements for the corrective action (e.g., construction water quality requirements). If a state has not adopted water quality standards, federal water quality standards are used. The Commonwealth of Virginia has developed standards for the protection of water quality (including turbidity and mercury concentrations) that may be requirements for corrective actions in the South River.

3.5.1.2 Total Maximum Daily Loading

The South River was first listed as an impaired stream in 1996 on Virginia's Section 303(d) TMDL priority list for not supporting aquatic life (i.e., the benthic community) and recreational use goals (i.e., bacteria). Recent assessments by VADEQ (2009) have identified nutrients and water column toxics (including mercury) as impairments, and sediment quantity and phosphorus were identified as the most probable stressors adversely affecting the benthic community in the South River. The majority of the sediment and fecal coliform load appears to originate from non-point agricultural sources in the watershed. Implementation of the sediment and bacteria TMDL, which identified load reductions for both sediment and bacteria, could alter transport of sediment and/or improve water quality through enforcement of agricultural best management practices (BMPs).

The TMDL for mercury in the South River (Eggleston 2009) used empirical relationships to estimate mercury load reductions that may be required to reduce fish tissue MeHg concentrations in smallmouth bass below the USEPA criterion of 0.3 µg/g. The report estimated that at least a 99% reduction in the current mercury load to the South River may be required to meet target water column mercury concentrations and achieve USEPA's fish tissue criterion.

The implications of the sediment, bacteria, and mercury TMDLs for this Remediation Proposal and for other actions within the South River watershed are not yet clear. However, as part of the adaptive management plan, the SRST will continue to study changes to the river system. As an example, DuPont funded an SRST study (Brent 2011) to determine potential effects of a recent upgrade to the Waynesboro wastewater treatment plant on MeHg concentrations in periphyton. This study documented that while the wastewater treatment plant upgrades resulted in decreased nutrient loading and may have contributed to locally depressed MeHg concentrations, other factors, such as IHg loading from upstream sources, have a greater effect on mercury methylation than nutrients.

3.5.2 Potential Action-Specific Requirements

3.5.2.1 Flood Control Requirements

The Commonwealth of Virginia floodplain management regulations (Code 10.1-602) require that that the Virginia Department of Conservation and Recreation coordinate federal flood protection programs administered by the U.S. Army Corps of Engineers (USACE), the U.S. Department of Agriculture, the Federal Emergency Management Agency, the U.S. Geological Survey, the Tennessee Valley Authority, other federal agencies, and local governments. The floodplain management regulations limit floodplain encroachments to those that will only cause insignificant increases in the base flood elevation (typically defined as less than 0.1 foot). For remediation alternatives that include placement of cap or fill material within the floodway, a hydraulic analysis may need to be performed to evaluate potential impacts to the base flood elevation.

3.5.2.2 Water Quality Standards

Discharges into navigable waters are regulated under Sections 401 and 404 of the Clean Water Act (33 USC 1341 and 1344); 40 CFR Part 230 (Section 404(b)(1) guidelines); and 33 CFR Parts 320 (general policies), 323 and 325 (permit requirements), and 328 (definition of waters of the United States). These requirements regulate the excavation of bank materials and the placement of fill material (including caps) below the ordinary high water elevation. The 401/404 regulations are implemented by USACE and USEPA. Under the Section 404(b)(1) guidelines, 40 CFR 230.10(b), no discharge (i.e., excavation or cap) shall be allowed if it:

- Causes or contributes to violations of water quality standards, pursuant to Section 401 of the Clean Water Act, after consideration of local dilution and dispersion
- Violates any applicable toxic effluent standard or discharge prohibition under Section 307 of the Clean Water Act
- Jeopardizes the continued existence of any endangered or threatened species, or contributes to the destruction or modification of any critical habitat for such species
- Violates any requirement imposed by the Secretary of Commerce to protect sanctuary areas

Preliminary conceptual designs of the remediation alternatives (discussed in Section 4) were developed to comply with these water quality standards.

3.5.3 Potential Location-Specific Requirements

3.5.3.1 Threatened and Endangered Species

The Endangered Species Act (16 USC 1536 [a] – [d]; 50 CFR Part 402) grants authority to and imposes requirements upon federal agencies regarding endangered or threatened species of fish, wildlife, or plants (listed species) and habitat of such species that has been designated as critical. Federal agencies must confer on any action that may jeopardize the continued existence of a species, or result in the destruction or adverse modification of critical habitat; and may include modification to the action (e.g., under the Clean Water Act permit or equivalent) to avoid the likelihood of adverse effects to listed species or their critical habitat.

The Virginia Natural Heritage Resources Information database, provided by the Virginia Department of Conservation and Recreation, was queried to identify potential threatened or endangered species in the South River. The query revealed that several threatened or endangered vascular plant, crustacean, mussel, amphibian, reptile, mammal, and bird species may potentially be present in the South River, but may not be present in particular areas addressed under this Remediation Proposal. Final corrective action designs will be developed such that potential impacts to listed species and critical habitats are minimized.

3.5.3.2 Cultural and Historic Resources

As part of the federal and/or state permit process, the responsible federal and/or state agency must consult with the State Historic Preservation Officer and the federal Advisory Council on Historic Preservation to determine if the project would affect cultural or historic sites on or eligible for the National Register of Historic Places. The Virginia Department of Historic Resources archives were queried using the online Data Sharing System to identify known and potential architectural and archaeological resources within the project area. A total of seven architectural resources (but no archaeological resources) are located within 200 feet of the South River within RRMs 0 to 2, including the listed Port Republic Road Historic District, consisting of a 35-acre area containing 122 contributing resources located on the west bank of the river. The John Crouse House dates to ca. 1808 and is located on the west

bank of the river within the Port Republic Road Historic District. Final corrective action designs will be developed such that potential impacts to these sites are minimized.

4 PHASE 1 REMEDIATION ALTERNATIVES

4.1 South River Science Team Remedial Options Program

Remediation technologies that may be capable of disrupting mercury transport, methylation, and/or exposure mechanisms are limited in number, and some have not been tested in flowing systems such as the South River or outside the laboratory. As discussed in Section 1.4, lessons learned from remediation of mercury sites demonstrate the complex nature of the problem based on the unique chemistry of mercury and its behavior in the environment. Moreover, all bank remediation technologies will release some amount of mercury during or after implementation of the remedy.

In 2009, the ROPs Work Group was initially convened by the SRST to review, evaluate, and test promising remediation technologies and approaches for the South River. Over the past 4 years, the ROPs Work Group has performed extensive scientific and engineering research aimed at advancing the most promising technologies to reduce bioaccumulation of mercury. For example, a range of university laboratory studies sponsored by DuPont are underway to test the feasibility of different treatment options. A university study is also underway to examine the potential adverse effects of biochar (a sorptive carbon medium) on benthic invertebrates. Two field pilot studies (described in Sections 4.3.1 and 4.3.2) have been implemented and another is planned in 2013 and/or 2014. The ROPs Work Group continues to survey the scientific and technical arena to identify and evaluate innovative treatment technologies that may be applicable to the South River.

4.2 Remediation Technology Screening

Between 2009 and 2012, the ROPs Work Group performed detailed reviews of a range of remediation technologies and associated implementation approaches that might be applicable to the South River system. The objectives of the screening process were to identify potentially implementable technologies and strategies, provide focus for ongoing science and engineering activities on the river, and develop a remedies matrix for this Remediation Proposal. The South River CSM, including abiotic and biotic pathway diagrams, guided the ROPs Work Group in assessing the applicability of potential remediation technologies. Technologies were sorted and rated as high, medium, or low according to their potential to address internal and external mercury loading to the South River aquatic system. Criteria

considered in this initial sorting of potential remedies built on current NCP evaluation criteria, and included the following:

- Effectiveness
  - Overall protection of human health and environment
  - Compliance with specific regulatory requirements
  - Long-term effectiveness and permanence
  - Short-term effectiveness
  - Reduction of toxicity, mobility, or volume
- Implementability
  - Technical feasibility
  - Constructability
  - Safety
  - Community acceptance
  - Regulatory acceptance
- Cost effectiveness
- Sustainability

The product of this effort was a preliminary remediation technology matrix specific to different mercury loading sources to the system. Table 4-1 summarizes the results of the technology screening evaluation for the aquatic system. Note that remediation technologies will continue to be evaluated as part of adaptive management.

Table 4-1

Preliminary Remediation Technology Screening Matrix

Potential Sources		Remediation Target	Remediation Priority[1]	Remediation Alternatives or Approach	Notes
External Sources of Mercury Loading	Site Outfalls	Reduce mercury loading to compartments in the aquatic system	High: – Most upstream source – Relatively large IHg load – IHg from outfalls may be more available for methylation than other sources of IHg – May confound potential downstream remedies	On-site source remediation (sewers, sumps, soil, SWMUs)	– Mass load and variation are quantified – Relative bioavailability of source is assumed to be high – Time required for interim remediation measure success is not known – Very high cost-benefit ratio for end-of-pipe treatment of large, dilute stream
				Filtration (membrane, sand, etc.)	
				Filtration plus pre- and post-treatment: – Thiol-based polymer – Activated carbon – Polymeric adsorption resin	
				Tin chloride ($SnCl_2$) reduction and air stripping plus capture	
	Riverbanks	Reduce mercury loading to compartments in the aquatic system	High: – Potentially most significant source of mercury to the river system – Soil-derived IHg may be more available for methylation than sediment-derived IHg	Physical stabilization or isolation	– Length of time to achieve desired objective is uncertain – Longevity of stabilization
				Chemical stabilization: – Carbon amendment and coagulants	– Length of time to achieve desired objective uncertain – Behavior/efficacy of amendments if eroded or inundated not known – Potential for deleterious ecological effects unknown
				Best management practices to reduce soil erosion: livestock management	
				Targeted removal plus stabilization or disposal	Soil may be removed as part of physical stabilization
	Floodplain Runoff	Reduce mercury loading to compartments in the aquatic system	Low: – Floodplain (adjacent to eroding banks) contributes less than 10% of total load between RRMs 0 and 10	Sediment traps	The importance of floodplain runoff is not known, but considered low based on the CSM
				Rerouting river/runs	
				Flood control measures (e.g., increase storage capacity)	
Internal Sources of Mercury Loading	Fine-Grained Sediment Deposits	Reduce importance of deposits as a source of MeHg to the aquatic environment	High: – Areas potentially support high rates of mercury methylation	Monitored natural recovery[2]	Importance of MeHg produced in bulk sediment vs. other habitats to overall food web burden not known
				(Im)permeable and/or reactive cap: – AquaBlok®, AquaGate®, Reactive Core Mat™, etc.	Changes in hydraulic sheer stress over time could destabilize cover
				Targeted removal plus stabilization/disposal	Removal may expose higher mercury concentrations at depth
				Large woody debris management	
				Maintenance/filling ditches/millraces	Account for very small proportion of MeHg to system
				Aeration/oxidation	– Effectiveness questionable – Bioavailability of IHg in sediment over time uncertain
	Interstitial Sediment	Reduce importance of sediment as a source of MeHg to the aquatic environment	Moderate: – Areas potentially support high rates of mercury methylation	MNR[2]	Reduced bioavailability of IHg over time unknown
				(Im)permeable and/or reactive cap: – AquaBlok®, AquaGate®, Reactive Core Mat™, etc.	Change in hydraulic sheer stress may occur over time
				Aeration/oxidation	
	Water Column	Reduce mercury concentrations	Moderate: – Important exposure medium at base of food web – Water column is an important transport pathway	Monitored natural recovery[2]	Length of time to achieve desired objective unknown
				Chemical treatment: – Removable carbon sorbent – Pump and treat	– Proportion of volume that must be treated unknown – Treatment longevity unknown
				Phytoremediation	
				Sediment traps	
				Aeration/oxidation	Likely that methylation areas will not respond to treatment

Notes:
1 Remediation priority from Reed Harris (2012)
2 Includes institutional controls on fish consumption by humans

Green	shading denotes a technology with a high potential to control mercury loading
Yellow	shading denotes a technology with a medium potential to control mercury loading
Orange	shading denotes a technology with a low potential to control mercury loading

4.3 Common Remediation Elements

As discussed in Section 1.3, DuPont is evaluating corrective action alternatives with VADEQ and USEPA for the remediation of upland mercury sources, impacted groundwater, and mercury discharges in the outfalls of the former DuPont Waynesboro facility, and these alternatives are regularly reviewed and discussed with the SRST. Until a final plan of corrective action is approved for the plant site, DuPont is implementing interim remedial measures that have included cleaning impacted sewers and cutting off or removing drainage structures known to be conveying mercury to the sewer system. Additional interim measures will continue to be implemented in conjunction with monitoring of groundwater and outfall discharges. Consistent with the USEPA (2005) recommendation for early source control, these coordinated upstream source control actions are included as common remediation elements of all of the South River remediation alternatives evaluated in this Remediation Proposal.

Ongoing field pilot demonstration projects are also included as common elements of this Remediation Proposal. As discussed above, the more promising sediment/soil remediation technologies for the South River have been assessed by DuPont through the ROPs Work Group, including bank stabilization to reduce the mass of bioavailable IHg entering the South River, and placement of amendments to decrease biological uptake of MeHg present in the bed sediments. Initial results have been obtained from pilot-scale demonstrations of these two technologies as summarized in Sections 4.3.1 and 4.3.2. The determination of applicability, effectiveness, safety, and feasibility will require further evaluation of these and other promising technologies in a step-wise fashion, coupled with monitoring, evaluation, and adaptive management, as described in Section 4.3.4.

4.3.1 Bank Stabilization Field Pilot Demonstration (October 2009 to Present)

As discussed in Section 2.4.3, the predominant ongoing source of IHg to the South River aquatic system is eroding banks. The ROPs Work Group selected a pilot site on the eastern (right) bank of the South River from approximately RRMs 0.11 to 0.16 (just downstream of the former DuPont Waynesboro facility). The main objective of the pilot is to evaluate reduction in riverbank erosion rates and particle-associated mercury loading to the river that can be achieved through bank stabilization. The pilot site, approximately 500 feet in length,

was selected for a number of reasons, including: evidence of bank erosion; bank soil mercury concentrations above background; DuPont property ownership; and safe, easy access to the riverbank for construction, maintenance, and monitoring. The adjacent private land use is recreational and is used only intermittently.

The bank stabilization pilot design incorporated three main components:

1. A rock toe at the base of the bank slope for slope protection
2. Soil lifts to engineer a more stable and gentler bank slope
3. Native vegetation on both the slope and top of the bank to provide further stability and habitat

In addition, woody debris was anchored to the rock toe to improve fish habitat. Weir rock was also incorporated into the toe design in the center of the pilot project area to allow for alterations of the stream bed, as recommended by the Virginia Department of Game and Inland Fisheries.

The primary pilot objectives are to: 1) evaluate reductions in riverbank erosion and loading of mercury-bound soil particles entering the South River that can be achieved through bank stabilization; 2) evaluate enhancement of existing near-bank aquatic and riparian ecosystems that can be achieved through bank stabilization; and 3) evaluate reductions in mercury concentrations within biological compartments within the river from bank stabilization. The secondary objectives of the pilot are to: 1) evaluate changes in groundwater/bank interactions between the river and the floodplain; 2) determine if the mercury methylation environment in adjacent sediment is altered by bank stabilization; and 3) determine if off-site changes in riverbank erosion and/or sediment deposition occur following bank stabilization.

The first 3 years of monitoring following construction demonstrated that mercury concentrations in bulk sediment and interstitial sediment porewater in the pilot project area decreased immediately following bank stabilization and have remained low. Uptake of IHg and MeHg by Asiatic clams was significantly reduced during the first year following bank stabilization, but subsequently increased in response to an unanticipated increase in mercury loading entering the pilot area from upstream sources (resulting from separate upland soil

remediation actions at the former Waynesboro facility). The pilot bank was stable even under the shear stresses experienced during a 10-year storm that occurred in April 2011, and vegetative cover has been established. A more detailed summary of this field pilot project is included in Appendix A.

4.3.2 In Situ Treatment Field Pilot Demonstration (July 2011 to Present)

Biochar (a carbon-based material) amendments have been shown in laboratory and field settings to reduce the biological uptake of soil- and sediment-bound mercury. A small (approximately 0.2-acre) pond located within the 2-year floodplain at RRM 9.3 was selected to field test the efficacy of biochar to reduce bioavailability. In July 2011, biochar was directly applied to half the pond, while the isolated other half was maintained as a control. The objectives of the pilot are to assess the efficacy of the amendment in reducing mercury concentrations in environmental media and to assess possible unintended consequences of the amendment on local biota. The pilot project targeted a 50% or greater reduction of IHg and MeHg concentrations in water, sediments, and biota in response to addition of biochar to half the pond.

Monitoring of surface water, sediment, porewater, and a wide range of biota has been conducted since 2011. During the first year following biochar application, significant reductions of biological uptake of mercury were observed in the pond. Monitoring is ongoing. A more detailed summary of this field pilot project is included in Appendix A.

In addition, a program to assess the efficacy of biochar in reducing the biological uptake of mercury in floodplain soils is in the planning stages.

4.3.3 Other Ongoing Research and Pilot Studies

As discussed above, the ROPs Work Group continues to review, evaluate, and test other promising technologies to reduce bioaccumulation of mercury in the South River. Over the past 4 years, the ROPs Work Group has performed extensive scientific and engineering research aimed at advancing the most promising technologies to reduce bioaccumulation of mercury (Table 4-2). The ROPs Work Group will continue to survey the scientific and

technical arena to identify and evaluate innovative treatment technologies that may be applicable to the South River.

Table 4-2

Remedial Options Program Work Group Research Initiatives

University Research Initiative	Lead Researcher	Research Objective	Status	Documentation
Smithsonian Environmental Research Center and University of Maryland – Baltimore County	Dr. Cindy Gilmour Dr. Upal Ghosh	Assess the efficacy of using amendments (activated carbon, biochar, Thiol Samms, and organoclay) to mitigate methylmercury production and bioaccumulation in mercury-contaminated sediments	Complete	Final report
		Further assess the efficacy of activated carbon and biochar to mitigate the bioaccumulation of methylmercury and assess observed methylmercury accumulation on solids	Complete	Final report
James Madison University	Dr. Robert Brent	Assess the efficacy of using mesocosms for investigating the dynamics of mercury uptake by periphyton	Complete	Presentation
University of Waterloo	Dr. Carol Ptacek	Laboratory batch and column studies to characterize South River soil and sediment and investigate potential treatment approaches to reduce mercury leaching	Ongoing	Master's thesis posters
University of Texas	Dr. Danny Reible	Development of a thin film diffusion gradient probe to passively assess porewater depth profiles of total mercury and methylmercury concentrations in South River sediment	Ongoing	Presentations Posters
University of Delaware	Dr. Donald Sparks Dr. Olesya Lazareva	Understanding geochemical and hydrological dynamics that influence transformation and mobilization of mercury from South River bank soils	Ongoing	Pending
University of Texas	Dr. Danny Reible	Assess the potential use of in-stream reactive caps incorporating absorbent materials like activated carbon or biochar to reduce bioaccumulation of methylmercury	2013	Pending
William and Mary – VIMS	Dr. Michael Newman	Assess the impact of detrital feeding biota exposed to newly amended sediments and biochar amended sediments allowed to age over several months	2013	Pending

University Research Initiative	Lead Researcher	Research Objective	Status	Documentation
James Madison University	Dr. Robert Brent	Extend the use of the mesocosms to assess the efficacy of adsorptive media like biochar or activated carbon to treat the water column of the South River and develop in-stream habitat structures incorporating activated carbon or biochar to improve physical habitat	2013	Pending
To be determined	To be determined	Assess local sources of organic carbon and assess the efficacy of using biochar in the floodplain to reduce bioaccumulation by terrestrial biota	2013	Pending

4.3.4 Adaptive Management

As discussed in Section 1.6, because of the South River's size and complexity, the inherent uncertainty associated with mercury cycling in this river system, and challenges noted from remediation of other mercury sites (Section 1.4), an adaptive management approach for remediation has been integrated into this Remediation Proposal. Adaptive management is particularly well suited to this Remediation Proposal, in part because remedial measures will be implemented in phases over 5 to 10 years or more, providing an opportunity to effectively integrate lessons learned. It will facilitate testing and monitoring remediation actions, particularly where there is a need to assess effectiveness prior to undertaking subsequent phases of corrective action, as is the situation on the South River. Where actions do not result in measureable improvements, changes in technologies or applications may be required. Implementation of corrective actions in the South River will also require landowner acceptance and flexibility to consider other stakeholder needs. Although the priorities and values of different landowners and other stakeholders can be considered through their reviews of suggested approaches, they can also be directly incorporated into the evaluation of remediation options with the use of a decision analytical approach in adaptive management.

The USACE Engineer Research and Development Center is assisting DuPont in developing an adaptive management plan that consists of the following three key components (Figure 4-1):

1. **Decision Model** to predict the effects of remediation alternatives on monitoring endpoints and objectives (decision criteria)
2. **Decision Analysis** to prioritize remediation alternatives relative to specific objectives, predicted performance, stakeholder preferences, and uncertainties
3. **Monitoring and Analysis Plan** to collect and analyze data about key conditions that test the decision model's predictions and assumptions and inform future management decisions

Use of the adaptive management learning approach, along with relative risk modeling currently being performed by the SRST (see Section 3.1.1), is expected to provide

quantitative feedback on net environmental improvements resulting from remediation actions, providing benefits to this Remediation Proposal.

Figure 4-2 illustrates the adaptive management cycle that will be utilized during the South River and SFS River phased remedial actions, and identifies key steps in the process. The adaptive management and relative risk models will serve as tools throughout the cycle for refinement of remediation approaches based on effectiveness, implementability (including stakeholder preferences), ecological effects, and cost.

Prior to constructing Phase 1 river corrective actions (RRMs 0 to 2), on-site Waynesboro Plant interim measures that support the long-term RAOs will have been implemented and monitored. The plant site interim measures monitoring results will be used to assess the effectiveness of the plant corrective actions and possibly to modify or refine the aquatic CSM.

As phased remedial measures are implemented in the river, SRST activities and studies will continue. For example, the SRST ROPs Work Group will continue to identify, evaluate, and test promising treatment and remediation technologies. The challenges associated with constructing remediation technologies in a flowing river will be addressed by identifying, evaluating, and testing feasible deployment technologies that do not create other adverse impacts. The SRST Outreach Sub-team is developing a plan that identifies affected stakeholders and a strategy for effective communication and feedback into the planning process. The outreach plan may be adjusted as the remediation process proceeds. Furthermore, an adaptive management cycle similar to the process summarized in Figure 4-2 may also be developed for remedial measures to be implemented in the floodplain, depending upon the effects of aquatic remediation on the terrestrial food web.

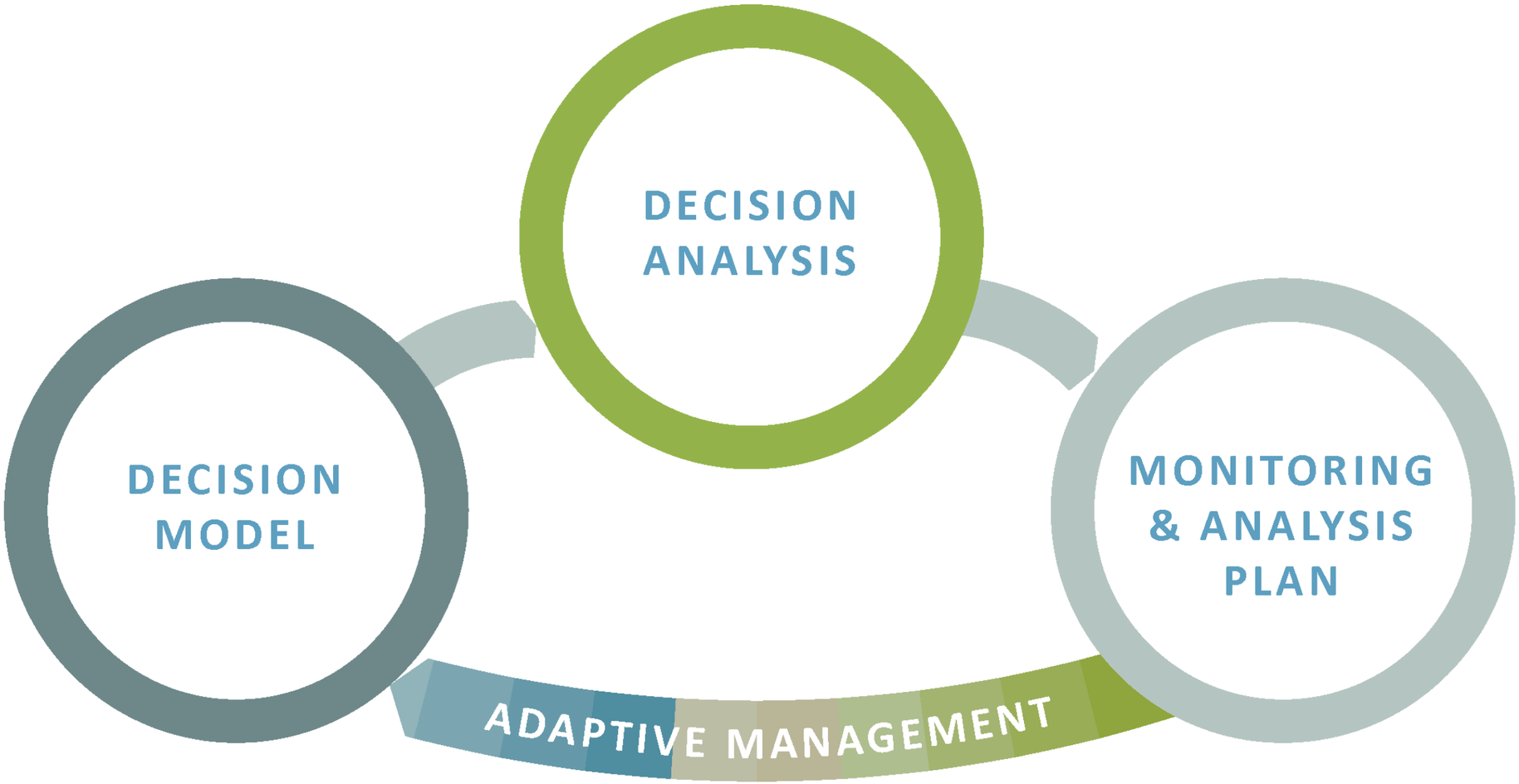

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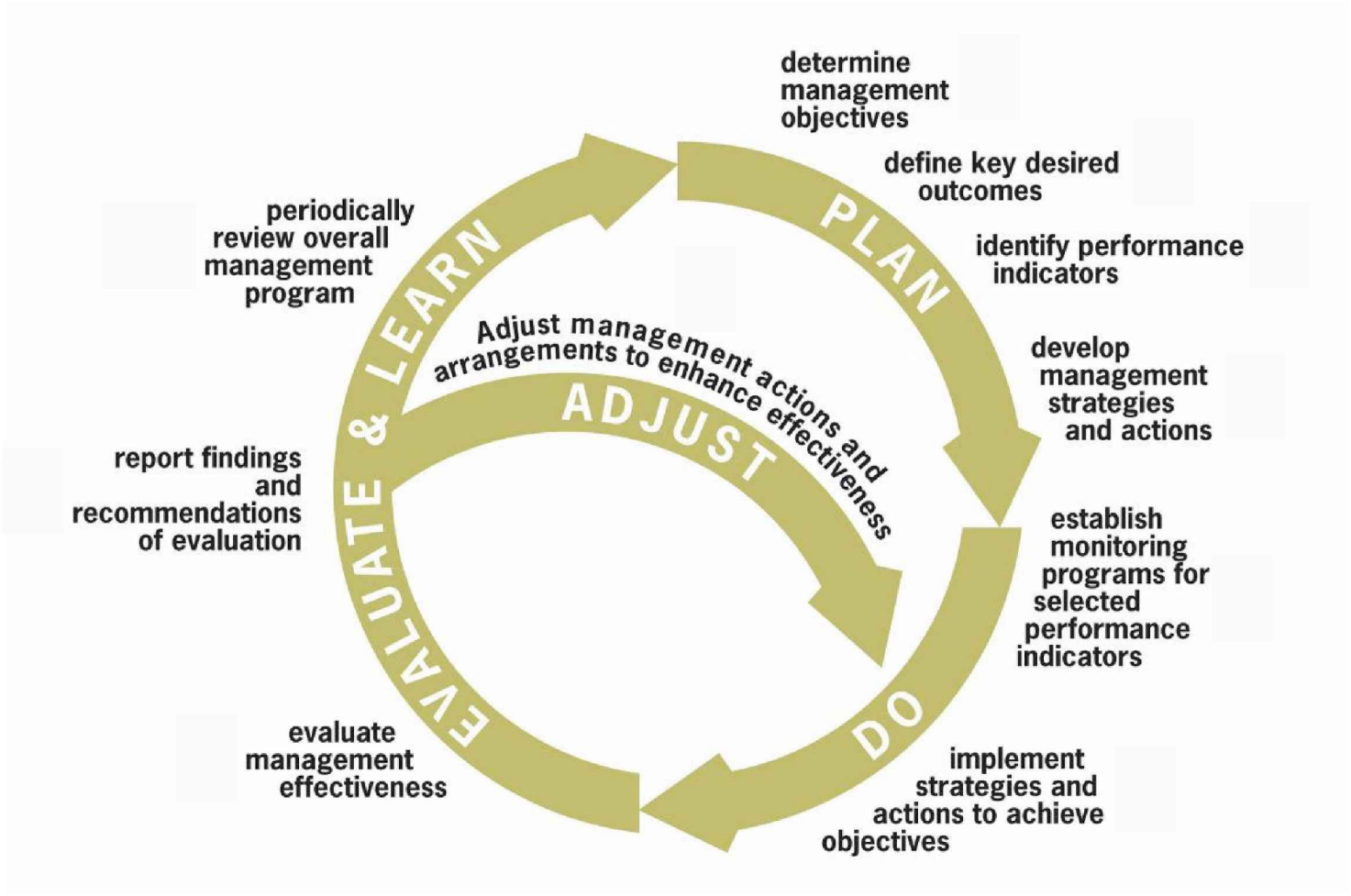
Figure 4-1
Adaptive Management Components
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River



SOURCE: Jones 2005. Tasmanian Parks & Wildlife Service.

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Figure 4-2
The Adaptive Management Cycle
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

4.4 Phase 1 Bank Management Area Remediation Alternatives

The Phase 1 BMA alternatives evaluated in this Remediation Proposal constitute broad categories of technologies that allow flexibility as future investigation results, agency reviews, stakeholder discussions, and corrective action designs progress. Each alternative includes various remediation technologies that may be applicable depending on unique characteristics of individual BMAs and/or property parcels. For the purpose of this Remediation Proposal, specific technologies were combined to develop the following BMA alternatives:

- Alternative 1: Institutional Controls and Monitoring
- Alternative 2: Enhanced Vegetative Stabilization (Figure 4-3)
- Alternative 3: Structural Stabilization (Figure 4-4)
- Alternative 4: Removal and Disposal (Figure 4-5)

For comparative evaluation purposes, the BMA alternatives detailed in Sections 4.4.1 through 4.4.4 were developed to have broad applicability to the South River, but include different combinations of remediation technologies to highlight the tradeoffs of different Phase 1 BMA remediation approaches. In addition, due to the varying nature of bank characteristics and multiple stakeholders, it may be appropriate to carry forward a range of the most promising BMA alternatives in the recommended remedy identified in Section 6.

4.4.1 Alternative 1: Institutional Controls and Monitoring

As summarized in Table 3-1, certain BMAs contain bank mercury deposits with elevated IHg concentrations that are covered by moderately stable, well-vegetated slopes. For these and potentially other BMAs, more intrusive bank stabilization alternatives may not be necessary or appropriate. However, institutional controls—potentially including conservation easements, along with long-term bank monitoring and adaptive management—may be warranted to verify the continued stability of these BMAs. Bank monitoring may include a range of visual observations to qualitatively or quantitatively evaluate long-term BMA stability, including topographic monitoring and accompanying surveys of bank pins, vegetative cover, vegetative type and density, changes in visual signs of erosion, and other appropriate metrics. Under all four BMA alternatives, long-term monitoring elements would be incorporated into the South River Monitoring Plan after corrective actions are selected

and upon remedy implementation. The details of the latter will be developed under VADEQ agency oversight in consultation with USEPA and as a collaborative effort with other members of the SRST.

4.4.2 Alternative 2: Enhanced Vegetative Stabilization

Enhanced vegetative stabilization incorporates a range of remediation technologies that use the existing bank soils and slopes to enhance the bank's stability by promoting native vegetation. This alternative includes location-specific combinations of relatively non-intrusive technologies including canopy management, enhancing native vegetation, at-risk tree management, placement of reactive amendments, toe protection, and long-term bank monitoring and adaptive management. Other promising treatments—including toe vegetative practices, live stakes, soil/geo lifts, and innovative alternatives—would also be considered during corrective action design. Within RRMs 0 to 2, a range of individual BMAs (or portions of BMAs) may have slopes amenable to enhanced vegetative stabilization techniques (Table 3-1). Figure 4-3 presents a schematic cross-section of the enhanced natural stabilization technologies incorporated into this BMA alternative. Similar to the institutional controls and monitoring alternative described above, enhanced vegetative stabilization also includes bank monitoring to evaluate long-term BMA stability, including topographic monitoring and accompanying surveys of bank pins, vegetative cover, vegetative type and density, changes in visual signs of erosion, and other appropriate metrics, along with adaptive management.

4.4.3 Alternative 3: Structural Stabilization

Similar to enhanced vegetative stabilization, structural stabilization also incorporates one or more techniques that work with the existing bank soils and native vegetation to stabilize a BMA or a portion of a BMA. Structural stabilization uses a more intrusive approach than enhanced vegetative stabilization as it may include installing other bank stability and reinforcement products and techniques. Structural stabilization may include location-specific combinations of technologies including minor bank reshaping as needed, placement of reactive amendments (potentially to a greater degree than under Alternative 2), slope stabilization focusing on green technologies (e.g., native vegetation and canopy management), slope stabilization using hard stabilization methods (e.g., riprap or chemical

stabilization), toe protection, and long-term bank monitoring and adaptive management. Other in-stream options such as the use of cross-vanes, j-hooks, and other structures could also be considered on a site-by-site basis during corrective action design. Figure 4-4 presents a schematic cross-section of the structural stabilization technologies incorporated into this BMA alternative. Similar to the alternatives described above, structural stabilization also includes bank monitoring to evaluate long-term BMA stability, including topographic monitoring and accompanying surveys of bank pins, changes in visual signs of erosion, and other appropriate metrics, along with adaptive management. Structural stabilization was the technology implemented at the bank stabilization field pilot demonstration.

4.4.4 Alternative 4: Removal and Disposal

This alternative involves the removal and off-site disposal of the targeted bank deposit. Slope reconstruction following removal may involve additional removal or shaping of bank soils and removing/replacing overlying vegetation to construct a stable bank based on the specific bank characteristics. Figure 4-5 presents a schematic cross-section of the bank removal alternative. No post-construction bank monitoring or management beyond limited invasive vegetation and physical (e.g., sediment transport) monitoring would likely be required under this option.

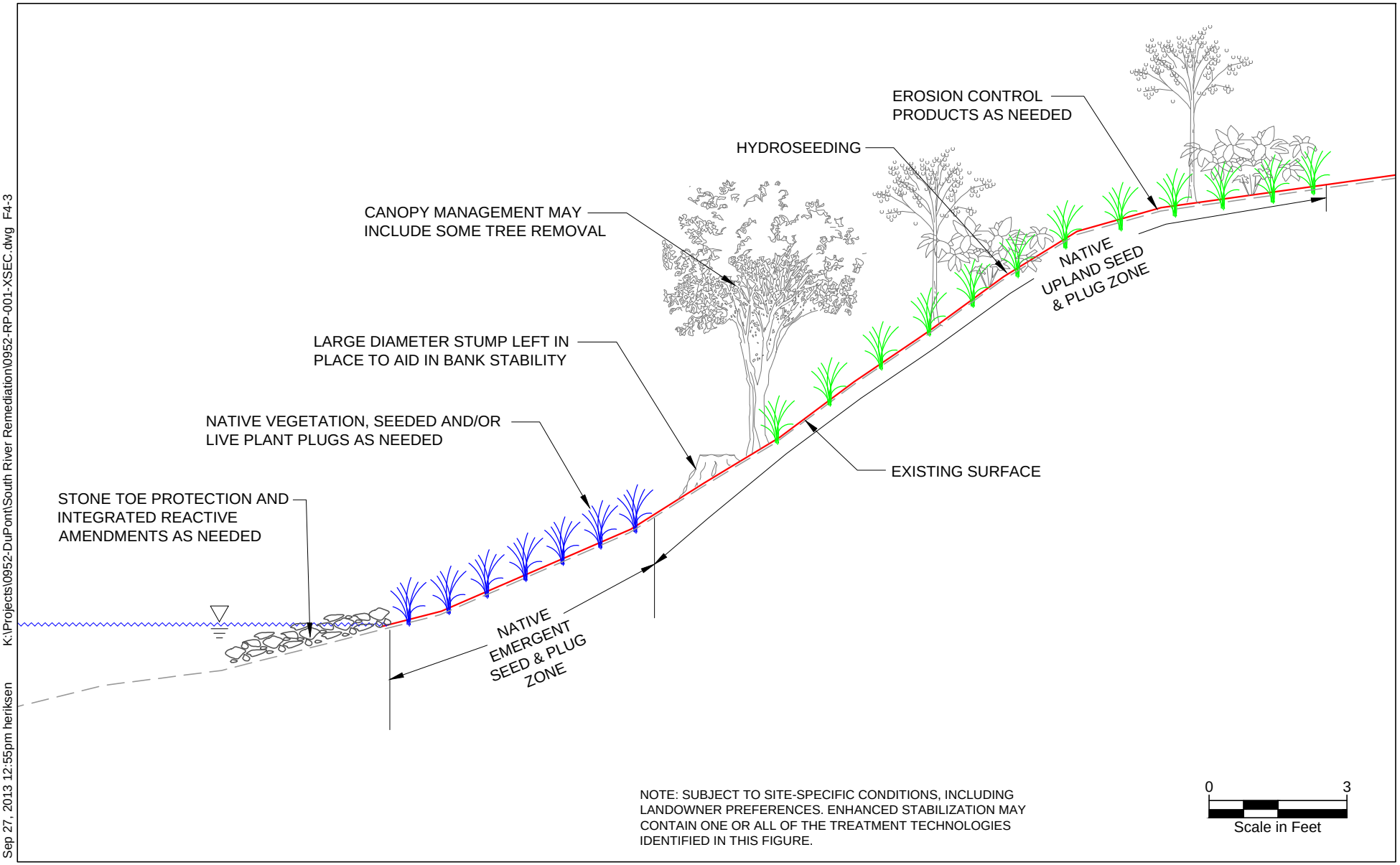

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Figure 4-3
Enhanced Vegetative Stabilization BMA Alternative
Remediation Proposal
South River

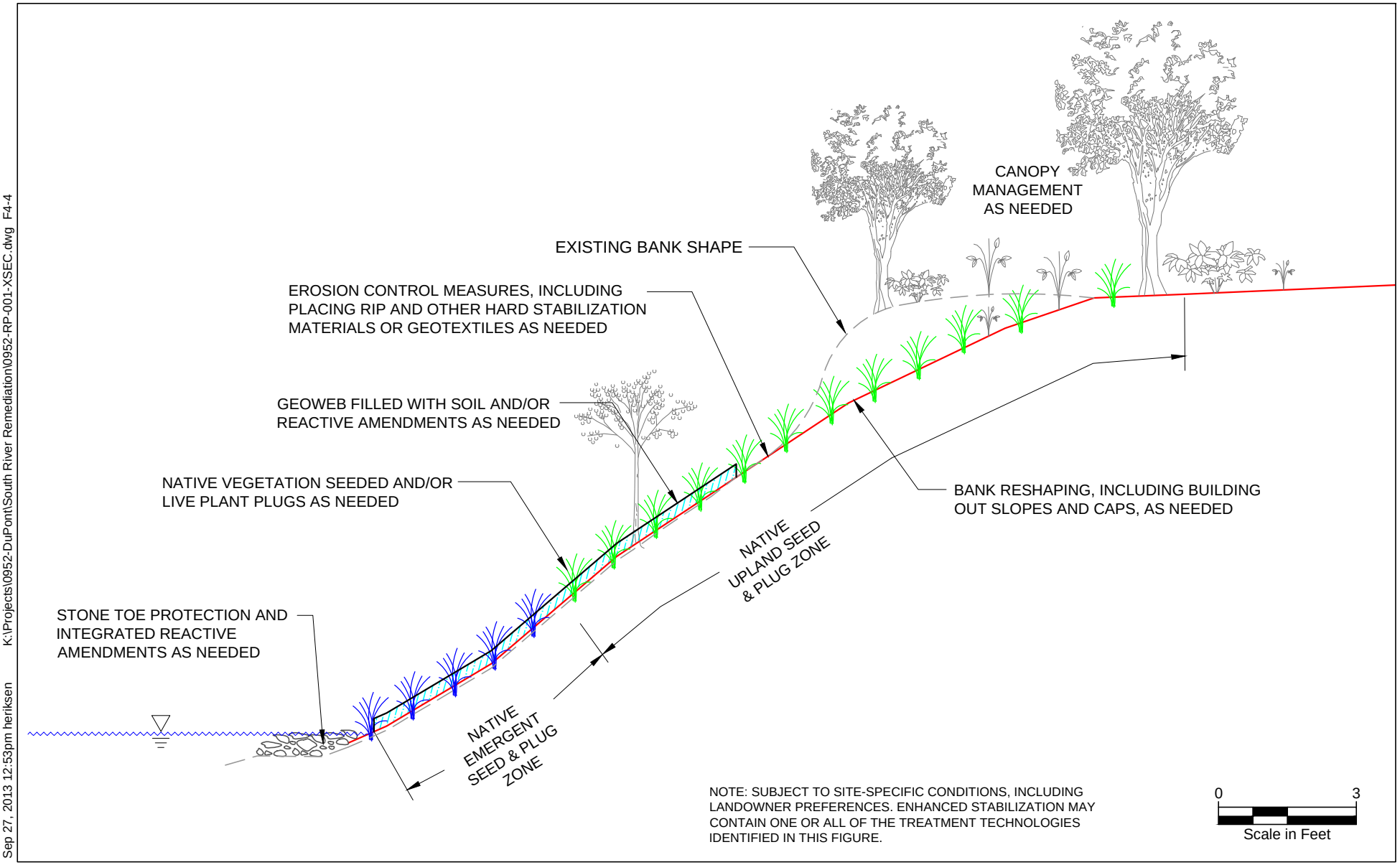

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Figure 4-4
Structural Stabilization BMA Alternative
Remediation Proposal
South River

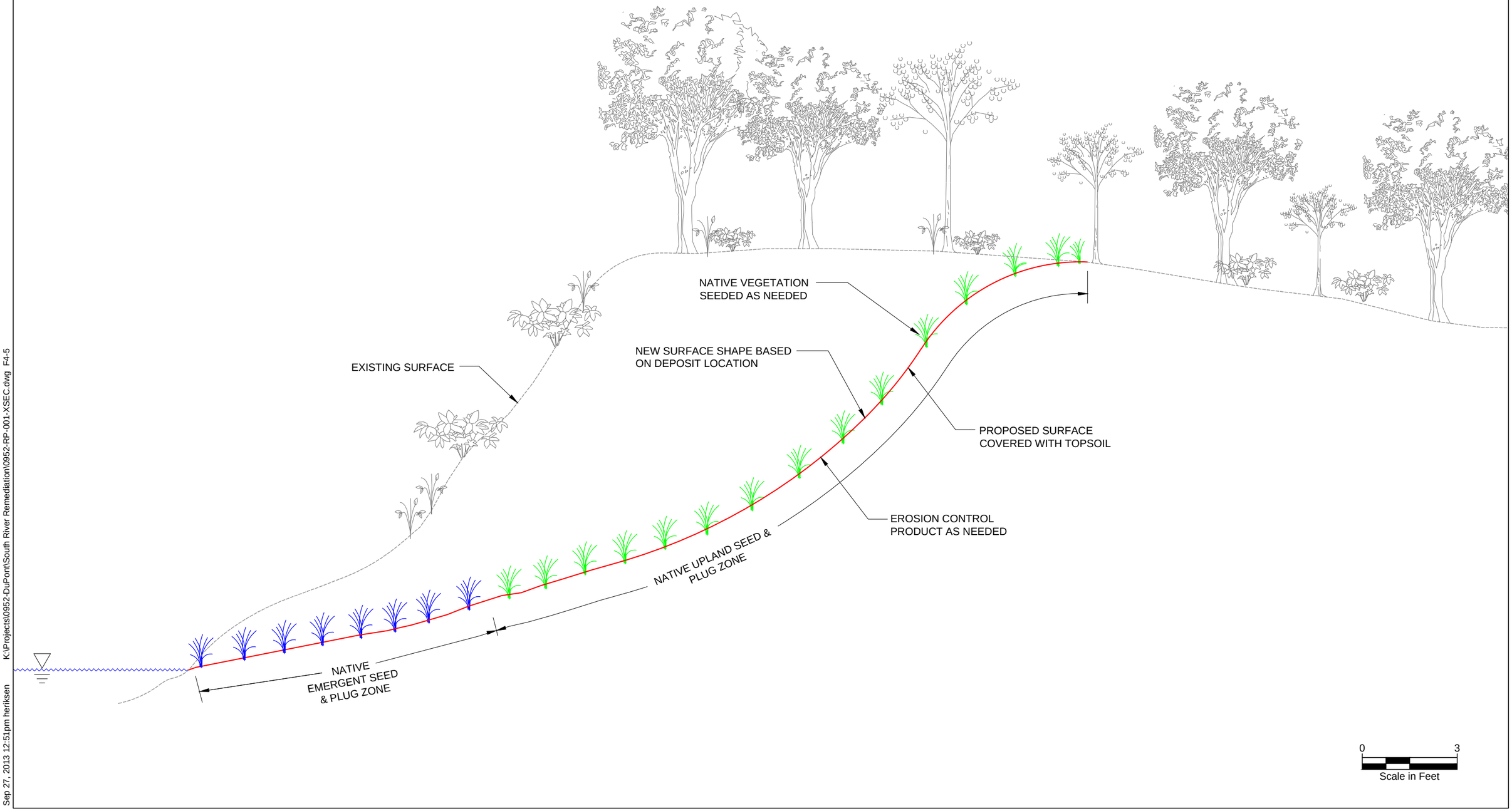

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Figure 4-5
Removal and Disposal BMA Alternative
Remediation Proposal
South River

5 PHASE 1 REMEDIATION ALTERNATIVE EVALUATION CRITERIA

The BMA remediation alternatives outlined in Section 4.4 are evaluated in this section against NCP and green and sustainable remediation criteria, as described below.

5.1 National Contingency Plan Criteria

Three main evaluation criteria—effectiveness, implementability, and cost—have been established by USEPA to address the overall objectives of the NCP (USEPA 1988).

5.1.1 Effectiveness

The evaluations of effectiveness of the different BMA remediation alternatives in this Remediation Proposal are focused on reducing MeHg exposure and improving bank and in-channel habitat functions in both the short- and long-term, as described in Section 3.2. This NCP evaluation criterion is further subdivided into five categories:

- **Overall Protection of Human Health and the Environment** addresses the overall ability of an alternative to eliminate, reduce, or control potential MeHg exposures in both the short- and long-term.
- **Compliance with Regulatory Requirements** assesses whether the alternative attains the identified chemical-specific, action-specific, and location-specific regulatory requirements (see Section 3.5).
- **Short-term Effectiveness** assesses effects and potential risks to human health and the environment related to construction and implementation of each alternative. Considerations include short-term impacts on workers and the community during the remediation, potential environmental effects of the response, effectiveness of mitigation measures, and the time until protection is achieved, also considering short-term habitat improvements resulting from remedy implementation.
- **Long-term Effectiveness and Permanence** evaluates the alternative's long-term effectiveness and permanence with respect to the ability to achieve long-term RAOs. Factors considered under this criterion include the magnitude of residual risk remaining after implementation and the adequacy and reliability of control measures (e.g., containment systems and institutional controls), also considering long-term habitat improvements resulting from remedy implementation.

- **Reduction of Toxicity, Mobility, or Volume through Treatment** addresses the degree to which an alternative reduces the toxicity, mobility, or volume of mercury in the South River.

5.1.2 Implementability

This NCP evaluation criterion is further subdivided into two categories:

- Technical feasibility, administrative feasibility, and availability of services and materials required for implementation
- USEPA, VADEQ, stakeholder, and community acceptance of the alternative

5.1.3 Cost

This NCP criterion evaluates present-worth (present-day dollars) direct and indirect construction, operating, and maintenance costs of implementing an alternative.

5.2 Green and Sustainable Remediation Practices

In addition to the NCP criteria, this Remediation Proposal includes an evaluation of each Phase 1 remediation alternative relative to sustainable remediation practices and green remediation. Sustainability aims to balance and optimize the environmental, social, and economic benefits of any action. Sustainable remediation is broadly defined as a remedy or a combination of remedies whose net benefit on human health and the environment is maximized through the judicious use of limited resources. Consistent with DuPont's corporate sustainability goals and the Sustainable Remediation Forum (SURF 2013; Ellis and Hadley 2009), the core elements of a sustainable remediation analysis include the following:

- Energy use
- Air quality/greenhouse gas emissions
- Water quality and quantity
- Sediment/soil quantity and quality
- Ecological services
- Human services and safety
- Economics

Recent USEPA guidance (2010 and 2012) encourages the incorporation of site footprint analysis, net results analysis, and use of BMPs associated with remediation. These concepts were incorporated into the sustainable remediation evaluation.

Green and sustainability metrics are summarized in Appendix B for BMA remediation alternatives. The preliminary sustainability analysis of the BMA remediation alternatives, presented in Appendix B, evaluates shorter term (i.e., construction) and longer term (i.e., monitoring, maintenance, and adaptive management) impacts for each alternative. Where possible, efforts will also be made to examine and incorporate green and sustainable remediation practices into the design and implementation of the response options.

5.3 Phase 1 Bank Management Area Alternatives Evaluation

This section evaluates each of the BMA alternatives in accordance with the NCP criteria specified in Section 5.1. The BMA alternatives evaluated in this Remediation Proposal are:

- Alternative 1: Institutional Controls and Monitoring
- Alternative 2: Enhanced Vegetative Stabilization
- Alternative 3: Structural Stabilization
- Alternative 4: Removal and Disposal

As discussed in Section 8, final designs for individual BMAs (or portions of BMAs) will be based on landowner preferences, access agreements, and regulatory agency approvals; final designs will also be tailored to site-specific bank characteristics. The remainder of this section includes the evaluation of each of the BMA alternatives in accordance with NCP criteria.

5.3.1 Effectiveness

Effectiveness includes the evaluation of the following elements: protection of human health and the environment; compliance with regulatory requirements; short-term effectiveness; long-term effectiveness and permanence; and reduction of toxicity, mobility, or volume through treatment. These elements are discussed in Sections 5.3.1.1 through 5.3.1.5.

5.3.1.1 Protection of Human Health and the Environment

This element assesses whether each alternative provides adequate protection of human health and the environment. The assessment evaluates the overall ability of an alternative to eliminate, reduce, or control potential MeHg exposures in both the short- and long-term.

Alternative 1 (Institutional Controls and Monitoring) would apply appropriate controls to aid in mitigating short-term exposure to mercury and monitoring to verify both the short- and long-term conditions and stability of banks. Alternative 1 does not include construction and thus would not provide an additional level of protection as compared to the other alternatives. The implementation of institutional controls may aid in preventing direct human exposure, thereby mitigating a component of the human exposure pathway; however, it would not comprehensively ensure protection. Monitoring would be used to confirm the short- and long-term remedy protectiveness already associated with well-vegetated and stable banks. For example, if monitoring concludes that a specific BMA is well-vegetated with stable slopes that are protective of human health and the environment, then no further action may be appropriate. Conversely, if monitoring results indicate erosion or loss of vegetation, implementation of bank stabilization or other actions to provide further protection may be selected as part of the adaptive management process. Overall, institutional controls would provide a level of protection to the human exposure pathway but would not mitigate ecological risks, should they be present. Monitoring would be used to verify the conditions on a periodic basis to evaluate the current level of protection and provide a mechanism to implement adaptive management strategies, as conditions warrant.

Alternative 2 (Enhanced Vegetative Stabilization) would provide short- and long-term protection of human health and the environment by mitigating exposure pathways and enhancing natural stabilization, further reducing potential erosion and transport of mercury-impacted material from certain BMAs or portions of BMAs where this alternative is implemented. Short-term releases of IHg may occur following completion of construction activities until the plant community fully develops. The length of time necessary for vegetation to reach maturity will vary among BMAs, depending on factors such as the viability of the bank soils, the health of the existing plant community, the direction of the bank face (south-facing banks receive more sunlight), and the shear stresses exerted on the bank (high-stress events may directly damage immature plants or undercut slopes). Overall,

the herbaceous plant community would be expected to reach maturity in 1 to 2 years. A monitoring and maintenance program would be implemented to monitor short-term conditions and ensure the long-term protectiveness of this alternative. If monitoring results indicate erosion or loss of vegetation, bank stabilization or other actions to provide further protection may be implemented as part of the adaptive management process. Enhanced vegetative stabilization would be a minimally intrusive remedy, working with the existing ecosystem to maintain the stability of the banks through enhanced growth of ground cover and understory plants. Enhanced natural stabilization is expected to have the added effect of improving existing ecosystem functions. Overall, Alternative 2 is anticipated to provide protection to human health and the environment in both the short- and long-term.

Alternative 3 (Structural Stabilization) would provide short- and long-term protection to human health and the environment by mitigating exposure pathways and further enhancing natural stabilization processes. Individual BMAs or portions of BMAs may have slopes amenable to in-place stabilization using combinations of bank reshaping, armor- or vegetation-based reinforcement, active management of understory and canopy vegetation, and toe protection.

Short-term releases of IHg may occur following completion of construction activities until the plant community fully develops, though the implementation of structural engineering options such as armoring applications would likely accelerate recovery. Some monitoring to verify short- and long-term conditions would be required to manage in-place stabilization remedies. If monitoring results indicate erosion or loss of vegetation, bank stabilization or other actions to provide further protection may be implemented as part of the adaptive management process. Since the degree of stabilization and protection is more robust compared with Alternatives 1 and 2, the long-term monitoring requirements of in-place stabilization are expected to be less frequent and less detailed than for enhanced vegetative stabilization. However, in-place stabilization is a more intrusive remedy that could require replacing or substantially altering the existing ecosystem to stabilize the banks; more than several years may be required before existing ecosystem functions are fully restored.

The structural stabilization alternative could require site access for equipment, including roads and staging areas for equipment transport and equipment decontamination. In areas of

relatively dense vegetation or in areas where access is limited, the BMA and surrounding areas may require extensive clearing and preparation to allow equipment access to the bank, at least temporarily disrupting existing ecosystem functions. On residential properties, the BMA and adjacent properties may require some clearing and temporary alterations to allow equipment access and remedy implementation. Overall, Alternative 3 is anticipated to provide protection to human health and the environment both in the short- and long-term.

Alternative 4 (Removal and Disposal) would provide short- and long-term protection of human health and the environment by removing bank deposits. Short- or long-term monitoring following construction would not be required because the deposits would be permanently removed from the environment. Removal would be the most intrusive remedy, resulting in temporary destruction of existing bank ecosystem functions. Though the BMA would be replanted, decades may be required before existing ecosystem functions are fully restored. Following construction, exposure pathways would be eliminated, thereby providing short- and long-term protectiveness to both human health and the environment.

5.3.1.2 Compliance with Regulatory Requirements

This element assesses whether the alternative attains the identified chemical-specific, action-specific, and location-specific regulatory requirements detailed in Section 3.5.

Alternative 1 (Institutional Controls and Monitoring) would not include any construction; therefore, no action-specific or location-specific regulatory requirements would apply.

Alternative 2 (Enhanced Vegetative Stabilization) would not include soil removal or reshaping; therefore, no action-specific or location-specific regulatory requirements would apply. However, if focused toe protection using armoring material is required, this alternative would require demonstration that the armor material would not negatively impact threatened or endangered species or flood elevations beyond the 0.1-foot limit mandated by the Commonwealth of Virginia (Floodplain Management Regulations; Code 10.1-602). Preliminary screening-level hydraulic analyses of this alternative were performed using the Hydrologic Engineering Centers River Analysis System (HEC-RAS) to evaluate projected post-construction changes in flood elevations in RRMs 0 to 2 under an approximate

100-year flood event. The preliminary HEC-RAS modeling results suggest that, depending on the specific designs and layouts (e.g., toe protection placed on adjacent banks), localized areas in RRMs 0 to 2 could potentially experience a 100-year flood elevation increase marginally above the 0.1-foot limit mandated by the Floodplain Management Regulations. However, as was the case for the bank stabilization field pilot demonstration (see Section 4.3.1), appropriate modifications to the stabilization designs and layouts can be incorporated during corrective action design to ensure that this alternative complies with action-specific regulatory requirements.

Alternative 3 (Structural Stabilization) would also have to demonstrate that the placement of top soil, armor stone, or other hard stabilization structures, or any changes to the bank slopes, would not negatively impact threatened or endangered species or impact flood elevations beyond the 0.1-foot limit mandated by the Floodplain Management Regulations. Similar to the results discussed above for Alternative 2, preliminary HEC-RAS modeling analysis to assess impacts to flood elevations indicates that this alternative can also be designed to comply with action-specific regulatory requirements. The potential for other hydraulic impacts resulting from structural stabilization actions (e.g., higher potential for downstream erosion) would also be assessed during corrective action design and permitting. Final designs would be developed to minimize potential impacts, consistent with the bank stabilization pilot.

Alternative 4 (Removal and Disposal) would have to demonstrate that the excavation of bank soils and associated extended habitat restoration timeframes would not negatively impact threatened or endangered species, as well as cultural and historic resources and other location-specific regulatory requirements. Final corrective action designs would be developed to minimize potential impacts to comply with action-specific regulatory requirements.

5.3.1.3 Short-term Effectiveness

This element assesses the short-term effects and potential risks to human health and the environment related to construction and implementation of each alternative. Considerations include short-term impacts on workers and the community during the remediation; potential

environmental effects of the response such as impacts to habitats, ecological communities, and potential releases to the environment; effectiveness of mitigation measures; and the time until protection is achieved. Short-term impacts to the environment are based on the extent of impacts and duration of construction (i.e., the greater the impacted area, bank removal volume, and duration, the greater the short-term impact).

Alternative 1 (Institution Controls and Monitoring) would not include any construction activities; thus, there are no short-term construction-related impacts associated with this alternative.

Alternative 2 (Enhanced Vegetative Stabilization) has fewer construction activities than Alternatives 3 and 4 and would not modify existing bank soils, but rather would promote the development of erosion-resistant vegetation through management of the canopy vegetation, at-risk trees, and vegetative planting (Figure 4-3).

Impacts on the Environment and Local Communities

Impacts to the environment and local communities are expected to be minimal for Alternative 2. However, there would be impacts to the floodplain and shoreline areas due to support activities, including construction of staging areas and access roads that would result in temporary removal of plant and wildlife habitat in the upland area. Such impacts are expected to be minimal because heavy construction equipment is not expected for implementation of this alternative unless toe protection is required, which may require the transport of relatively limited amounts of armoring material to the edge of the river, possibly requiring access through the floodplain.

The length of time necessary for the plant community to fully develop will depend on the viability of the bank soils, the health of the existing plant community, the direction of the bank face, and the shear stresses exerted on the bank. The removal of at-risk trees under this BMA alternative will improve short-term effectiveness by reducing threats to bank slope destabilization. When canopy management is the only action requiring equipment access, these activities can be successfully completed in the winter when the understory vegetation is dormant, to protect the vegetation.

Community impacts due to increased truck traffic, primarily resulting from the delivery of construction materials, are expected to be minimal. Disruption to the community due to dust and noise is also a short-term risk that may require further consideration.

Risks to Remediation Workers

Implementation of Alternative 2 would result in some health and safety risks to site workers due to the proximity of nearshore work and aquatic-based hazards. Based on the scope of Alternative 2, it is anticipated that the risks associated with implementation would be mitigated, although not eliminated, through the development of an Occupational Safety and Health Administration (OSHA)-compliant health and safety program (i.e., OSHA 1910-120). In addition, quality control procedures during construction and BMPs would further reduce risks to workers.

Alternative 3 (Structural Stabilization) may incorporate a range of remediation technologies and techniques, including bank reshaping as needed, slope stabilization using a range of different options (emphasizing green and sustainable approaches that include canopy management and native vegetation, but also using other hard stabilization techniques as needed), and/or toe protection (Figure 4-4). Bank reconstruction would include removal and/or shaping of bank soils, including the overlying vegetation, from areas where BMA slopes may not be stable. Reshaping would be targeted to have a low impact on the tree and vegetation community, but some impact would be unavoidable. This would be accomplished using earth-moving equipment—including backhoes, excavators, and bulldozers—and may require construction of an access road to the BMA. After the final slope is constructed, the surface of the disturbed soils would be stabilized and restored with native vegetation or other material.

Impacts on the Environment and Local Communities

Localized bank removal may be a component of this alternative, depending on the degree of regrading that may be required to facilitate implementation of structural stabilization. If less aggressive stabilization techniques are applicable for the bank/river characteristics, fewer short-term construction-related impacts would occur. Inadvertent sloughing of bank material during construction (e.g., from construction equipment disturbance) could affect the water column of the adjacent South River and be transported outside the construction zone.

Such occurrences may contribute to temporary increases in turbidity and/or THg concentrations within the water column. Temporary controls such as turbidity curtains would be implemented to limit bank soil transport from the construction zone.

There would be additional impacts to the floodplain and shoreline areas due to heavy construction equipment including construction of staging areas and access roads that would result in removal of plant and wildlife habitat in the upland area. Such impacts would be a function of the magnitude of removal for a particular BMA as well as the selected location for support facilities and access points. Based on the specifics of this alternative, only minor upland modifications for staging and access would be required, but this would be evaluated during corrective action design on a case-by-case basis.

Following construction, restoration would be completed to reestablish vegetation and promote bank stability. Development of erosion-resistant vegetation and stable slopes under this BMA alternative would likely occur over 1 to 2 years, with native vegetation reaching maturity in 3 to 5 years, similar to Alternative 2 described above. Where applied, hard stabilization techniques would be immediately effective with respect to erosion resistance. Bank angle directly influences short-term effectiveness, as steeper banks that are addressed through the use of vegetation-based stabilization techniques would be more susceptible to erosion during the interim period when the desired plant community has not reached maturity.

Community impacts could occur due to increased truck traffic, resulting from the transportation of bank removal and restoration materials delivered to the site. The increased truck traffic would persist for the duration of the alternative's construction as well as increase the risk for accidents along the transport routes. Disruption to the community due to dust and noise is also a short-term risk that may require further consideration during corrective action design. In the event that dust and noise from remediation activities becomes a nuisance, BMPs and other mitigation measure could be implemented, including wetting roads, stockpiles, and staging areas; modifying working hours and durations; using noise shrouds; and other approaches.

Risks to Remediation Workers

Implementation of Alternative 3 would result in health and safety risks to site workers, especially considering the nature of the work being conducted on the banks and in the nearshore area due to factors such as height of banks, slope stability, and water hazards. Risks to site workers increase as the duration and scope of the alternative increases (e.g., more equipment and traffic). Similarly, soil removal and related transportation have the potential to produce airborne particulate emissions that could impact site workers. Controls such as those required under OSHA 1910-120 can be implemented to manage and mitigate these short-term risks, but risks cannot be completely avoided. Controls could include erosion and sedimentation control measures associated with access and support areas, traffic planning to minimize the potential for vehicle accidents, and proper construction BMPs (e.g., lined dump trucks equipped with spill plates, covering materials in open trucks, dust suppression, and limiting truck speed on site).

Alternative 4 (Removal and Disposal) would include removal of the existing vegetation, including trees and bank soil, to remove deposits with elevated IHg concentrations. Following removal, grading of bank soils would be completed to facilitate restoration and stability. Construction activities would be completed utilizing earth-moving equipment including backhoes, excavators, and bulldozers. After the final slope is constructed, the surface of the disturbed soils may be vegetated or armored.

Impacts on the Environment and Local Communities

Due to the intrusive nature of removal and the transportation operations required, Alternative 4 has the potential to impact the adjacent South River and local air and biota.

Inadvertent sloughing of bank material during construction could affect the water column of the adjacent South River. Such occurrences may contribute to temporary increases in turbidity and/or THg concentrations within the water column. Temporary structures such as cofferdams, deflection walls, turbidity curtains, or similar applications could aid in the removal activities to avoid misplacement of materials, though such structures could temporarily impact the flow of water in the river and could increase flow velocities and sediment scour by reducing the river cross section. As a result, this alternative has the

greatest potential to have an impact on neighboring properties by temporarily altering the hydrology of the river.

There would be additional impacts to the floodplain and shoreline areas due to support activities including construction of staging areas and access roads that would result in removal of plant and wildlife habitat in the upland area. Such impacts would be a function of the magnitude of removal for a particular BMA as well as the selected location for support facilities and access points. Relative to the other alternatives, Alternative 4 is anticipated to require the most extensive upland modifications.

Following construction, restoration activities would be completed to reestablish vegetation and promote stability of bank material. Development of herbaceous vegetation (grasses and forbs) would likely occur over a period of 2 to 5 years. However, decades would be required for woody vegetation to reach maturity.

Community impacts due to increased truck traffic, primarily resulting from the transportation of removed materials from the bank areas and backfill and restoration materials delivered to the site, are also considerations for Alternative 4. The increased truck traffic would persist for the duration of the alternative construction as well as increase the risk of accidents along the transport routes. Additionally, the risks of spills or releases of impacted materials would increase during removal and transport. Disruption to the community due to dust and noise is also a short-term risk that may require further consideration during corrective action design. Some of the preliminary BMAs are located in residential neighborhoods and therefore this alternative could have larger-scale implications associated with nuisance dust and noise during construction activities. In the event that dust and noise from remediation activities becomes a nuisance, mitigation measures could potentially be implemented, including wetting roads, stockpiles, and staging areas; modifying working hours and durations; using noise shrouds; and other approaches.

Risks to Remediation Workers

Implementation of Alternative 4 would result in health and safety risks to site workers, especially considering the nature of the work being conducted on the banks and in the nearshore area due to factors such as height of banks, slope stability, and water hazards.

Risks to site workers increase as the duration and scope of the alternative increases (e.g., more equipment and traffic). Controls such as those required under OSHA 1910-120 can be implemented to manage and mitigate these short-term risks, but they cannot be completely avoided. Additional controls would include erosion and sedimentation control measures associated with access and support areas, traffic planning to minimize the potential for vehicle accidents, and proper construction BMPs (e.g., lined dump trucks equipped with spill plates, covering materials in open trucks, dust suppression, and limiting truck speed on site).

5.3.1.4 Long-term Effectiveness and Permanence

This element evaluates the alternatives with respect to the ability to achieve the long-term RAOs discussed in Section 3.3, and specifically to reduce MeHg exposure and improve habitat conditions throughout the South River and SFS River. Factors considered under this criterion include the magnitude of residual risk remaining after implementation and the adequacy and reliability of control measures, also considering long-term effects on ecological and human exposure and habitat improvements resulting from remedy implementation. Institutional controls (e.g., fish consumption advisory) will continue to provide a level of protection from potential MeHg exposure for the four alternatives considered here.

The assessment of the magnitude of residual risk includes consideration of the extent to which the alternative would reduce potential aquatic exposures to MeHg. Evaluation of adequacy and reliability of the alternative includes an assessment of the following: whether the technologies have been used under similar conditions; whether the combinations of technologies in the alternative have been used together effectively; general reliability and effectiveness; reliability of monitoring and maintenance requirements and availability of labor and materials required; and the potential need to replace technical components of the alternative, along with a consideration of potential exposure pathways and the associated risks should the remediation action require replacement.

The period of time considered for long-term effectiveness and permanence starts after construction and establishment of the alternative is complete (i.e., after the period of time considered for short-term effectiveness).

Alternative 1 (Institutional Controls and Monitoring) has the potential to achieve the long-term RAO over time in certain BMAs and associated downstream in-channel sediments through MNR processes (see Section 6.3). Institutional controls may aid in limiting human exposure during the recovery period.

Magnitude of Residual Risk

This alternative would not involve any active remediation; hence, it would rely on MNR processes to reduce MeHg exposure and improve habitat conditions. Such processes may take extended periods of time to reduce the magnitude of existing risk; it is possible that MNR in the absence of any remediation may not result in residual risk reductions or habitat improvement. Institutional controls may aid in reducing direct human exposure, and monitoring would provide a basis to evaluate ongoing natural processes to reduce MeHg concentrations.

Adequacy and Reliability of Alternative

Alternative 1 would not involve active remediation; therefore, considerations relating to the adequacy and reliability of specific remediation technologies are not applicable. Several institutional controls (e.g., fish consumption advisories) already have been in place in the South River and SFS River, and additional controls such as conservation easements have been used successfully at other similar sites. The adequacy and reliability of natural recovery processes at the site would be documented through long-term monitoring.

Alternative 2 (Enhanced Vegetative Stabilization) is anticipated to accelerate achievement of the long-term RAO, relative to Alternative 1. Alternative 2 provides long-term effectiveness by utilizing green remediation methods including enhancing vegetation quality and quantity through canopy management and planting (e.g., hydroseeding or other methods). Such methods aid in reducing IHg loading from BMAs or portions of BMAs and enhance natural stabilization processes through the installation of deep-rooted native plants, further reducing potential bank erosion and sediment transport. Bank stability would aid in promoting downstream habitat improvements in the South River and SFS River, further contributing to achievement of the long-term RAO.

Magnitude of Residual Risk

Under Alternative 2, bank deposits with elevated IHg concentrations would remain in the environment; therefore, the potential exists for future exposure to human and ecological receptors due to vegetation loss or erosion and transport. The selection of appropriate erosion-resistant vegetation containing deep-rooted native plants and the management of current understory vegetation through proper canopy management techniques would aid in reducing IHg loading from BMAs. Canopy management may depend, in part, on whether the bank has a north- or south-facing slope. South-facing slopes are expected to be more amenable to canopy management. In addition, the development of erosion-resistant vegetation and stable slopes under this BMA alternative would likely occur over a time period of 1 to 2 years, reaching maturity in 3 to 5 years. As such, the BMA may be subject to erosion until native vegetation reaches maturity, but is anticipated to provide long-term effectiveness once the vegetation is fully established. The vegetation and resulting stability would be designed to withstand specific hydraulic conditions to prevent erosion and transport downstream and provide habitat functions.

Adequacy and Reliability of Alternative

Enhanced vegetative stabilization has been applied at other similar sites, including the Tittabawassee River in Michigan and the Housatonic River in Massachusetts (Anchor QEA, unpublished data). Thus, this alternative uses technologies that have been shown to be reliable and effective in reducing contaminant transport in the long-term. Restoration efforts and appropriately selected native plants and canopy management techniques would effectively address each BMA and ensure long-term stability of banks. To further assess the reliability and effectiveness of Alternative 2, model predictions of erosion in areas receiving remediation could be further evaluated during corrective action design.

The construction equipment and techniques incorporated into Alternative 2 (Figure 4-3) have been successfully used at similar sites and are expected to support long-term reliability and permanence with minimal maintenance requirements. However, if erosion of restored bank stabilization materials should occur that exposes the underlying bank soil, an assessment would be conducted to determine the need for, and methods of, repair. Depending on the timing and location of the repair, access roads and staging areas may need to be temporarily constructed in the nearby upland area. Periodic small-scale repairs would

likely pose minimal risks to humans and ecological receptors that use or inhabit the disturbed BMA and upland area.

A combination of physical, chemical, and biological monitoring of the restored riverbanks would be used to evaluate the long-term effectiveness of Alternative 2. Monitoring would likely include topographic monitoring and accompanying surveys of bank pins, vegetative cover, vegetative type and density, changes in visual signs of erosion, Asiatic clam tissue sampling, and other appropriate metrics, along with adaptive management. The specifics of the monitoring and adaptive management program would be developed during corrective action design. The results would be used in the adaptive management framework to initiate maintenance requirements, if necessary. If required, labor and materials needed to perform maintenance are expected to be readily available. The South River Monitoring Plan is being developed by the SRST in parallel with this Remediation Proposal.

Alternative 3 (Structural Stabilization) is also anticipated to achieve the long-term RAO. This alternative is similar to Alternative 2 and provides long-term effectiveness by using green and structural engineering methods to enhance vegetation quality and quantity through canopy management and planting native vegetation (e.g., hydroseeding or other methods). In addition, this alternative increases long-term effectiveness through bank reshaping and armoring to provide immediate and increased long-term bank stability. Compared to Alternative 2, structural stabilization would provide greater long-term effectiveness and permanence by adding structural components to increase bank stability. The added protection mitigates exposure pathways and promotes downstream habitat improvements in the South River and SFS River to achieve the long-term RAO.

Magnitude of Residual Risk

Similar to Alternative 2, bank deposits with elevated IHg concentrations would remain in the environment and therefore the potential exists for future exposure to human and ecological receptors due to vegetation loss or erosion and transport. However, the addition of structural stabilization provides an added level of long-term protection compared to Alternative 2, which relies on established vegetation. The vegetation and structural components of Alternative 3 would be designed to withstand specific hydraulic conditions to prevent erosion and transport and provide habitat functions.

Adequacy and Reliability of Alternative

Structural stabilization has been applied at other sites under similar conditions. Similar to Alternative 2, such techniques have been successfully demonstrated in the South River bank stabilization field pilot demonstration (see Section 4.3.1), as well as in the Tittabawassee and Kalamazoo Rivers in Michigan, the Housatonic River in Massachusetts (Anchor QEA unpublished data), and other similar river systems.

This alternative uses technologies that have been shown to be reliable and effective in reducing exposure to humans and ecological receptors. Restoration efforts and appropriate selection of native plants and canopy management techniques would effectively reduce long-term IHg loading and ensure long-term BMA stability. To further assess the reliability and effectiveness of Alternative 3, model predictions of erosion in areas receiving remediation could be further evaluated during corrective action design.

The construction equipment and techniques included in Alternative 3 have been successfully used at similar sites and are expected to support long-term reliability with minimal maintenance requirements. The structural component of this alternative decreases the likelihood of maintenance being required. If required, access roads and staging areas may need to be temporarily constructed in the nearby upland area. Periodic small-scale repairs, if necessary, would likely pose minimal risks to humans and ecological receptors that use or inhabit the disturbed BMA and upland area.

Similar to Alternative 2, a combination of physical, chemical, and biological monitoring of the restored riverbanks would be used to evaluate the long-term effectiveness of Alternative 3. Monitoring would likely include topographic monitoring and accompanying surveys of bank pins, changes in visual signs of erosion, Asiatic clam tissue sampling, and other appropriate metrics, along with adaptive management. The specifics of the monitoring and adaptive management program would be developed during corrective action design. The results would be used in the adaptive management framework to initiate maintenance requirements, if necessary. If required, labor and materials needed to perform maintenance are expected to be readily available. The South River Monitoring Plan is being developed by the SRST in parallel with this Remediation Proposal.

Alternative 4 (Removal and Disposal) is anticipated to achieve the long-term RAO via removal and off-site landfill disposal of BMA deposits, and subsequent restoration activities. This alternative would reduce BMA exposure pathways and the potential for bank erosion and downstream migration of eroded material, thereby improving habitat conditions in the South River and SFS River. Both ecological and human exposure pathways to MeHg would be eliminated through removal and permanent disposal at an off-site disposal facility and restoration of post-removal surfaces. A disposal facility and location would be selected to provide effective long-term management of the excavated materials, controlling potential future exposure to human and environmental receptors.

Magnitude of Residual Risk

Implementation of Alternative 4, along with upstream source control and remediation measures, would reduce the exposure pathway of humans and ecological receptors to MeHg by permanently removing bank soils from the environment. Residual impacts would be addressed through habitat restoration and stabilization of banks after removal to mitigate the potential for future erosion. Given the documented limitations associated with removal, unavoidable residual IHg will likely remain following excavation and will require backfill or capping for long-term control. The restoration activities conducted following removal activities will enhance habitat recovery processes and provide long-term stability of banks, thereby reducing the potential for future exposure to residual contamination.

Removed bank soil would be permanently disposed at an off-site disposal facility. A disposal facility and location would be selected to provide effective long-term management of the dredged materials, controlling potential future exposure to human and environmental receptors.

Adequacy and Reliability of Alternative

Bank excavation using dry excavation techniques and the removal and stabilization of erodible banks has been applied at other sites with similar conditions. The removal and stabilization of bank soils using a combination of stabilization techniques (e.g., enhanced vegetative and structural stabilization) has been successfully demonstrated in the Tittabawassee and Kalamazoo Rivers in Michigan, the Housatonic River in Massachusetts (Anchor QEA unpublished data), and other systems similar to the South River. This

alternative uses techniques that have been shown to be reliable and effective in reducing contaminant transport, as well as exposure to humans and ecological receptors. Bank soil removal combined with restoration would effectively address BMAs and ensure long-term stability of banks through restoration.

Excavation can be effective and reliable in reducing the long-term potential for exposure of human and ecological receptors through removal of contaminants; however, there are some limitations associated with this approach (e.g., residual contamination following removal). Restoration elements can be effectively utilized to address residual contamination, and planting deep-rooted native plants would enhance natural stabilization processes, further reducing bank erosion and transport and promoting downstream habitat improvements in the South River and SFS River.

5.3.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

This element addresses the degree to which an alternative reduces the toxicity, mobility, or volume of mercury in the South River.

Alternative 1 (Institutional Control and Monitoring) would not include any construction; therefore, no reduction in toxicity, mobility, or volume would be expected.

Alternative 2 (Enhanced Vegetative Stabilization) would not include soil removal or reshaping; therefore, a reduction in the volume of mercury is not expected to occur. However, stabilization of bank soils and incorporation of reactive treatment amendments could reduce the mobility and toxicity of mercury loading to the South River.

Alternative 3 (Structural Stabilization) may include limited soil removal to facilitate the placement of structural stabilization elements. As such, this alternative has the potential to reduce the volume of mercury remaining in the South River, depending on the level of excavation that would be required. In addition, stabilization of bank soils and incorporation of reactive treatment amendments could reduce the mobility and toxicity of mercury loading to the South River.

Alternative 4 (Removal and Disposal) would provide a reduction in volume of mercury-impacted soil remaining in the South River through removal. However, these materials would be contained (without treatment) in an off-site landfill facility.

5.3.2 Implementability

Implementability addresses the ease or difficulty of implementing an alternative, considering technical feasibility, administrative feasibility, and availability of required services and materials. Technical feasibility considers difficulties and unknowns in construction and operation, reliability of the selected technology, and limitations of construction due to conditions that restrict or hinder access such as utilities, bridges, or other infrastructure. Administrative feasibility considers coordination with other agencies and offices to obtain necessary approvals including the ability to obtain access agreements with adjacent property owners.

All of the alternatives are technically and administratively implementable when appropriately applied to a BMA. All of the alternatives have been implemented at other similar sites. All equipment, personnel, and materials necessary to implement the alternatives are anticipated to be locally available. Administratively, all alternatives are readily implementable but may require additional outreach and community involvement to gain approval and obtain access to private land. Alternative-specific implementability considerations are provided below.

Alternative 1 (Institutional Controls and Monitoring) is readily implementable. The implementation of institutional controls may require coordination with third party landowner/lessees and any parties with easements for access. Implementation of institutional controls, such as continued fish consumption advisories, would require coordination with state public health departments and other appropriate agencies for the dissemination of information to the public and surrounding communities regarding those advisories.

Implementation of monitoring activities may be affected by landowner considerations, including the provision of shore-based access to the bank areas, which may influence the thoroughness of bank inspection and monitoring. A lack of shore-based access would require

monitoring to be performed from boats in the river, which may limit the monitoring efforts. Some monitoring could be performed from boats in the river assuming access and site characteristics (water depth) are adequate. Monitoring is anticipated to occur over a 30-year duration.

Alternative 2 (Enhanced Vegetative Stabilization) is also readily implementable. Landowner permission would be required to establish staging areas and access roads; however, heavy construction equipment may not be required because bank reshaping, grading, and armoring are not components of Alternative 2, with the exception of toe protection, which would be considered on an individual BMA basis. As such, upland access and support facilities may not be required or would be limited. Community outreach, based on the location of each BMA, would be required to gain acceptance of alternative implementation as well as access to the BMA.

Alternative 3 (Structural Stabilization) may require access roads and staging areas through privately held property parcels. Landowner considerations may affect the implementability of structural stabilization for individual BMAs. High or steep banks may pose unique implementation challenges for the placement of certain slope stabilization materials and reshaping or removal of the bank material may be necessary. A thorough investigation and reconnaissance of site utilities and other infrastructure would be required prior to any intrusive work. During corrective action design, specific technologies and options to be used at each BMA or portions of a BMA would be optimized where the structural stabilization alternative is selected as the preferred remedy. Bank reshaping is not anticipated for BMAs with bank angles already conducive to the potential process options and within a stable range, although augmentation of the bank soils to increase the viability of the revegetation program is still possible and readily implementable.

Alternative 4 (Removal and Disposal) would require the greatest degree of landowner approvals and site access, including roads and staging areas, due to the intrusive nature of alternative components and material and equipment requirements. Access roads and staging areas would be required for heavy equipment transportation and storage, imported and contaminated soil staging and transport, and equipment decontamination. The magnitude of support facilities and access roads depends on the location and characteristics of each BMA.

In areas of dense vegetation or in areas where access is limited, the BMA and surrounding areas may require extensive clearing and preparation to allow equipment access to the bank, increasing the complexity and difficulty of alternative implementation. Extensive removal would also require staging areas to allow for the removed materials to be handled as necessary prior to off-site transport and disposal. A thorough investigation and reconnaissance of site utilities and other infrastructure would be required prior to any intrusive work. Implementation of Alternative 4 would require the greatest degree of community and landowner acceptance.

5.3.3 Cost

General cost estimates for each of the four BMA alternatives were developed using approximate unit costs (i.e., per 100 lineal feet of BMA) based on a review of prior DuPont project data including the South River bank stabilization field pilot demonstration (see Section 4.3.4). Additionally, a review of cost data available for similar projects completed at other sites and obtained from vendors and manufacturers was used in the development of the alternative costs. Consistent with USEPA (2005) guidance, preliminary cost estimates for each alternative were developed to an anticipated accuracy range of -30 to +50%.

A discount rate of 7% was utilized for the present-worth calculation as specified by USEPA guidance. For costing purposes and comparison of alternatives, a 30-year monitoring period was assumed for Alternative 1 (Institutional Controls and Monitoring), Alternative 2 (Enhanced Vegetative Stabilization), and Alternative 3 (Structural Stabilization). The monitoring costs included in this Remediation Proposal do not include long-term (100-year) monitoring of the overall ecological system, which is being developed separately by VADEQ and would apply to all four BMA remediation alternatives.

As discussed in Section 3.3.2.5, this Remediation Proposal identified approximately 1.0 mile of preliminary BMAs in RRMs 0 to 2, combining the 0.3 mile of banks identified from the loading analysis with the 0.7 mile of banks identified from the bank stability evaluation. These banks, along with an additional 1.5 miles of banks, will be evaluated further during corrective action design to identify final BMAs in RRMs 0 to 2 (Figure 3-5 and Table 3-1).

Approximate unit costs and total costs for an assumed 1.0 mile of preliminary BMAs in RRMs 0 to 2 for each of the four alternatives are summarized in Table 5-1.

Table 5-1
Preliminary BMA Remediation Alternative Cost Estimate Summary

Description		Estimated Capital Cost for RRMs 0 to 2 BMAs	Estimated OM&M Cost for RRMs 0 to 2 BMAs	Estimated Total Cost for RRMs 0 to 2 BMAs	Estimated Total Cost Per 100 Lineal Feet of BMA
Alternative 1	Institutional Controls and Monitoring	$0	$1,700,000	$1,700,000	$32,000
Alternative 2	Enhanced Vegetative Stabilization	$900,000	$1,500,000	$2,400,000	$46,000
Alternative 3	Structural Stabilization	$2,200,000	$1,500,000	$3,700,000	$70,000
Alternative 4	Removal and Disposal	$25,000,000	$0	$25,000,000	$480,000

Notes:
1 Present-worth basis costs are for a preliminary total BMA remediation length of 1.0 mile; see Section 3.3.2.5.
2 All cost estimates are preliminary and subject to future revisions.
3 This cost estimate has been developed based on a conceptual level design at an accuracy of approximately -30% to +50%.
4 Costs and volumes are rounded as appropriate.
5 Costs include taxes assumed to be based on 5% of total construction costs.
6 All cost estimates include material and labor unless otherwise noted. Unit costs are estimated using standard estimating guides (e.g., R.S. Means Heavy Construction Cost Data), vendors, professional judgment, and experience from similar projects.
7 The estimates were developed using current and generally accepted engineering cost estimation methods. Note that these estimates are based on assumptions concerning future events and actual costs may be affected by known and unknown risks including, but not limited to, changes in general economic and business conditions, site conditions that were unknown to Anchor QEA at the time the estimates were performed, future changes in site conditions, regulatory or enforcement policy changes, and delays in performance. Actual costs may vary from these estimates and such variations may be material.
8 Costs do not include property costs (where applicable), access costs, legal fees, agency oversight, or public relations efforts.
9 This estimate is based on our current understanding of the site and the resulting conceptual development of the design. Subsequent site-specific investigations may further refine this estimate. This estimate should therefore be considered preliminary and will be subject to revision as additional data and information become available as part of design-related investigations. The concepts shown in these estimates will also likely be optimized as part of future design.

6 SOUTH RIVER REMEDIATION PROPOSAL

6.1 Comparative Analysis of Phase 1 BMA Alternatives

Based on the analysis of BMA remediation alternatives conducted in Section 5.3, all of the Phase 1 alternatives provide for protection of human health and the environment and meet RAOs. Alternative 1 would use institutional controls, monitoring, and adaptive management to confirm protectiveness and provide a mechanism to implement adaptive management strategies, as conditions warrant. However, Alternative 1 does not include construction and thus would not provide an additional level of protection as compared to the other alternatives. Alternatives 2 through 4 would comply with action- or location-specific regulatory requirements, which are not applicable to Alternative 1 as no construction would be conducted.

There are no short-term risks associated with Alternative 1 as no construction activities would be conducted. There are considerably higher short-term risks associated with implementation of Alternative 4 than Alternatives 2 and 3 due to the removal and disposal components that increase risks to the environment, disturb existing habitats, and have the potential to transport disturbed material outside the construction zone. In addition, Alternative 4 has a higher potential for spills during material transport, greater potential for nuisance dust and noise, and increased risks to site workers.

While Alternative 1 has the potential to achieve the long-term RAO over time in certain BMAs and associated downstream in-channel sediments through MNR processes, Alternatives 2 through 4 have greater long-term effectiveness and permanence in achieving RAOs. Exposure pathways would be mitigated and improvements in habitat in the South River and SFS River would be achieved through natural stabilization processes such as installation of deep-rooted native plants and canopy management as well as the implementation of structural elements in Alternative 3 to increase long-term bank stability. Relative to Alternative 4, the magnitude of residual risk is greater for Alternatives 2 and 3 as mercury would remain in the environment. Following implementation, residual risks under Alternatives 2 through 4 are anticipated to be minimal and appropriately managed and mitigated.

All of the alternatives are technically implementable. All of the remediation technologies included as components of the alternatives have been successfully implemented at other similar sites and the techniques are well established, proven methods in the construction industry. All equipment, personnel, and materials necessary to implement the alternatives are anticipated to be locally available. Administratively, all alternatives are readily implementable, although all of the alternatives would require additional outreach and coordination with private landholders and regulatory agencies. Upland support facilities, such as staging areas and access roads, would be required components of Alternatives 2 through 4. The complexity, magnitude, and duration of Alternative 4 is greater than the other alternatives; under this alternative, it would likely require more than 2 years to complete construction in RRMs 0 to 2. Because Alternative 4 is the most complex, associated with the longest construction duration, and would also require considerable access agreements, agency reviews, and uncertain landowner approvals, Alternative 4 is the least implementable of the BMA alternatives.

The approximate present-worth costs of the BMA alternatives applied to RRMs 0 to 2 are summarized in Table 5-1. Alternative 1 has the lowest present-worth cost (approximately $1.7 million), primarily associated with monitoring and administrative tasks. The overall cost of the remaining alternatives is a function of the increasing complexity of the construction components. Alternative 2 incorporates relatively low cost green engineering methods and has the second-lowest present-worth cost (approximately $2.4 million). Alternative 3 includes additional structural components and localized removal, which increases the overall present-worth cost of this alternative nearly twofold above Alternative 2 to approximately $3.7 million. Because of the relatively higher unit costs of removal and disposal, Alternative 4 has the highest present-worth cost of approximately $25 million, more than six times higher than Alternative 3.

As discussed in Appendix B, a preliminary sustainability analysis was performed as a component of this Remediation Proposal to examine and incorporate green and sustainable remediation practices into the evaluation of BMA remediation options. This sustainability analysis included evaluations of short- and long-term elements of alternative implementation, including future activities required such as maintenance and adaptive management, focusing on the anticipated overall direction of the effect the action would

have on a range of sustainability core elements. The evaluation revealed that Alternatives 1 and 2 have the highest sustainability scores, Alternative 3 has an intermediate score, and Alternative 4 has the lowest sustainability score, largely because implementation of this relatively invasive alternative is anticipated to result in negative short-term effects to many of the sustainability core elements.

6.2 Recommended Phase 1 BMA Remediation Alternatives

Based on the evaluations summarized above, Alternatives 2 and 3 best meet the RAOs and NCP evaluation criteria, and these two alternatives are distinct from the remaining alternatives in achieving greater protectiveness with far less short-term impact on the environment during remedy implementation, less impact on the community, and less impact on sustainability core elements. While Alternative 1 has the potential to achieve RAOs in certain BMAs and over an extended time period, Alternative 2 is distinctly more protective in both the short- and long-term, and is associated with only a marginal additional cost. However, the short-term impacts and costs associated with implementing Alternative 4 are substantial and disproportionate to the marginal additional protectiveness that would be achieved beyond Alternative 3. Thus, neither Alternatives 1 nor 4 meet the NCP evaluation criteria.

As discussed in Section 1.5, USEPA's risk management principles and guidance (2002, 2005) were developed to help inform scientifically sound and nationally consistent risk management decisions at contaminated sediment sites. The USEPA principles are equally relevant to bank soils and in-channel sediment in the South River. The evaluation of BMA remediation alternatives summarized above was performed consistent with this guidance, and identified Alternatives 2 and 3 as the most efficient and effective remedies, consistent with NCP requirements.

During corrective action design, additional investigations and evaluations will be performed to further assess which elements of Alternatives 2 and/or 3 are most appropriately applied to a given BMA (or portion of a BMA) based on landowner preferences, site characteristics, regulatory requirements, and other factors. The corrective action design evaluations will further refine the remedy for each BMA, likely including appropriate combinations of these

two alternatives to specific situations. As detailed corrective action design proceeds, all promising technologies including focused bank soil removal will be considered and integrated into comprehensive remedies for individual banks to maximize overall protectiveness and minimize disruption in an optimal balance, considering specific bank characteristics and landowner requirements.

As discussed in Section 4.3.4, corrective actions in the South River and SFS River will be implemented under an adaptive management approach. Careful monitoring of the outcome of the Phase 1 remedial measures will help adjust the scope of subsequent remediation phases as part of an iterative learning process, recognizing the importance of natural variability in ecological systems and variability in measures of effectiveness of remediation actions. Figure 4-2 in Section 4.3.4 summarizes the adaptive management cycle that will be used to implement remediation actions in the South River and SFS River aquatic environment, and identifies key decision steps in the process.

6.3 Natural Recovery

The recommended remedy for the South River outlined above includes enhanced vegetative and/or structural stabilization of BMAs to substantively reduce IHg loading to the South River and accelerate MNR processes within channel areas. Utilizing adaptive management, in-channel sediments (e.g., embedded gravel deposits) will be evaluated after BMA remediation has been completed to track and effectively integrate lessons learned, including those that pertain to MNR. This section summarizes relevant MNR processes that will be tracked using the adaptive management approach.

The National Research Council (NRC 2000) defines natural recovery as "un-enhanced natural processes to protect human and environmental receptors from unacceptable exposures to contaminants." As discussed in USEPA (2005) and ESTCP (2009), the successful implementation of natural recovery depends on the following conditions:

- Natural recovery processes are transforming, immobilizing, isolating, or removing chemical contaminants in sediments to levels that achieve acceptable risk reduction within an acceptable time period

- Source control has been achieved or sources are sufficiently minimized such that these natural recovery processes can be effective

As a sediment remedy, MNR relies on physical, chemical, and/or biological processes to isolate, destroy, or otherwise reduce exposure to or toxicity of contaminants in sediment to achieve RAOs (NRC 2000; USEPA 2005; ESTCP 2009). These processes may include biodegradation, biotransformation, bioturbation, diffusion, dilution, adsorption, volatilization, chemical reaction or destruction, resuspension, and burial by clean sediment. Monitoring is needed to assess whether risk reduction and ecological recovery by natural processes are occurring as expected. Monitoring programs evaluate the critical elements of the CSM to both verify with adequate certainty the ongoing effectiveness of natural processes and quantify the trajectory toward risk reduction. Monitoring programs may also evaluate other environmental characteristics necessary to support biological communities (e.g., dissolved oxygen).

Natural recovery has occurred to date in the South River, despite the fact that concentrations in fish tissue have not declined in recent years. For example, IHg concentrations on suspended sediment are reported to have declined from a peak of approximately 1,200 µg/g during the time that mercury was in use at the former Waynesboro facility (1929 to 1950), to less than 30 µg/g today (Skalak 2009). The rate of recovery has slowed and is likely not to change further unless there are reductions in IHg loads from plant outfalls and riverbanks. In addition, further reductions in in-channel surface sediment (e.g., fine-grained sediment deposits and near-bank sediment) IHg concentrations may be necessary to achieve long-term RAOs.

Natural recovery is expected to occur in South River interstitial sediment, where IHg is stored and methylated. Following IHg load reductions, there are several natural processes by which either sediment IHg concentration or the mercury methylation capacity of interstitial sediment may decline over time, including:

- Dilution with low-IHg-concentration upstream sediment
- Release of fine-grained particles by physical bed turnover
- Reduced bioavailability of IHg associated with fine particles over time
- Decrease in mercury methylation rates over time

Sediment IHg concentrations will be diluted over time through mixing of bed sediment with lower concentration sediment transported from the upstream watershed and from floodplain soils. As noted in Section 2.4, about 6% of the annual sediment load transported from the upstream watershed (above RRM 0) is deposited within each downstream mile of the South River, and after a distance of 9 to 25 miles, the entire sediment load has been exchanged with other solids from bank erosion, runoff, and sediment resuspension. This mechanism is likely to have the greatest effect on the most upstream reaches of the South River, so recovery should occur soonest in the first several RRMs.

Physical turnover of the stream bed also acts in concert with upstream delivery of relatively low IHg concentration sediment to further reduce in-channel surface sediment concentrations over time. Based on geomorphological studies and age-dating of hyporheic zone sediment, the residence time of fine sediment in the hyporheic zone of the South River has been estimated at approximately 20 to 50 years (Pizzuto et al. 2011). This suggests that following remediation of plant outfalls and reduction of IHg loading from riverbank erosion, IHg concentrations in surface sediments will slowly further decrease due to exchange with low-IHg solids from upstream. While this process occurs, older, buried sediment with relatively high IHg concentrations will continue to provide substrate for methylation.

Additional natural mechanisms may also act to decrease the bioavailability or methylation of mercury, leading to faster natural recovery than predicted by simple dilution. These mechanisms include 'aging' of IHg and sediment, which may affect mercury bioavailability or methylation, respectively, over time, as discussed below.

The bioavailability of sediment IHg to methylating bacteria changes over time because of geochemical interactions between IHg and inorganic and organic ligands in surface water and sediment. As a result, IHg recently loaded to an aquatic environment is more readily methylated than ambient or older IHg in the system. For example, Chadwick et al. (2012) found IHg added to a lake was more particle reactive than ambient mercury, but was also more readily methylated in the anoxic lake hypolimnion. Over time, redox processes, including the precipitation and dissolution of iron and manganese oxides, contributed to the 'aging' of the mercury (i.e., progressively lower partitioning behavior of new mercury, such that it approaches old mercury characteristics). In anoxic zones, formation of sulfide

complexes was observed, leading to more strongly complexed IHg species. Other research suggests that over time, these mercury-sulfur species aggregate into nanoparticles, which further aggregate and increase in size over time, reducing the bioavailability to methylating bacteria (Hsu-Kim et al. 2013).

It is also possible that the aging of sediment particles, independent of effects on IHg speciation, may suppress mercury methylation in sediment. Older sediment with relatively high IHg concentrations may become less bioavailable to heterotrophic bacteria due to nutrient removal from sediment particles, where the vast majority of heterotrophic activity (including methylation) occurs in river sediment. For example, Fischer et al. (2002) evaluated the relationships between bacterial abundance and productivity and organic matter quality and quantity in a high gradient stream. The quantity and quality (as measured by particulate nitrogen) of organic matter were found to be the best predictors of microbial abundance, suggesting that as older sediment particles are replaced with newer particles, bacterial abundance, including the abundance of mercury methylating bacteria, will shift to the newer particles. Turnover of sediment organic matter can be rapid (approximately 2 months) and is often higher in mid-channel areas than near-bank areas, suggesting that this process may be more rapid in a well-mixed environment like the South River. In addition, recent and prospective further reductions in nutrient loading to the South River from the Waynesboro wastewater treatment plant could further reduce mercury methylation in sediment.

7 PRELIMINARY MONITORING AND COMMUNITY OUTREACH PLAN

This section describes the preliminary monitoring and community outreach plan for the Remediation Proposal. It is designed to provide information related to the potential efficacy of the recommended Phase 1 remedy discussed in Section 6.2, along with subsequent remediation phases, as well as their ability to reduce exposure of humans and ecological receptors to mercury over time. The monitoring plan takes into account specific goals, objectives, and concerns outlined in the Consent Decree, including elements of Exhibits C, D, and E. As previously noted, this plan is built upon the findings of the Ecological Study (URS 2012b) provided to NRDC and Sierra Club in September 2012.

The primary purpose of the monitoring plan is to describe an approach to evaluate the effectiveness of the remediation actions based on the short- and long-term RAOs described in Section 3.3.1 of this Remediation Proposal. DuPont has taken into account the valuable comments provided by NRDC and their expert, Dr. Robert Livingston, as well as the long-term monitoring data that have been collected in the South River and SFS River by governmental and non-governmental groups since the 1970s. The monitoring plan recognizes the important information that has been collected by these groups over the past several decades. DuPont will implement the components of this Remediation Proposal and all future work under the RCRA regulatory framework; therefore, the final designs for remediation and monitoring will be developed in collaboration with VADEQ, in consultation with USEPA. As this monitoring plan is implemented, there will be frequent and open communication with those involved with the existing monitoring efforts to efficiently share data and experience, and provide input to the adaptive management process.

This section provides a broad overview of the goals and rationale for the major components of the short- and long-term monitoring plans. Sample collection methodologies will follow those developed for the Ecological Study in collaboration with the regulatory agencies and with the larger SRST. Summaries of the preliminary scope for the short- and long-term monitoring strategies are provided in Table 7-1 and Section 7.2, and Table 7-2 and Section 7.3, respectively. As discussed in Section 8, the monitoring plan is subject to review and potential modification by VADEQ in consultation with USEPA and the SRST during corrective action design and adaptive management process.

7.1 Objectives

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 monitoring are to provide data to:

- Monitor human and ecological exposure to mercury
- Monitor system responses to remediation
- Monitor the integrity of the remediation action
- Provide input to the adaptive management framework and relative risk model to determine whether any aspect of the remediation action, monitoring strategy, corrective action design, or CSM needs to be modified

The short-term monitoring plan (Section 7.2) is designed to measure improvements over relatively rapid timeframes (e.g., 2 to 10 years) and small spatial scales (e.g., adjacent to a particular BMA). The short-term monitoring will assess whether the physical specifications of the remedy are being met and ensure that the physical integrity of the remedy is repaired should it be affected by flooding or other events. Secondly, the short-term monitoring will provide chemical and biological information that will feed into the relative risk model and the adaptive management approach. Combined, these sets of information will allow for rapid feedback on the efficacy, integrity, and performance of the remedy, and whether or not the RAOs are being met.

In contrast, the long-term monitoring described in Section 7.3 addresses changes in potential mercury exposures of humans and ecological receptors, as well as habitat improvements in the South River and SFS River over longer timeframes and larger spatial scales. While the short-term monitoring will be focused primarily in the South River at or near those areas where BMA remedies are being implemented, the long-term plan is designed to cover a timeframe of many years to decades and a much larger area, including watersheds of the South River and SFS River. It will also include routine inspections of remediated areas to ensure the continued integrity and performance of the remedy and to maintain and/or repair BMAs as necessary.

Similar to the short-term monitoring plan, chemical and biological results from the long-term monitoring will also feed into the relative risk modeling (Section 3.1.1) and the adaptive management approach (Section 4.3.4). 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 in estimating changes in the potential exposures and risks to humans and ecological receptors that result from changes in mercury loading to the South River and SFS River. It is expected that once remediation 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 Remediation Proposal, there will be open and frequent outreach and communication with local communities, physicians and health clinics, and relevant public-health groups.

7.1.1 Data Use and Evaluation

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. For example, if THg or MeHg concentrations in earthworm tissue do not change significantly over the first 3 years, sample frequency may be reduced to once every 2 years. This approach is consistent with the framework specified in the Consent Decree, Exhibit D, No. 11 for the Ecological Study wherein sample locations, tests, or analytes may be dropped if such locations, tests, or analytes do not materially affect the outcome of the study. However, in this case, the decision of whether or not to continue with specific sample locations, tests, or analytes will

be focused on their usefulness in the context of the adaptive management approach and any ongoing or planned remediation actions.

Sample collection methodologies will follow those developed for the Ecological Study in collaboration with the regulatory agencies and with the larger SRST. Current monitoring protocols are summarized in Appendix D. The monitoring plan may also be refined further during the corrective action design phase (see Section 8), and will be expanded once potential downstream and floodplain areas are better understood. Summaries of the scope for the short- and long-term monitoring strategies beginning with Phase 1 actions are provided in Table 7-1 and Section 7.2, and Table 7-2 and Section 7.3, respectively.

Table 7-1

South River Preliminary Short-Term Monitoring Plan Elements

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	Reduce Bank Erosion	Topography	Low-Range Bank Erosion Rate	Transects Across Each BMA	Annually for First 3 Years; Post-storm	Bank Angles and Average Annual Erosion Rate	Structural and/or Vegetative Stabilization	Refine Effectiveness Estimates
		Bank Pins	Low-Range Bank Erosion Rate	Transects Across Each BMA	Twice Annually for First 3 Years; Post-storm	Average Annual Erosion Rate	Structural and/or Vegetative Stabilization	Refine Effectiveness Estimates
		Vegetation	≥70% Root Density; 1.0 Root Depth/Bank Height	Transects Across Each BMA	Annually for First 3 Years; Post-storm	Root Density and Depth; Bank Height	Additional Vegetation Enhancement	Refine Effectiveness Estimates
		Bank Characteristics	Minimal Undercutting or Slumping	Transects Across Each BMA	Annually for First 3 Years; Post-storm	Extent of Undercutting and Slumping	Structural and/or Vegetative Stabilization	Refine Effectiveness Estimates
		Design and Implementation	Landowner Approvals and Permits	BMA Properties	N/A	N/A	N/A	Refine Implementation Estimates
	Reduce Mercury Loading from Bank	Surface Sediment	>75% Mercury Concentration Reduction	Downstream of BMAs (Nearshore)	Twice Annually for First 3 Years	IHg and MeHg Concentrations	N/A	Refine Effectiveness Estimates
		Periphyton	>75% Mercury Loading Reduction	Downstream of BMAs (Nearshore)	Twice Annually for First 3 Years	IHg and MeHg Accumulation Rate	N/A	Refine Effectiveness Estimates
		Asiatic Clam Cage Sampling	>75% Mercury Loading Reduction	Downstream of BMAs (Nearshore)	Twice Annually for First 3 Years	IHg and MeHg Accumulation Rate	N/A	Refine Effectiveness Estimates
	Reduce In-Channel Mercury Exposure	Periphyton	>50% Mercury Concentration Reduction	Downstream of BMAs (Channel)	Annually for First 10 Years	IHg and MeHg Accumulation Rate	N/A	Refine CSM
		Asiatic Clam Cage Sampling	>50% Mercury Concentration Reduction	Downstream of BMAs (Channel)	Annually for First 10 Years	IHg and MeHg Accumulation Rate	N/A	Refine CSM
Maintain or Improve Riparian and Aquatic Habitat	Improve Bank Vegetation	Vegetation	>80% Cover; <10% Invasives	Transects Across 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 BMAs	Annually for First 10 Years	Rapid Bioassessment Protocol Scores	N/A	Refine Effectiveness Estimates

Table 7-2

South River Preliminary Long-Term Monitoring Plan Elements

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 • Develop non-lethal mercury monitoring techniques for the South River	• THg and MeHg in filets and biopsy plugs • Sex, reproductive status • Total length, weight	Twice annually (May and October)	8	**South River:** • RRM -2.7* • RRM 0.1 to 2.3 • RRM 5.2 to 11.8 • RRM 16 to 23.5 **SFS River:** • Lynwood, VA, near Rt. 708 bridge • Shenandoah, VA, boat ramp • Newport Landing • Hamburg, VA, near Rt. 211 bridge • Fosters Landing near Rt. 684 bridge • Bentonville Landing near Rt. 613 bridge • Karo Landing **Shenandoah River:** • Rt. 17/50 bridge • Berryville, VA, near Rt. 7 bridge
Snapping turtle[1]	Monitor trends in human exposure to MeHg in snapping turtles	• THg and MeHg in turtle blood or nail tissue[2] • Sex, reproductive status • Total length, weight	Once annually (May to July)	3	
Mallard duck[1]	Monitor trends in human exposure to MeHg in mallard ducks	• THg and MeHg in breast muscle tissue • Sex, reproductive status • Total length, weight	Once annually (October to January [waterfowl hunting season])	3	

Monitoring Element	Objective	Measurements	Proposed Sampling Frequency	Samples per Location	Locations
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 MeHg in water and dietary items • Monitor exposure of ecological receptors (e.g., piscivorous birds) to MeHg in YOY fish • Document potential declines in exposure due to remediation	THg and MeHg in whole fish	Once annually (August to October)	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 SFS near Shenandoah, VA

Monitoring Element	Objective	Measurements	Proposed Sampling Frequency	Samples per Location	Locations
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 (May)	3	RRM -2.7* RRM 0.1 RRM 3.5 RRM 11.8 RRM 23.5 SFS near Lynwood, VA SFS near Shenandoah, VA
Benthic invertebrates	• Monitor exposure to invertivorous ecological receptors (e.g., YOY fish) • Monitor responses to decreasing mercury loads	Tissue THg, MeHg in benthic invertebrates	Twice annually (May and October)	3	
Periphyton	• Monitor THg and MeHg in periphyton, which is an important exposure medium for benthic invertebrates • Provide a data set for comparison with short-term monitoring elements	Tissue THg, MeHg in benthic invertebrates	Twice annually (May and October)	3	
Asiatic clam tissue	Provide a data set for comparison with short-term monitoring elements	Tissue THg, MeHg in benthic invertebrates	Twice annually (May and October)	3	

Monitoring Element	Objective	Measurements	Proposed Sampling Frequency	Samples per Location	Locations
Terrestrial					
Adult Carolina wren	Monitor songbird exposure to MeHg	• THg and MeHg in blood • Weight • Sex and reproductive status	Once annually (June to July)	3 to 8 individuals	**South River (Reference):** • Waynesboro Nursery (RRM -6.2) • Ridgeview Park (RRM -1.2) **South River:** • RRM 0.1 to 2.3 • Wertman Property (RRM 9) • Grottoes City Park (RRM 22) **SFS River:** • 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 MeHg in spiders • Monitor MeHg transfer between aqueous and terrestrial compartment of the South River	• THg and MeHg in composite spider samples • Size	Once annually (June to July)	5 individuals	
Earthworms	• Monitor exposure of terrestrial ecological receptors to MeHg in earthworms • Monitor potential terrestrial MeHg bioaccumulation	THg and MeHg in earthworm tissue	Once annually (June to July)	3 composite samples	

Monitoring Element	Objective	Measurements	Proposed Sampling Frequency	Samples per Location	Locations
Water Quality and Habitat Quality Monitoring					
Water quality**	• Monitor trends in water quality • Provide information on inter-annual variability of MeHg production • Continue to describe behavior of mercury species in South River	Surface water: • THg, MeHg**, TSS, TOC, DOC • Water quality parameters (T, pH, DO, conductivity • Nutrients (Phosphorous)*	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 River:** • Lynnwood, Rt. 708 • Shenandoah, below dam • Rt. 663
Benthic invertebrate community	Monitor improvements to benthic community and benthic habitat	• Benthic community (300 count subsampling) • Sediment THg, MeHg	Twice per year	6	RRM -2.7* RRM 0.1 RRM 3.5 RRM 11.8 RRM 23.5 Middle River*
		Substrate condition	Once per year	--	

Notes:
DO: dissolved oxygen; DOC: dissolved organic carbon; MeHg: methylmercury; NA: not applicable; RRM: relative river mile; SFS: South Fork Shenandoah; T: temperature; THg: total mercury; TOC: total organic carbon; TSS: total suspended solids; VDH: Virginia Department of Health; YOY: Young-of-Year

* 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

1 Final determination of which additional species, if any, that will be monitored will be made in collaboration with VDH and the regulatory agencies.

2 Data have shown good correlation between mercury in muscle and mercury in blood and nails; thus, non-lethal methods will be employed where possible.

7.2 Short-Term Monitoring

The short-term monitoring plan is designed to work within the adaptive management framework described in Section 4.3.4 by defining success criteria, contingency actions, and decision analysis options. The short-term monitoring seeks to understand the influence of implementation of specific remediation action alternatives, including point source remediation (Section 7.2.1) and bank stabilization between RRMs 0 and 2. The scope of short-term monitoring will be expanded once potential downstream and floodplain areas to be remediated are identified. Table 7-1 summarizes the short-term monitoring elements included in this Remediation Proposal that address this phase of the remedy.

7.2.1 Point Source Remediation

7.2.1.1 Plant Site

While mercury is no longer used at the former DuPont Waynesboro facility, the plant site has been a source of THg to the South River since mercury was used at the plant beginning in 1929. Mercury was used in these historical operations, but its use was discontinued in 1950. Recent on-site corrective measures designed to remove or mitigate historical mercury contamination of process areas unexpectedly resulted in increased loading of mercury to the South River. This short-term pulse of mercury into the system led to a temporary increase of mercury in surface water and biota compared to that observed in previous years. In response, USEPA and VADEQ have required additional interim measures to further control off-site mercury migration. The interim measures under consideration include sewer and below-ground pipe abandonments; cleaning; slip lining; and installation of filtration sumps to intercept sewer water, remove sediment, and filter out mercury from these historical structures. The sumps will intercept contaminated sediment during and after remediation. Implementation of the interim measures is currently planned to extend into fall 2014, and chemical and biological monitoring, as noted below, will be implemented over the short-term to help evaluate the efficacy of these actions and resultant changes in mercury loading to the South River. The goal is to implement the interim measures to control further mercury loading from the plant site to the South River.

In order to detect the effects of the planned on-site interim measures on mercury transport and exposure in the South River, a monitoring regime for the South River has been

implemented in advance of the interim measures. The monitoring regime includes sampling periphyton, transplanted Asiatic clam tissue, and benthic invertebrates at RRMs 0.2 and 2.3 prior to remedy implementation. These data are being collected along with quarterly outfall monitoring data and monthly surface water sampling in the South River. Two sampling events were conducted in spring 2013 prior to implementation of the interim measures, and two events will be conducted in spring 2014 and spring 2015 following completion of the interim measures to evaluate changes in concentrations of IHg and MeHg in the South River food web. These pre- and post-interim measures data will provide useful information that will be integrated into corrective action design.

7.2.1.2 Waynesboro Sewage Treatment Plant

Point sources are also important for phosphorus loading to the South River, which is a primary cause of benthic impairment in the river (VADEQ 2009). DuPont funded an SRST study (Brent 2011) to determine potential effects of a recent upgrade to the Waynesboro sewage treatment plant on MeHg concentrations in periphyton. The study evaluated the concentrations of mercury in periphyton, which are the epilithic communities of algae and other microbial organisms and fine detrital material. The study documented that the sewage treatment plant upgrades have resulted in decreased nutrient loading that may have contributed to locally depressed MeHg concentrations in the South River. However, factors other than nutrients have a greater effect on mercury methylation in the system. The preliminary monitoring plan outlined below includes collection of data on nutrient concentrations and other ancillary parameters important for understanding mercury behavior (see Section 7.3.3.2).

7.2.2 Phase 1 Bank Stabilization: RRMs 0 to 2

The short-term monitoring plan for Phase 1 of the remedy provides an array of monitoring tools to measure the system responses to specific remediation alternatives implemented between RRMs 0 and 2. Because the remediation options that best meet the general response objectives for RRMs 0 to 2 are Alternatives 2 (Enhanced Vegetative Stabilization) and 3 (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 using a combination of erosion pins, surveys (e.g., LiDAR and/or laser transects), and/or root analysis will be used to confirm that bank erosion rates decline and banks maintain their stability in response to remediation actions. Routine annual inspections for the first 3 years, followed by event-based inspections (e.g., 5-year and greater storm recurrence interval) will be an important component to understand potential long-term bank stability. Information gained from these inspections can be used to improve designs for other reaches. Protocol SRTR-1 describes the methodology used to perform bank inspections, and protocol SRBC-1 describes the methods used to monitor the vegetative community (Appendix D).

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, including:

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

Sediment sampling will be conducted in a manner consistent with other South River studies according to the method described in protocols SRSE-1 and SRSE-2 (Appendix D). The biological tissues to be sampled will include periphyton and Asiatic clam tissue, which have been used with success to measure mercury uptake in near-bank regions (URS 2011). These methods are described in protocol SRTI-1 and SRBI-1, respectively (Appendix D). Specific sampling designs, including sample sizes based on statistical power analysis, will be developed with VADEQ in consultation with USEPA and SRST as part of corrective action designs and will be project-specific. Elements of the short-term monitoring plan could change as other reaches are considered or other technologies are adopted.

The sampling frequency to be selected for the short-term monitoring will be based on the expected changes in the monitoring parameters. For example, riparian quality characteristics are not likely to change over the course of a year and are likely to remain stable from year to year, while mercury loading dynamics may change seasonally with changes in discharge rates and water temperature. Sampling designs will also be integrated with similar monitoring of the remediation of upland mercury sources, impacted groundwater, and mercury discharges in the plant outfalls, as discussed in Section 1.3.

7.3 Long-Term Monitoring

Table 7-2 summarizes the long-term monitoring elements included in this Remediation Proposal to address currently planned remedies. This plan will be expanded once downstream and floodplain areas to be remediated are defined. The general response objectives for the long-term RAOs are:

- Reduce MeHg exposure
- Improve habitat conditions throughout the South River and SFS River

Potential human and ecological receptor exposure to MeHg concentrations occurs primarily through the diet by consumption of biological tissue that has bioaccumulated MeHg. Due to the nature of mercury fate and transport in aquatic environments, exposure to MeHg in biological tissue is not expected to change significantly over the short-term. However, the long-term monitoring plan will measure mercury in those biological and abiotic media that are important for human and ecological exposure, particularly those food items (biotic media) that might be consumed by humans or ecological receptors. Media are selected based primarily on their importance for exposure and their propensity to change in response to declines in mercury loading. Potential human exposure monitoring is addressed in Section 7.3.1, and ecological exposure is addressed in Section 7.3.2.

In addition to mercury, the South River has impairments to the benthic invertebrate community and benthic habitat due to sedimentation from land use practices and water quality impacts. The emphasis on controlling bank erosion as part of the remedy may also have benefits for the benthic invertebrate community on a long-term basis. In addition, the data generated by this aspect of the plan will provide input to a better understanding of

interannual variation in MeHg production and nutrient loading. This monitoring is described in Section 7.3.3. The following sections introduce the major components of the monitoring, the rationale for their inclusion, and a brief description of the long-term monitoring plan, which is summarized in Table 7-2.

7.3.1 Sample Size Determination and Trend Analysis

The sample sizes selected for the long-term monitoring plan were based on statistical evaluations of data collected in the South River during the Ecological Study or by the SRST. The analyses described here 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 protocol SRDA-1 (Appendix D).

The goal of the long-term monitoring plan is to have a probability of at least 75% of finding a significant downward trend in mercury concentrations within 5 to 10 years. Three different trend tests were considered:

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

Power simulations were performed for each species (e.g., smallmouth bass) or response (e.g., surface water mercury). For each species or response, 1,000 simulations were performed for each combination of percent decrease, sampling frequency per year, and the number of subjects simulated at each sampling time. The simulations were performed in three reaches of river: RRMs 0.1 to 2.3, RRMs 5.2 to 11.8, and RRMs 16 to 23.5. Mean THg and variability of species were calculated separately for each indicated reach of the river. The final sample size selected for the monitoring elements are included in Table 7-2.

7.3.2 Interannual Variability

A challenging aspect of long-term mercury monitoring in aquatic systems or watersheds is understanding how changes in climate and river hydrology affect the concentrations of mercury in various media. This is due to the role that bacteria play in mercury cycling (i.e.,

methylation) and the role of the biological food web in controlling ecological exposure. In addition, physical processes like dilution can reduce exposure over biologically relevant timeframes.

The Ecological Study observed that MeHg in surface water exhibits a strong relationship to water temperature in the South River (URS 2012b). MeHg concentrations in surface water increased once surface water temperatures reached approximately 12°C. However, occasional peaks in MeHg concentrations at higher temperatures do occur, indicating that other factors besides temperature influence MeHg production and ultimately the concentrations in surface water. In addition, statistical modeling found that season, surface water temperature, and discharge were important predictors for THg and MeHg in surface water and sediment (URS 2012b).

The relationship between MeHg and climate can be used to understand the status of MeHg production in the South River. For example, daily South River discharge and surface water temperature as measured at Waynesboro (RRM 2.7) show highly variable but repeatable seasonal patterns of high discharge and low temperatures in the first and third quarters of each year (Figure 7-1, top panel). This pattern is more evident in the water temperature quotient, which is calculated by dividing the surface water temperature by the discharge (Figure 7-1, middle panel). Higher values of this quotient indicate periods of time where surface water temperatures are high and discharges are low. This value tracks closely with the percentage of MeHg in unfiltered surface water in a South River reference area (RRM 2.7; Figure 7-2, bottom panel). In addition, a clear interannual pattern is observed where certain years appear to have warmer and drier conditions than other years. For example, 2008 data show relatively high water temperature quotient values and correspondingly high percent MeHg values. In contrast, 2013 has had the lowest quotient values and the lowest percent MeHg observed in the second or third quarter of the year.

The long-term monitoring plan will use climate data and monthly surface water sampling to track the MeHg production status of the South River and SFS River. The water quality sampling regime is described in Section 7.3.5.2.

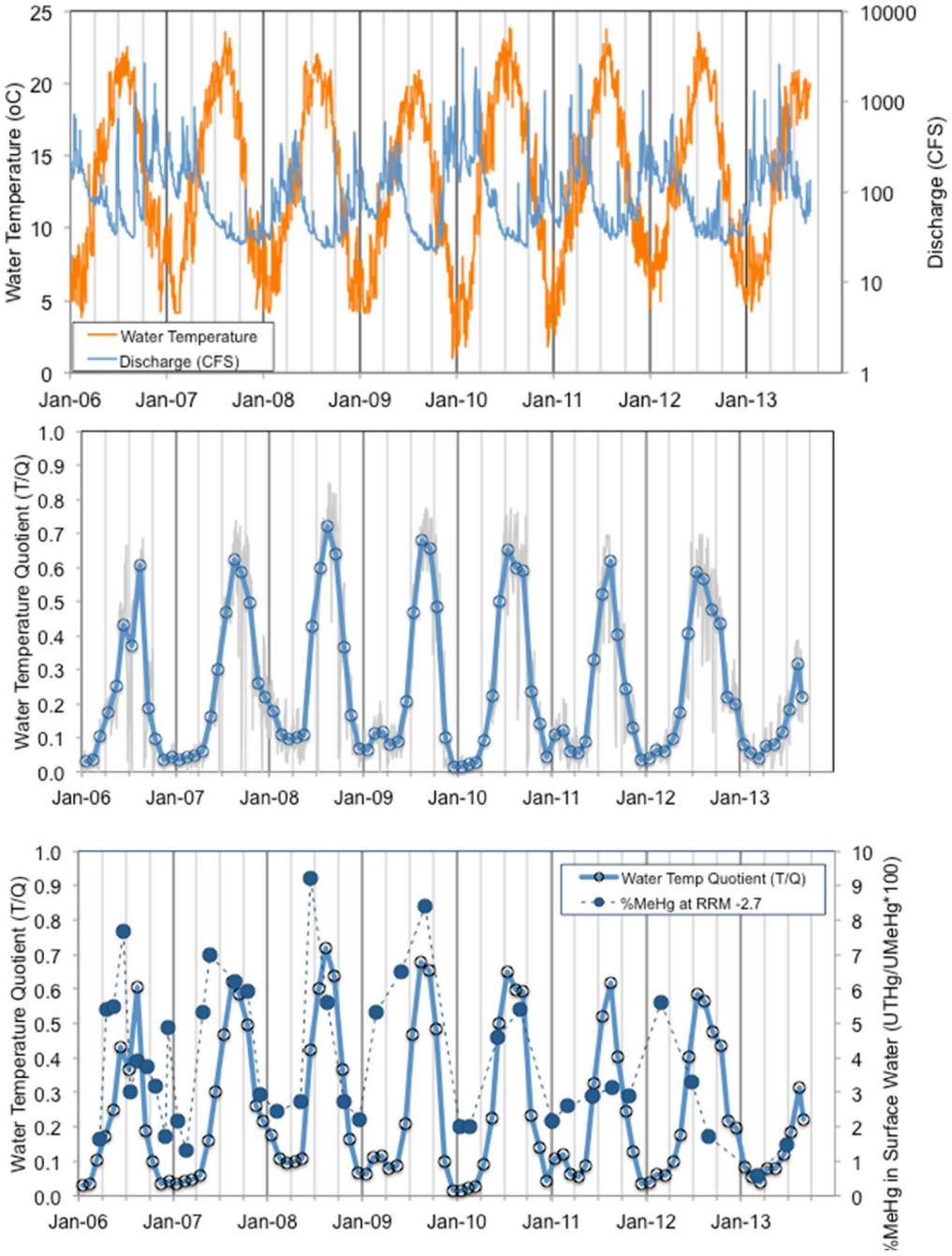

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Figure 7-1
Seasonal Variations of South River Water Temperature, Discharge, and Percent Methylmercury in Surface Water
Remediation Proposal
South River and a Segment of the South Fork Shenandoah River

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7.3.3 Human Exposure Monitoring and Community Outreach

The primary data to be collected as part of the human exposure monitoring effort are mercury concentrations in food items that might be consumed by humans that utilize the South River and SFS River. It is expected that potential food items including adult fish (smallmouth bass and largemouth bass [*Micropterus salmoides*]) will be useful for monitoring this potential exposure. Examples of other food items that may be considered for monitoring include snapping turtles (*Chelydra serpentine*) and mallard ducks (*Anas* sp.). DuPont will confer with the Virginia Department of Health (VDH) and USEPA regarding a determination of which, if any, of the additional food items should be monitored.

This section provides a description of the current state of knowledge regarding mercury toxicity, current institutional controls on fish consumption, and the strategy for collection of additional monitoring data to assess human health pathways.

MeHg forms complexes with free amino acids and other sulfhydryl-containing blood components that are transported through the body and across placental and blood-brain barriers (Burger and Gochfield 1997; USEPA 1997; Basu et al. 2005). In contrast, IHg is poorly transported across the blood-brain barrier and is stored primarily in the kidney and liver. Exposure to MeHg has been reported to adversely affect a wide range of biological functions in upper trophic level organisms, including neurotoxicity, blood and serum chemistry, histology, growth and development, metabolism, behavior, vision, hearing, motor coordination, and reproduction (Eisler 1987; Colborn et al. 1993; Wolfe et al. 1998).

MeHg is transported across biological membranes to a greater extent than IHg (Mason et al. 1996) and biomagnifies in food webs, reaching high concentrations in larger, predatory organisms. As a consequence, 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 VDH and VADEQ. A consumption ban on eating fish from the South River and SFS River was put in place in 1977 because mercury in some fish exceeded the Food and Drug Administration (FDA) action limit of 0.5 milligrams per kilogram (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, 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.

In response to Exhibit E in the Consent Decree, and through working closely with VDH, Department of Game and Inland Fisheries, and VADEQ, 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 5 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 as part of this Remediation Proposal.

The current consumption advisory is reviewed periodically by VDH to ensure it is based on the most current toxicological data for IHg and MeHg. Creel studies have been undertaken twice in the past 7 years and will be conducted every 3 to 4 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 contamination 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 7 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 who 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 numerous 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 this Remediation Proposal, 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 VADEQ continue to maintain a focus on fish consumption to ensure that these exposures remain below advisory levels, DuPont and the SRST continue to review and evaluate other potential dietary exposures to human receptors. Other potential human exposure pathways are shown in Figure 1-1 in Section 1.3.1. The results of some of these evaluations have been documented either in peer-reviewed publications and shown to not be material exposure routes (e.g., ingestion of garden crops [Berti et al. 2012]), or are ongoing (e.g., ingestion of livestock). The results of the other evaluations are in progress and

will be developed through the human health risk assessment process described in Section 1.3.1.

In response to discussions with Dr. Livingston, and in order to monitor the potential for unacceptable exposures of humans, the long-term monitoring plan will include routine sampling of adult fish. Adult fish will be included because they are the primary route for human exposure to mercury in the South River, and continue to be a major focus of the existing consumption advisory and outreach to local communities, health clinics, and physicians. In addition, some other species (e.g., waterfowl and snapping turtles) may be monitored because of their potential use as food items. These other species are not routinely consumed, but may be eaten by some individuals and also have exhibited elevated mercury levels. A final decision on which, if any, of these additional items should be monitored will be made through collaboration with VDH and USEPA. More details on the rationale for their consideration is described in the following sections and summarized in Table 7-2.

7.3.3.1 Adult Fish

The consumption of fish tissue is one of the main sources of potential mercury exposure in the South River and SFS River. The adult fish monitoring program has the following three primary objectives:

- Identify trends in potential human exposure
- Assess variability in THg and MeHg concentrations in adult fish based on seasonality and sex
- Develop a non-lethal fish tissue biopsy method for future monitoring to avoid negative population impacts

Monitoring fish tissue concentrations could reveal important information for current exposure and future sampling. Although the concentrations of mercury in adult fish may not decline significantly within the first few years of remediation in the South River, studies conducted in other aquatic systems have shown that if the remedy is effective, a measureable decline in fish tissue mercury concentrations may occur over the course of several years (e.g., Munthe et al. 2007).

The collection of additional fish tissue data will be used to improve the sensitivity of fish tissue monitoring. A comprehensive study of adult fish mercury concentrations in the South River found significant differences in mercury concentrations of fish due to both seasonality and sex (Murphy 2004). Specifically, mercury concentrations were found to be 20% higher in spring compared to summer or fall months, and mercury was higher in female fish compared to male fish. Collection of fish tissue samples in the spring and fall may help measure relatively small declines in adult fish tissue concentrations resulting from remediation.

In addition to being an important exposure medium for human exposure to mercury, adult fish are important components of the aquatic ecosystem and will be sampled in a manner that will not negatively impact the population. In the South River, adult fish will be collected from wider reaches to avoid excessive electrofishing at particular sampling stations; sampling reaches will also be selected to minimize spatial variability of mercury concentrations in abiotic and biological media. Sample locations in the SFS River will be the same locations as those that have been sampled in the past (e.g., Murphy 2004). The sampling method for adult fish sampling is described in protocol SRBF-1 (Appendix D).

In a further effort to reduce cumulative impacts on the fish populations in the South River, the collection of adult fish will be used to further develop of a non-lethal biopsy plug method in the future to avoid sacrificing adult fish. This technique has been used in the South River with success (e.g., Collins et al. 2011), but additional data are necessary to validate the method and replace the current VADEQ lethal fish sampling methods. The sampling method for non-lethal fish sampling is described in protocol SRBF-1 (Appendix D).

7.3.3.2 Examples of Additional Food Items

Examples of potential food items that may be considered for monitoring are snapping turtles and mallard ducks. A final decision on which, if any, of these additional items should be monitored will be made through collaboration with VDH and USEPA.

Snapping Turtles

Snapping turtles are a semi-aquatic piscivorous ecological receptor that are common in the South River. They are a long-lived (up to 50 years) apex predator, feeding on relatively large

fish and, as such, are capable of accumulating mercury to a greater degree than other animals in the South River (Hopkins et al. 2013). In addition, while there are no quantitative data regarding human consumption of these organisms, anecdotal information suggests they may be eaten by some individuals in the South River and SFS River watersheds.

There has been a large amount of data collected to date on snapping turtles in the South River. Hopkins et al. (2011) reports collecting and tagging more than 4,500 adult and hatchling snapping turtles, with samples from meat, blood, and nails submitted for mercury analysis. These studies have demonstrated that nail and blood mercury concentrations are strongly predictive (R^2 ~ 0.9) of mercury concentrations in meat, providing an ideal non-lethal monitoring technique.

Mallard Ducks

Blood, feathers, edible tissue, and organs of mallard ducks from the South River watershed have been sampled for mercury (Savoy and Evers 2007, 2008). Although mallards sampled from contaminated portions of the river had blood and feather mercury concentrations that were higher than those observed in reference areas, subsequent sampling of muscle and liver tissue by VADEQ reported lower tissue THg concentrations in these tissues (0.53 and 2.3 mg/kg wet weight, respectively).

Results from these human exposure monitoring efforts will be shared and discussed with VDH and other relevant regulatory agencies to determine the need for additional outreach to local communities, and potentially whether additional consumption advisories are warranted.

7.3.4 Ecological Exposure Monitoring

This section outlines the strategy for collection of additional monitoring data to assess ecological exposure pathways. The objective of this effort is to detect changes in the exposure of aquatic and terrestrial ecological receptors to mercury and the potential system responses to remediation.

Pathways and mechanisms of ecological exposure to mercury in the South River and SFS River have been studied extensively in work performed as part of the Ecological Study

(URS 2012b) and ongoing Natural Resource Damage Assessment. A comprehensive understanding of mercury fate, transport, and exposure has been developed from these two programs and studies associated with the ongoing human health and ecological risk assessments (see Section 1.3.1). The ecological exposure CSM is shown in Figure 1-2 in Section 1.3.1.

7.3.4.1 Aquatic Ecological Receptors

Potential exposure of aquatic ecological receptors will be monitored through the measurement of mercury species in young-of-year (YOY) smallmouth bass, sediment, and benthic invertebrates. The rationale and strategy for each of these elements is summarized in the following paragraphs. Periphyton and Asiatic clam tissue sampling will also be included in the long-term monitoring program, consistent with the rationale outlined in Section 2.3.5.

Young-of-Year Fish

YOY fish are an ideal monitoring element to track long-term changes in mercury exposure due to the relatively short exposures 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 2 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).

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. Changes in MeHg will be evaluated in the context of changing mercury loads and interannual variation by measuring MeHg concentration in YOY fish annually.

YOY smallmouth bass will be collected from six sample locations including one reference area at RRM -2.7, three areas from the South River, and two areas in the SFS River. The rationale for collecting fish from larger areas is to avoid oversampling the smallmouth bass or non-target species population. Smallmouth bass ranging from 60 to 110 millimeters (mm) total length will be collected in the fall of each year, beginning in 2013. Ten YOY smallmouth bass will be collected in the fall of 2013, and the results of the sampling will be used to determine adequate sample sizes for future efforts. YOY fish sampling methods are described in protocol SRBF-1 (Appendix D).

Since YOY are not typically consumed by humans, they are less appropriate in assessing the human exposure pathway. Hence, an additional monitoring program for potential human exposure to mercury from consumption of adult fish and other food items is discussed in detail in Section 7.3.1.1.

Sediment and Benthic Invertebrates

The long-term monitoring plan includes measurement of IHg and MeHg in sediments to assess whether the remedy is effective in reducing concentrations in channel margins and in the gravel matrix. Sediment is an important location for mercury storage and mercury methylation. Mercury originally released from the plant adsorbed to suspended sediment and was stored in the floodplain and in sediment in the South River. Sediment is stored as deposits adjacent to the stream bank and behind obstructions and is distributed throughout the coarse gravel matrix of the South River stream bed. Material sediment deposits associated with BMAs will be remediated as part of this Remediation Proposal and will be monitored as part of the short-term monitoring (Section 7.2). It is expected that methylation and MeHg concentrations in the gravel matrix of the streambed will decline over time as the result of natural processes, which are described in Section 6.3. As part of the long-term monitoring effort, fine-grained sediment will be collected from the stream bed in the South River and SFS River. Samples will be collected in the spring, during the period of highest MeHg concentrations in surface water and sediment (URS 2012b; Flanders et al. 2010). Samples will be collected following protocols SRSE-1 and SRSE-2, depending on the substrate type.

The long-term monitoring plan for the South River will include twice annual collection of benthic invertebrates. Benthic invertebrates are the base of the food web in the South River

because they feed on periphyton and particulate organic material transported by the water column (Tom et al. 2010). Invertebrates, in turn, are fed upon by forage fish and are a key element in the trophic transfer of mercury. Several long-term monitoring plans in the United States have measured metal levels in benthic invertebrates and used this information to quantify improvements in water quality and restoration effectiveness (Clements et al. 2000; Hornberger et al. 2009). Protocol SRBI-2 (Appendix D) describes collection of benthic invertebrate tissue.

7.3.4.2 Terrestrial Ecological Receptors

Terrestrial organisms are exposed primarily through the consumption of dietary items that have accumulated MeHg from the terrestrial and aquatic food web. Stable isotope studies suggest that mercury concentrations in top-level terrestrial predators can be accounted for via bioaccumulation from terrestrial sources (Newman et al. 2011), such as through ingestion of soil-dwelling invertebrates (e.g., earthworms). In addition, spiders accumulate mercury by feeding on a variety of invertebrates, including emergent aquatic insects (Howie 2010) and are fed on by songbirds (Cristol et al. 2008). For this reason, long-term terrestrial exposure monitoring will provide data to evaluate both pathways by collecting samples of spiders, earthworms, and Carolina wrens (*Thryothorus ludovicianus*); samples will be collected following protocols SRBS-1, SRET-1, and SRAT-1, which are included in Appendix D. Samples will be collected in the spring, during the period of highest MeHg concentrations in surface water and sediment (URS 2012b; Flanders et al. 2010). This element of the long-term monitoring plan is summarized in Table 7-2.

7.3.5 Water Quality and Habitat Quality Monitoring

Potential improvements to South River benthic habitat are anticipated due to corrective actions undertaken to control mercury loading from bank erosion. The long-term monitoring plan incorporates additional benthic community monitoring and water quality monitoring to assess these improvements. Water quality monitoring is also an important part of tracking interannual variation in the production of MeHg. Sample locations, monitoring parameters, and monitoring frequencies are summarized in Table 7-2.

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 (VADEQ 2009). The most probable stressors causing the impairment are loadings of sediment and phosphorus from point and non-point sources. 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. High densities of the aquatic invertebrate chironomids and hydropsychids, which thrive in poor quality habitat, are further evidence of this impairment.

Improvements to the conditions causing the impairment of benthic habitat are occurring through treatment of point sources and encouragement of BMPs in the watershed. The exclusion of livestock from the river is the most important BMP for improving benthic habitat quality. Other BMPs considered by the benthic TMDL include bank stabilization and riparian habitat improvement, actions that may be undertaken as part of this Remediation Proposal.

7.3.5.1 Benthic Habitat and Invertebrate Community Monitoring

Monitoring the benthic invertebrate community is an effective way to quantify biological responses to long-term improvements in water quality and habitat quality in the South River. The benthic community will be monitored in the spring and fall to provide a reasonable representation of communities. Samples will be collected from locations in reaches of the river found to have impaired benthic invertebrate communities, one reach with relatively unimpaired communities, and two reference areas. A substantial baseline data set exists for these areas so that temporal trends can be assessed.

It is expected that benthic habitat and the benthic invertebrate community will improve over time as bank stabilization proceeds and BMPs in the watershed are implemented. However, the timeframe over which this improvement will occur is uncertain. As a result, the temporal frequency of monitoring may be modified if significant annual changes are not observed.

The level of taxonomic resolution is a critical component of any sampling plan with macroinvertebrates. In previous years, organisms were identified to the level of species where possible, including chironomids and oligochaetes. Given the specific water quality or habitat requirements for different species of these two groups, little additional information is gained by species- or genus-level identification. The benthic invertebrate community will be measured using a 300-organism count subsample with identification to the lowest practical taxonomic level (i.e., genus or species). Chironomids will be identified to tribe or subfamily, and oligochaetes will be enumerated. Sample collection and analysis is described in protocol SRBI-3 (Appendix D).

Several statistical approaches developed for the Ecological Study (URS 2012b) will be used to measure changes in the benthic invertebrate community. Univariate statistical comparisons of benthic metrics will be made between data collected from different sample locations and the reference area to determine if communities are improving relative to changes in the reference areas. In addition, multivariate statistical analyses that include other site-specific variables, such as community metrics, stream embeddedness, and surface water and sediment mercury and nutrient concentrations, will determine which variables are driving recovery dynamics.

Because of the 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 long-term monitoring plan will include quantitative substrate analysis. Traditional rapid bioassessment protocols for substrate and other habitat characteristics (e.g., Barbour et al. 1999) 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.

7.3.5.2 Water Quality Monitoring

The long-term monitoring plan will continue the collection of surface water samples for mercury species, nutrients, and ancillary parameters that DuPont and VADEQ currently coordinate. Samples are collected from bridges on the South River and SFS River following methods developed by the SRST. The rationale for the selection of these three areas of focus and the monitoring plan design are described below. Surface water samples will be collected following protocol SRSW-1.

Mercury Species

Analysis of surface water samples for THg and MeHg in the water column of the South River and SFS River builds on the extensive baseline data set, provides a measurement of mercury exposure for the base of the food web, and provides important information on interannual variation in MeHg production. The South River surface water mercury database has data from as far back as 1999, providing extensive characterization of pre-remediation conditions. Samples are collected on an approximately monthly basis, providing high frequency data on mercury loading rates and mercury behavior. Interannual variability can be evaluated by comparison of MeHg concentrations in various phases of surface water (i.e., filter-passing vs. particulate) on a monthly or annual basis and combined with an evaluation of climatological data and water quality (e.g., temperature data).

Nutrients and Ancillary Parameters

Nutrients and ancillary parameters (e.g., total suspended solids, sulfate) will be collected to monitor water quality and contribute to understanding of mercury behavior and interannual variation. Dissolved phosphorus concentrations have consistently exceeded VADEQ's "threatened waters" threshold and are considered a probable cause for benthic invertebrate population impairments in the South River (VADEQ 2009). In addition to dissolved phosphorus and other nutrients listed in Table 7-2, ancillary parameters important for understanding mercury behavior are also included in the long-term monitoring plan.

7.4 Data Management

Efficient management of the extensive data collected during the monitoring phase of the project and integration of these data with past data will be critical to the evaluation,

interpretation, and presentation of results. As part of the Ecological Study of the South River, a master database has been developed that incorporates analytical data generated during this project, as well as available historical data. In addition, advanced geographic information systems analysis has been to combine spatial data (e.g., current and historical aerial photography, geomorphology studies, land use and habitat delineations, and hydrology) with analytical and other types of data. The resulting analyses were presented in detail in the Ecological Study (URS 2012b) and form the basis of the database that will be used to analyze monitoring data, as described in protocol SRDA-1 (Appendix D).

For the monitoring phase of the project, 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.

8 IMPLEMENTATION AND MANAGEMENT

As discussed in Section 1, this Remediation Proposal is being developed to satisfy the requirements of the Consent Decree, and in consideration of regulatory agency (e.g., NCP) guidelines. Corrective action design and implementation of the recommended remedy described in Section 6.2 is anticipated to be performed under a forthcoming legal agreement ("Agreement") under the RCRA regulatory program between DuPont and VADEQ in collaboration with USEPA. The overall objectives of the Agreement are to accelerate remediation design and implementation of this Remediation Proposal, beginning with the Phase 1 actions described herein, reducing exposures of humans and ecological receptors to mercury in the South River and a segment of the SFS River. All work performed under the Agreement will be performed consistent with the requirements of the NCP, and also consistent with USEPA (2005) guidance.

A monitoring plan for the recommended remedy is provided in Section 7. However, this plan is subject to review and potential modification by VADEQ in consultation with USEPA and the SRST. Under VADEQ oversight, the detailed specifics of the monitoring and adaptive management program will be developed during corrective action design. As discussed in Section 3.1.1, because the outputs from the relative risk model can be applicable to understanding net risk reduction from the implementation of a remediation action, it will be coupled to the monitoring and adaptive management plan to provide a more holistic view of the benefits from implementing specific elements of the Remediation Proposal.

8.1 Next Steps

The key upcoming tasks and approximate schedules for implementation of this Remediation Proposal include the following:

- RCRA Permit Amendment – end of 2013/early 2014
- Pre-design sampling and analysis and bank characterization needed to develop site-specific BMA designs in RRMs 0 to 2 – late 2013/early 2014, including the following:
  - Bank angle
  - Bank height
  - Surface soil texture and viability

  - Existing vegetation quality and quantity
  - Bank facing direction
  - Toe condition and potential for undercutting
  - Expected shear stresses on bank face
  - Other indications of potential future bank erosion, including potential bank "failure" factors identified in the Ecological Study (URS 2012b)
  - Proximity of bank IHg deposit to bank face
  - Potential impacts on neighboring banks/floodplain properties

- Phase 1 Interim Measures Design, Implementation, and Monitoring Work Plan – spring 2014
- Baseline Monitoring – spring/summer 2014
- Completion of Waynesboro Plant Interim Measures – fall 2014
- Baseline Monitoring – spring/summer 2015
- Phase 1 Landowner and Agency Discussions – 2014 and 2015
- Phase 1 Interim Measures Design (Preliminary and Final) – 2014 and 2015
- Phase 1 Interim Measures Construction – 2015 and 2016
- Phase 2+ Design – 2016 and beyond
- Phase 2+ Construction – 2017 and beyond

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APPENDIX A
BANK STABILIZATION PILOT AND TREATMENT PILOT TECHNICAL BRIEFING PAPERS

Bank Stabilization Pilot Study: Technical Briefing Paper

This briefing paper summarizes key findings from performance monitoring studies conducted between 2010 and 2013 as part of the Bank Stabilization Pilot Study. Study findings resulting from the physical, chemical, and biological sampling efforts are summarized below. The information reviewed and presented herein are not comprehensive; additional details regarding the scope of work, methodologies, assessments, and conclusions are documented in URS (2012, 2011a, 2011b, and 2010) and Turner and Jensen (2008).

Introduction

In the fall of 2009, a section of stream bank (Pilot Site) along the South River in Waynesboro, Virginia was physically stabilized and re-planted with a native vegetative community to abate localized bank erosion. The bank stabilization pilot design incorporated three main components: 1. A rock toe at the base of the bank for slope protection; 2. Soil lifts to engineer a more stable and gradually sloping bank and 3. Native vegetation on both the slope and top of the bank, providing further stability and habitat. The objective of the Bank Stabilization Pilot Study monitoring program is to assess whether control of mercury (Hg) loading to the water column and sediment from eroding bank soil will result in reductions of Hg concentrations in the aquatic environmental media (i.e., pore water, sediment, surface water, and biological tissue). Monitoring also included a geomorphic assessment based on cross sectional information, and plant stock survival, as well as an assessment of the re-established vegetative community. This briefing paper describes key findings of the physical, chemical and biological monitoring thru the 2013 annual monitoring event. Additional monitoring is scheduled for the fall of 2013.

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Physical

Pre- and post-stabilization channel morphology monitoring was conducted by evaluating eight stream cross sections within the project area: two upstream of the Pilot Site, five within the Pilot Site area, and two downstream of the Pilot Site. Erosion monitoring was also conducted along both the stabilized and opposite banks utilizing erosion pins to determine erosion rates. Monitoring data collected to date demonstrate that the pilot bank has remained stable, withstanding a near 10-year recurrence storm event. However, minor changes to channel morphology within the wetted channel and opposing bank have occurred. These changes included deposition of coarse sand attributed to active floodplain bedload transport, and deposition occurring along the left bank upstream of the Pilot Site (Transect Up-3) where a historical side channel/floodplain bench is located. Additionally, mid-channel deposition of

boulder material was documented, likely from movement of constructed launchable rock toe material at the Pilot Site.

Chemical

Sediment, pore water, and Asiatic clam (*Corbicula fluminea*) tissue samples were collected and analyzed to detect potential changes in mercury concentrations before and after stabilization.

Sediment

Collection of sediment samples associated with the Bank Stabilization Pilot Study monitoring occurred in 2008 as part of a near-bank characterization event, and in 2009 to provide pre-stabilization data. Post-stabilization monitoring included data collections in November 2009, June 2010, June 2011, March and June 2012, and June 2013 (Table 1; Figure 1). Results of the sediment component of the monitoring program indicate the following:

- Total mercury (THg) concentrations in sediment collected post-stabilization are generally lower than concentrations of THg in pre-stabilization sediment samples (Table 1). THg reduction in nearbank sediment is thought to be a result of decreased erosion due to bank stabilization and partial capping through placement of the rock toe. Additionally, Hg concentrations in fine-grained sediments accumulating within the rock toe reflect the concentration of Hg on solids within the water column.
- Variability among post-stabilization near-bank THg concentrations has been reduced compared to pre-stabilization sampling events.
- THg concentrations in sediment are generally similar to those measured on suspended particles.

Pore Water

Pore water samples associated with Bank Stabilization Pilot Study monitoring were collected in June, July, and August 2009 to provide pre-stabilization data. Post-stabilization data were collected in June 2010, June 2011, June 2012, and June 2013 (Table 2; Figure 2). The pore water component of the monitoring program indicates the following:

- Filtered inorganic mercury (FIHg) concentrations in pore water have generally declined on an average basis; however, these declines are not statistically significant due to the high variability observed in the area adjacent to the rock toe (Table 2).
- Filtered methylmercury (FMeHg) concentrations in pore water are highly variable at the Pilot Site, and have not declined over time (Table 2).

Asiatic Clam Tissue

Previous studies have demonstrated the utility of using transplanted Asiatic clams to measure mercury uptake; clams were deployed along the Pilot Site as part of the monitoring program using these same methods. To measure Hg uptake rates by Asiatic clams, tissue data were collected from seeded clams in 2009 (pre-stabilization), and 2010, 2011, 2012, and 2013 (post-stabilization) (Figure 3; Figure 4). The Asiatic clam tissue monitoring program indicates the following:

- Asiatic clam uptake data indicate significant decreases in IHg uptake in 2010; increases in IHg uptake were observed in 2011 and 2012, and in 2013 significant decreases were observed (Figure 4). These increases in 2011 and 2012 are thought to be related to increased IHg loading from the plant outfall associated with perturbations to the on-site sewer system during remedial activities.

- No significant differences in MeHg concentrations over time were observed; however, higher concentrations in the near-bank area compared to mid-channel were identified (Figure 4).

Biological

Biological monitoring included an assessment of the vegetative community and a structural habitat quality assessment following USEPA Rapid Bioassessment Protocols.

Vegetative Community

Prior to construction, opportunistic species, including Grape vine (*Vitis* sp.), Virginia creeper (*Parthenocissus quinquefolia*) and Poison ivy (*Toxicodendron radicans*), dominated the Pilot Site vegetative community. Removal of these species occurred during construction, and they were replaced by a community of native grasses and trees post-stabilization. Results of post-stabilization vegetative community monitoring indicate the following:

- First year growth upstream and downstream of the Pilot Site reached 100% coverage, while maximum Pilot Site bank cover reached 70%. Additional plant stock that was planted at the Pilot Site in 2011 continues to thrive.
- Non-native species have become established along the Pilot Site, representing a minimal portion vegetative community.
- Natural recruitment of herbaceous and woody species such as sycamore saplings, have colonized the rock toe of the Pilot Site in a similar manner to naturally occurring gravel bar islands.

Habitat Quality

Habitat quality assessments were performed along the Pilot Site following USEPA Rapid Bioassessment Protocols (Barbour et al., 1999) in order to assess bank stability, vegetative protection, epifaunal substrate/available cover, embeddedness, and substrate characterization within the river channel. Results indicate the following:

- Baseline bank stability and vegetative protection within the Pilot Site were both suboptimal prior to stabilization.
- Immediately following construction, the Pilot Site bank was categorized as suboptimal or optimal in terms of stability, and poor or suboptimal in terms of vegetative protection. This assessment occurred shortly after construction, during the winter, prior to plant growth.
- Post-construction surveys in late Spring 2010 identified that vegetative protection had returned to pre-construction levels of suboptimal.
- Surveys conducted through 2012 identified bank stability and vegetative protection as optimal. Epifaunal substrate/available cover and pool substrate characterization were both suboptimal, while embeddedness was optimal.
- Surveys conducted in 2013 identified an area at the edge of the bank where the geotextile fabric is visible. This area and the area along Rockfish Run will be closely monitored for potential changes that might impact the integrity of the bank stabilization.

Summary of Preliminary Findings

A summary of preliminary findings from the Bank Stabilization Pilot Study monitoring program through the 2013 annual monitoring event are as follows:

- The stabilized bank has withstood a 10-year flood event, and exhibits signs of continued stability; however, minor changes in channel morphology are evident. These changes are

most notably in the near bank area associated with the launchable toe as well as in movement of fine sediments below the confluence of Rockfish Run associated with a historical snag being washed away during the 10-year flood event.

- Chemical monitoring suggests that mercury concentrations in sediment and pore water have declined on an average basis since stabilization, but that the high variance in the pre-stabilization data set prevents detecting significant differences. The 2013 chemical monitoring data indicate a reduction in THg in all media in comparison to previous years monitoring data.
- Biological tissue data demonstrated an initial decrease in IHg in transplanted *Corbicula* following stabilization. An increase in IHg concentrations, however, was observed in 2011 and 2012, which is thought to be related to temporal perturbations to the system associated with remedial activities at the former DuPont plant site. Decreases in IHg concentrations in transplanted *Corbicula* were observed in 2013.
- The vegetative community is well established and aids in stabilization of the Pilot Site.

Table 1
Mercury Concentrations in Sediment
Bank Stabilization Pilot Study
Technical Briefing Paper

Sample ID	Sediment Type	Sample Date	THg (mg/kg)	Average THg (mg/kg)	Standard Deviation	Relative Standard Deviation
Pre-Stabilization						
T1	Interstitial	August 2008	54	19	24	128%
T3_T5			19			
T6			1.2			
C	Bulk	March 2009	2.4			
Post-Stabilization						
A	Interstitial	November 2009	0.4	0.43	0.15	34%
B			0.3			
C			0.6			
UP		June 2010	1.9	1.1	0.8	78%
A			1.6			
B			0.3			
C			0.4			
UP		June 2011	3.9	3.8	1.1	28%
A			2.6			
B			3.6			
C			5.2			
UP		March 2012	1.7	3.1	1.9	62%
A			2.2			
B			2.6			
C			6.0			
UP		June 2012	4.1	3.1	0.8	27%
A			2.1			
B			3.2			
C			3.1			
UP		June 2013	1.3	1.3	0.40	30%
A			1.1			
B			1.9			
C			1.0			

Table 2
Pore Water FIHg and FMeHg Monitoring Summary
Bank Stabilization Pilot Study
Technical Briefing Paper

Sampling Date	Mean FIHg (ng/L)	FIHG Range (ng/L)	SD	Mean FMeHg (ng/L)	FMeHG Range (ng/L)	SD
June 2009	53	2.26 - 131	42	10	1.04 - 40.5	11
July 2009	51	5.23 - 292	83	3.9	0.36 - 14.4	4.0
August 2009	82	2.73 - 510	153	2.3	0.04 - 6.83	2.0
June 2010	27	2.94 - 176	48	4.4	0.14 - 20.9	6.6
June 2011	27	14.1 - 47.8	13	3.3	0.13 - 13.7	4.5
June 2012	25	5.37 - 32.7	9	3.4	1.1 - 7.18	2.0
June 2013	9	4.48 - 21.1	4	2.1	0.26 - 4.49	1.4

Notes:

Samples were collected at transects A-C".

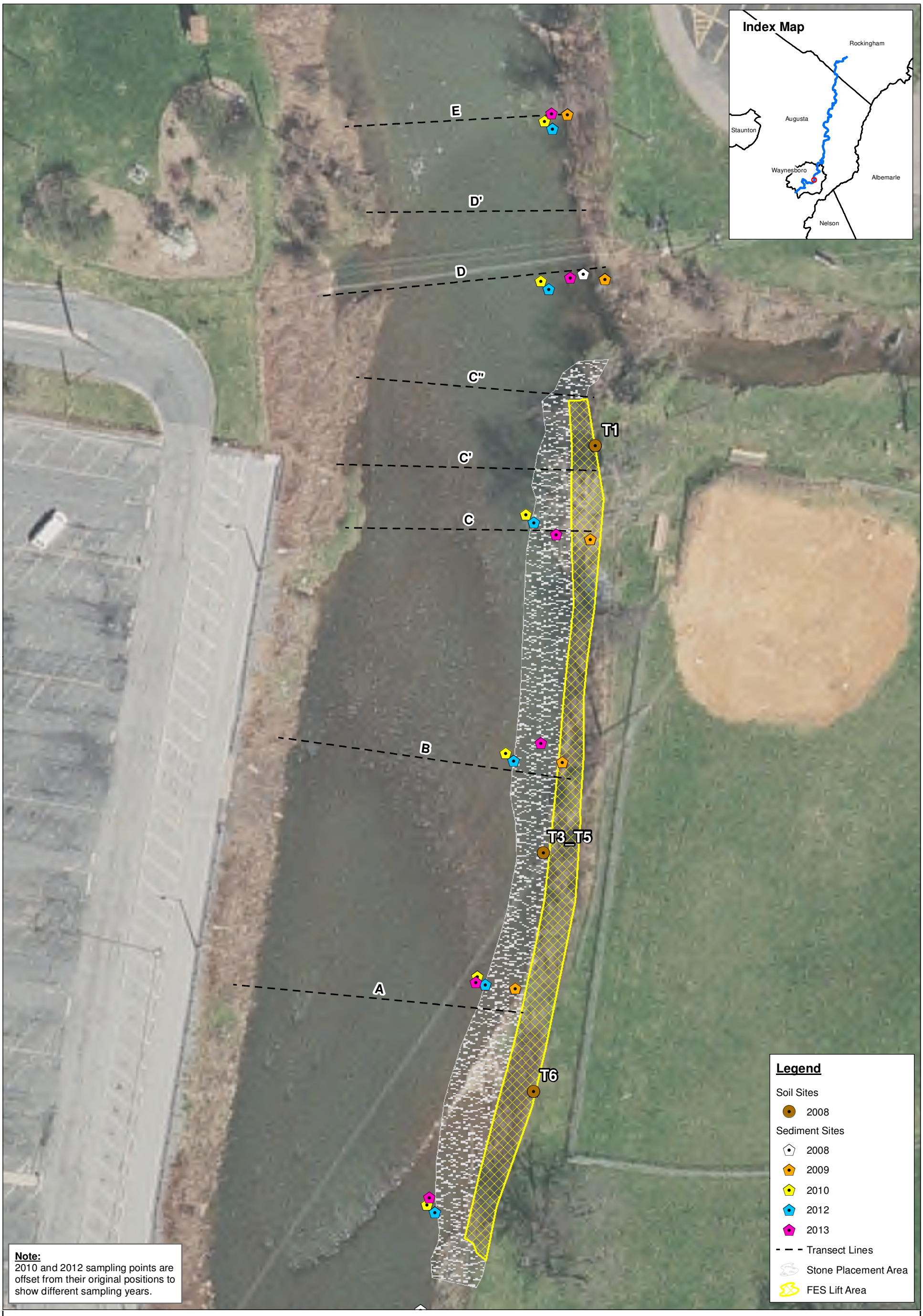
FIHg: Filtered inorganic mercury

FMeHg: Filtered methylmercury.

SD: Standard deviation.

Bank Stabilization occurred in Fall 2009

10-Yr Storm event occurred April 2010



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SOUTH RIVER PROJECT

PROJECT NO. 18985624

0 20 40 80 Feet

1 inch = 40 feet

Figure 1
Sediment Sampling Locations
Bank Stabilization Pilot Study
Revised Technical Briefing Paper

Source: Aerial Photography - SURDEX 2005

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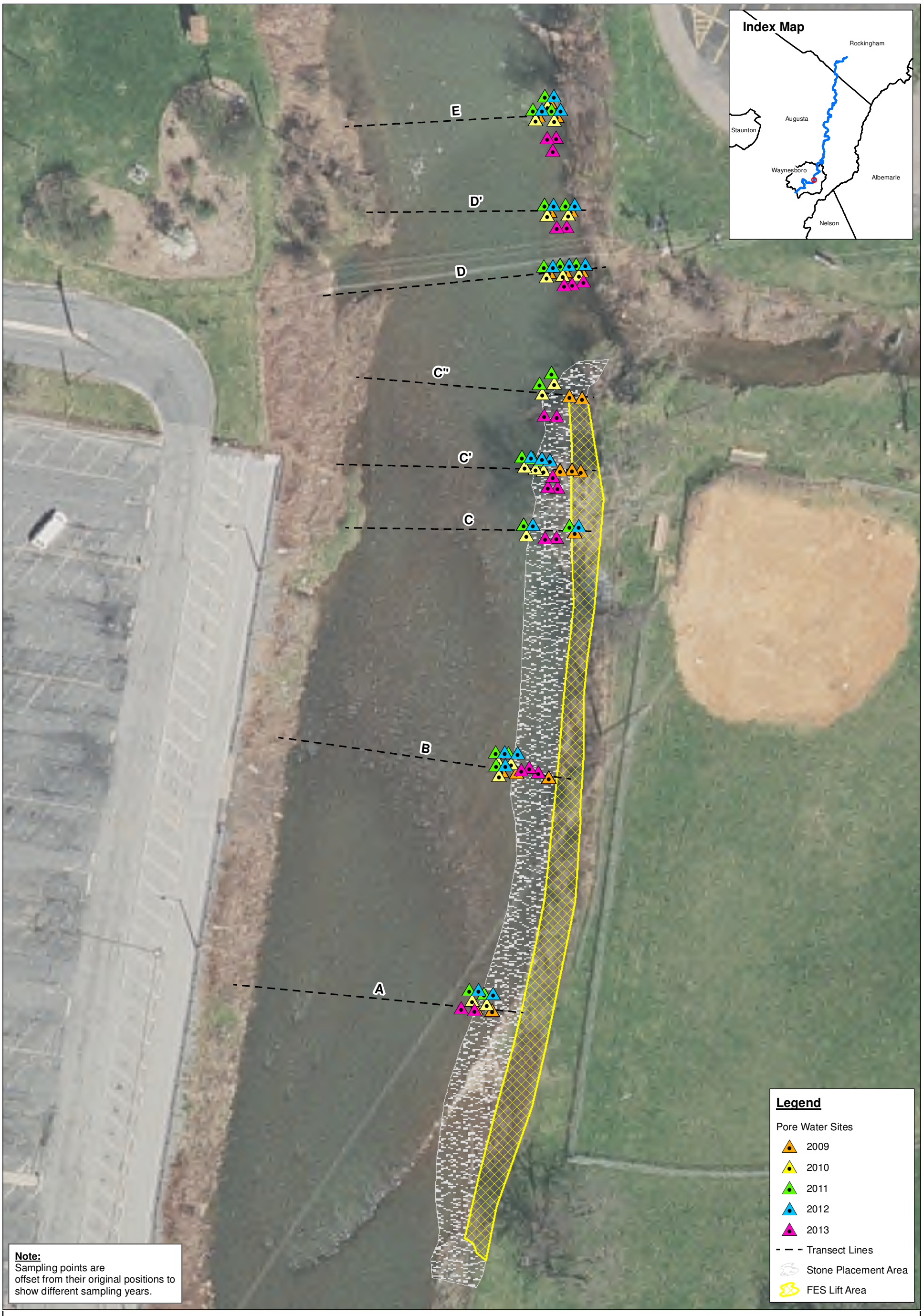

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SOUTH RIVER PROJECT

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1 inch = 40 feet

Figure 2
Pore Water Sampling Locations
Bank Stabilization Pilot Study
Technical Briefing Paper

Source: Aerial Photography - SURDEX 2005

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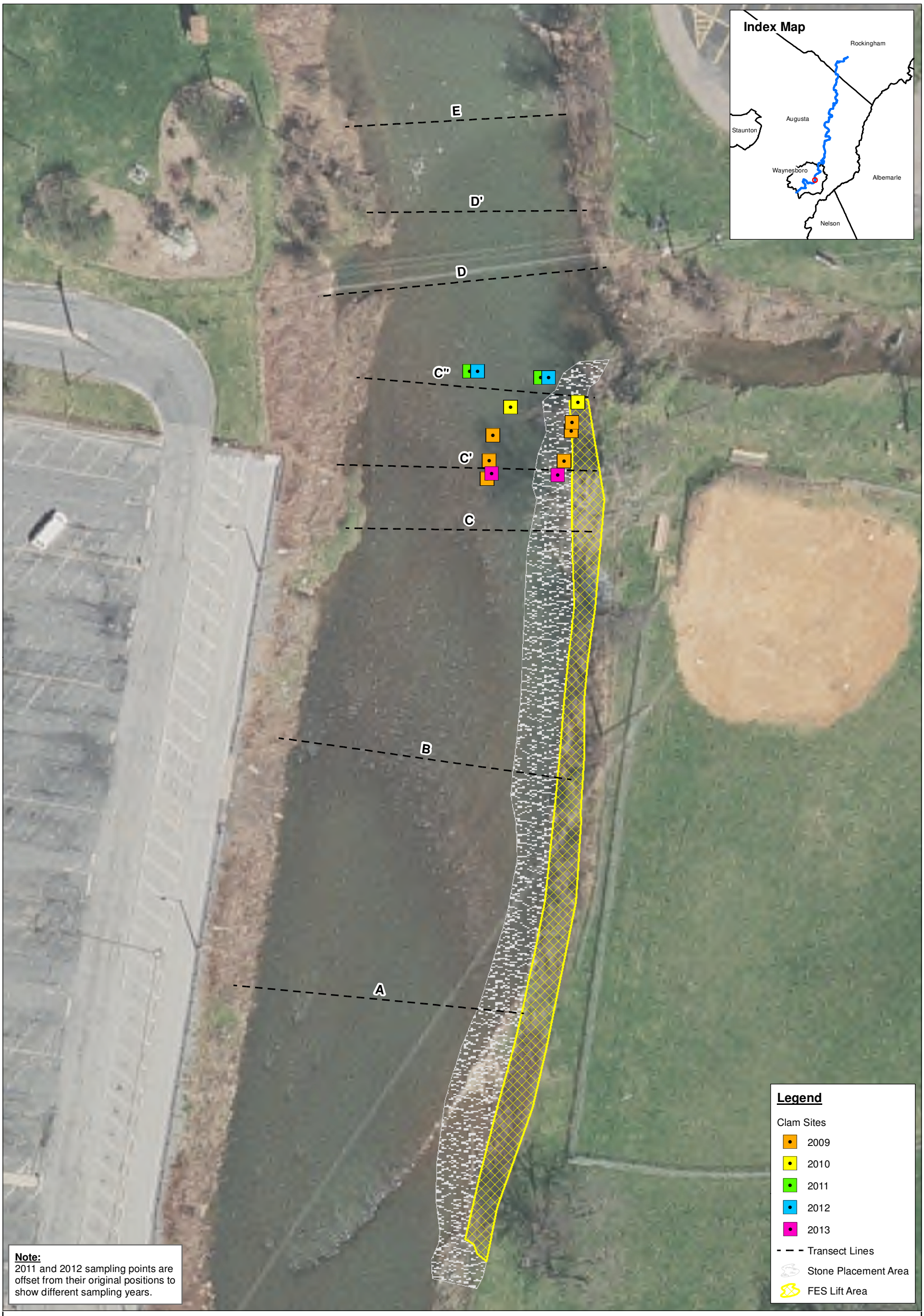

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SOUTH RIVER PROJECT

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0 20 40 80 Feet

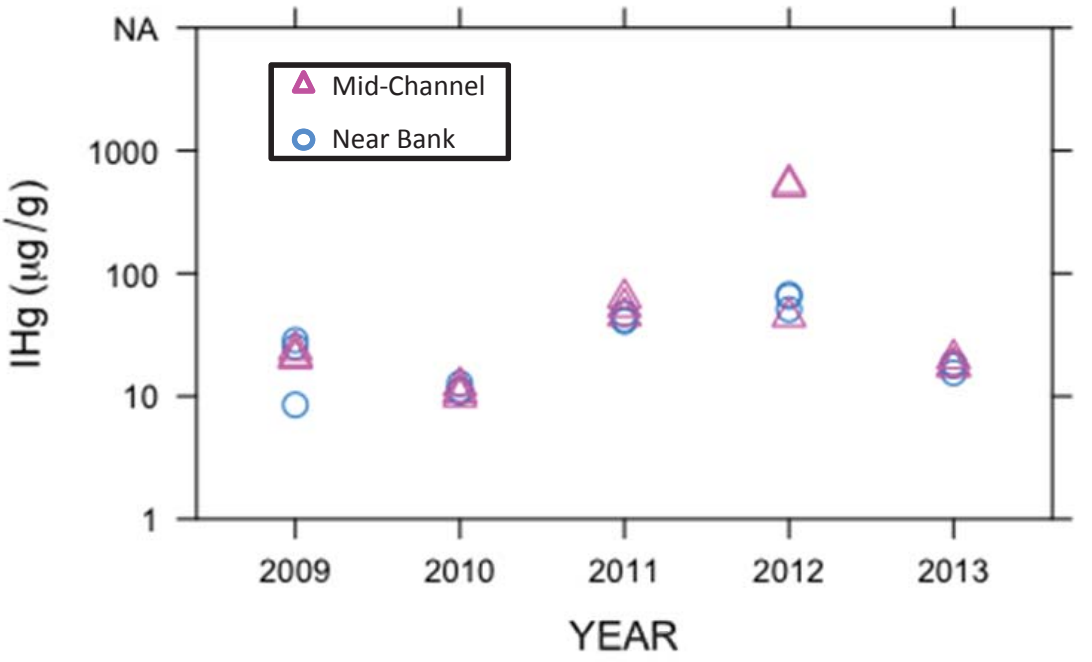
1 inch = 40 feet

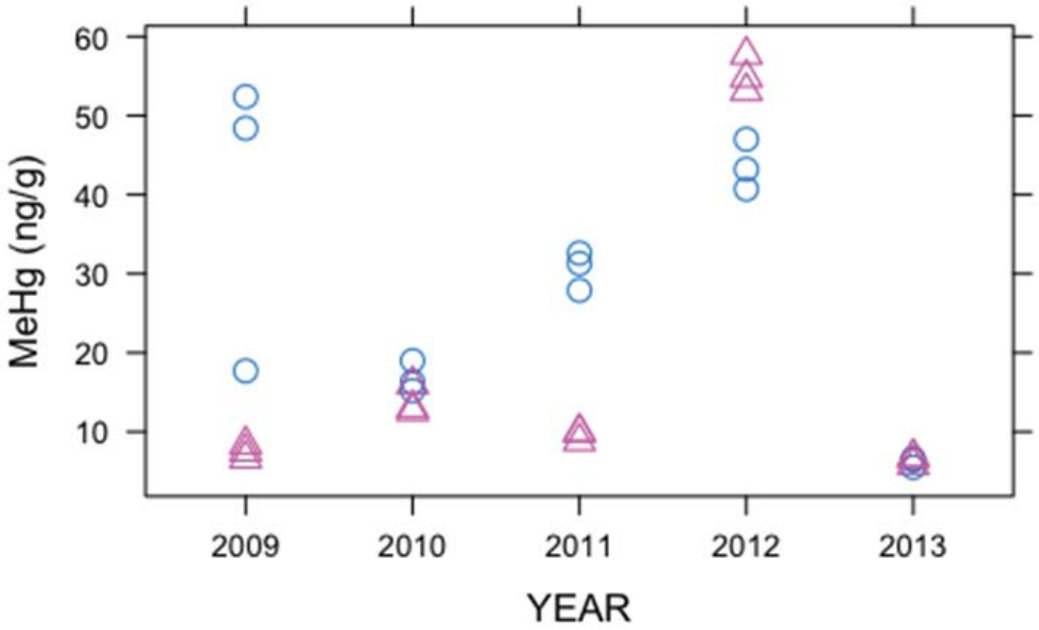
Figure 3
Asiatic Clam Sampling Locations
Bank Stabilization Pilot Study
Revised Technical Briefing Paper

Source: Aerial Photography - SURDEX 2005

S:\Projects\IMS\DUPONT\STHRIVER\Projects\WaynesboroPilot\TechnicalBriefingPaper2013\Revised\Figure 3 Asiatic Clam Sampling Locations Revised.mxd

Figure 4
Asiatic Clam IHg and MeHg Uptake
Bank Stabilization Pilot Study
Technical Briefing Paper





Use of a Carbon Amendment to Reduce Bio-uptake of Mercury in a South River Floodplain Pond: Technical Briefing Paper

This briefing paper summarizes the objectives, study approach, and preliminary findings of the South River Pond Pilot Study. Ongoing annual monitoring has been conducted since the study pond was amended in the spring of 2011. The data reviewed and presented herein include results and findings from monitoring conducted in 2011, 2012, and 2013.

Introduction

Mercury was used between 1929 and 1950 at DuPont's Waynesboro, Virginia site, and was released and transported into surface water, sediments, soils, and biota of the South River. Remedial options are currently being evaluated for their ability to reduce the bioavailability of mercury to South River biota; one involves the use of carbon based sediment amendments. To assess the viability and efficiency of a sediment amendment remedial option, the Pond Pilot Study was implemented in 2011 in a South River floodplain pond using a two-phased approach (URS, 2011). Phase I included pond site selection, characterization of the pond, permitting, strategy development, and delineation of water/wetlands surrounding the pond. Phase II included amendment selection and deployment, engineering activities, and post-amendment annual monitoring (on-going).

References

- ✓ Hopkins, W. A. 2009. Reproduction and Development in *Bufo Americanus* from the South River, VA. 2008-2009 Annual Report. Prepared for E.I. DuPont de Nemours Company.
- ✓ Ptacek C. and D. Blowes. 2010. *Riverbank Sediment Characterization and Preliminary Treatment Results.* University of Waterloo Powerpoint Presentation. South River Science Team Expert Panel Meeting, October 2010, Virginia.
- ✓ Reible, D., P. Bireta, and R. Landis. 2012. Field measurement of porewater Hg using DGT. South River Science Team Expert Panel Meeting, October 2012, Virginia.
- ✓ URS Corporation, 2011. Amendment Pilot Work Plan, South River Amendment Pilot Study, Waynesboro, Virginia. Wilmington, Delaware.

Objectives

The purpose of the study is to test the efficacy of a sediment carbon amendment in limiting the bioavailability of mercury to biological receptors. Specific objectives are listed below:

- ❑ Assess the efficacy of the carbon amendment in reducing mercury concentrations in environmental media and bioavailability to biological receptors.
- ❑ Assess potential unintended consequences of the carbon amendment on water quality, sediment characteristics, and the benthic community.
- ❑ Demonstrate progress toward innovative remedial strategies.

Study Area Selection Process

A review of aerial imagery was performed to identify ponds within the South River floodplain for potential carbon amendment. The following descriptive information was gathered for each pond: accessibility, pre-existing data, presence of suitable monitoring organisms, and location on the floodplain. Based on review of this information, a candidate pond near relative river mile (RRM) 8.7 was chosen for the Pond Pilot Study (Figure 1).

The Pond Pilot Study site (pond) is adjacent to a smaller pond which was included in a previous study concerning mercury concentrations in the tissue of American toads (*Anaxyrus americanus*) (Hopkins, 2009). The property is not easily accessible by the public and is not located near public roads. The property is part of the Conservation Reserve Enhancement Program (CREP), and has broad areas that are planted with a variety of hardwood saplings. The property will be restored to pre-disturbance conditions at the conclusion of the pilot study, including vegetative cover.

The pond is approximately 42 feet by 103 feet, but physical features vary with groundwater elevation, river stage, and flood inundation. During the initial study period in 2011, the pond had a surface area of 3,365 ft^2 and volume of 2,580 ft^3. The surface water level in the pond varies seasonally from approximately 2.5 to 6.0 feet in depth. The pond is an isolated, groundwater-fed floodplain feature, which also receives input from the river during flooding conditions. The direction of groundwater flow in the vicinity of the pond is toward the southeast based on groundwater elevation data. The substrate of the pond is not uniform—the margins are primarily silt, which increases in depth on the northwestern edge; the central area of the pond is primarily cobble.

Investigation Approach

In June 2011, a 'semi-impermeable' barrier was installed in the pond to create two discrete study areas or cells. The southern cell received the carbon amendment and is referred to as the amended cell. The northern cell remained untreated, serving as a control. The primary materials used to construct the barrier consisted of galvanized pipe, high-density polyethylene (HDPE) membrane (20-30 mm thickness), and sandbags.

In July 2011, approximately 2,000 pounds of commercially available biochar (i.e., Cowboy Charcoal®) were saturated with water and applied to the amended cell of the pond by way of a pneumatic biochar applicator. Biochar is a carbon-rich product created from biomass (e.g., hardwood) that is heated to elevated temperatures under oxygen deficient conditions. Biochar has proven effective in reducing biological uptake in metal-contaminated sediments (Ptacek, 2010).

Physical media (i.e., surface water, sediment, and pore water) and biological tissues [*Caenis sp.* (Mayfly nymph), Chironomidae (midge larvae), Planorbidae (aquatic snail), young-of-year bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*) and wood frog tadpoles (*Rana sylvatica*)] have been monitored for inorganic mercury (IHg) and methylmercury (MeHg) as part of the Pond Pilot Study. Pore water IHg has also been monitored using diffusion gel thin film (DGT) devices (Reible et al., 2012). Additionally, the benthic macroinvertebrate community, *in situ* water quality, and sediment characteristics have been monitored to assess potential unintended

consequences of the carbon amendment. Monitoring took place prior to barrier installation ("pre-barrier"), prior to adding the carbon amendment ("baseline"), and at 1, 2, 4, 8, 12, 16, 20, 43, 50, 61, 97, and 104 weeks post-amendment. One additional monitoring event is scheduled to take place at approximately 118 weeks post-amendment.

Study Results

A summary of results thru the 2013 annual monitoring from the South River Pond Pilot Study is provided below. While the setup of the pilot study occurred in such a way to eliminate differences between the amended and control cells, not all conditions can be controlled for in a field pilot. Hence, these preliminary results should be reviewed in the context of uncertainties associated with any dynamic natural system such as the effects of surface water mixing from overtopping barrier during natural flooding events, redistribution of biochar over time, water depth, fresh particulate Hg deposition due to periodic runoff or flooding, baseline sediment physical and chemical differences between the amended and control side, biological and chemical factors.

Study results from the South River Pond Pilot Study thru the 2013 annual monitoring are as follows:

- Surface Water: Filtered inorganic mercury (FIHg) and filtered methylmercury (FMeHg) concentrations in surface water are significantly lower in the amended cell than the control cell (Figure 2).
- Aquatic Macroinvertebrates:
    - IHg concentrations in *Caenis sp.*, Chironomidae, and Planorbidae tissue are generally lower in the amended cell (Figure 3).
    - MeHg concentrations in *Caenis sp.* and Planorbidae tissue are significantly lower in the amended cell (Figure 4). Chironomidae tissue MeHg results are less consistent.
- Wood Frog Tadpoles: MeHg concentrations in wood frog tadpole tissue were significantly lower in the amended cell at post-amendment weeks 43 and 97 (Figure 5). There was no difference in IHg tissue concentrations at week 43. However, concentrations of IHg in tadpole tissue were significantly lower in the amended cell at post-amendment week 97.
- Bluegill Sunfish: MeHg concentrations in young-of-year bluegill tissue were significantly lower in the amended cell at post-amendment week 50. However, concentrations of MeHg in fish tissue were significantly lower in the control cell at week 104. (Figure 5). There was no difference in IHg tissue concentrations.
- Pore Water: IHg and MeHg concentrations in pore water are generally lower in the amended cell (Figure 6).
- Sediment: Consistent overall trends in grain-size-normalized sediment IHg and MeHg concentrations between cells are not evident (Figure 7).

- Benthic Community: Unintentional consequences of the carbon amendment on the native benthic community composition in the Pilot Study pond are not evident.

Summary of Preliminary Findings

The application of biochar appeared to remove mercury from the water column, as evidenced by the significant decline in water mercury concentrations. The amendment appeared to reduce MeHg uptake by ecological receptors that are more closely associated with surface water exposures, including snails, wood frog tadpoles, and young of the year bluegill. This is consistent with the current conceptual model for mercury exposure in low trophic level and young organisms, which may receive 50% of their mercury load via aqueous exposures.

The results of the DGT sampling, which showed a 50% decrease in pore water MeHg concentrations, strongly suggest that either methylation is suppressed in sediment or that partitioning is affected, reducing the labile MeHg (Reible et al., 2012). MeHg concentrations were lower in sediment following amendment consistent with the hypothesis that methylation was suppressed.

Preliminary findings from the South River Pond Pilot Study thru the 2013 annual monitoring are as follows:

- The carbon amendment may have had a positive effect, reducing methylmercury concentrations in surface water and biological receptors monitored during the high methylation period in Spring 2012.
- The carbon amendment may be causing a reduction in the concentrations of IHg and MeHg in environmental media, and the bioavailability of MeHg to biological receptors.
- To date, no adverse effects of the sediment carbon amendment on water quality, sediment characteristics, or the benthic community have been observed.
- Preliminary results and findings of the South River Pond Pilot Study provide input use of amendments in remedial options strategies for reducing the bioavailability of mercury to South River biota.

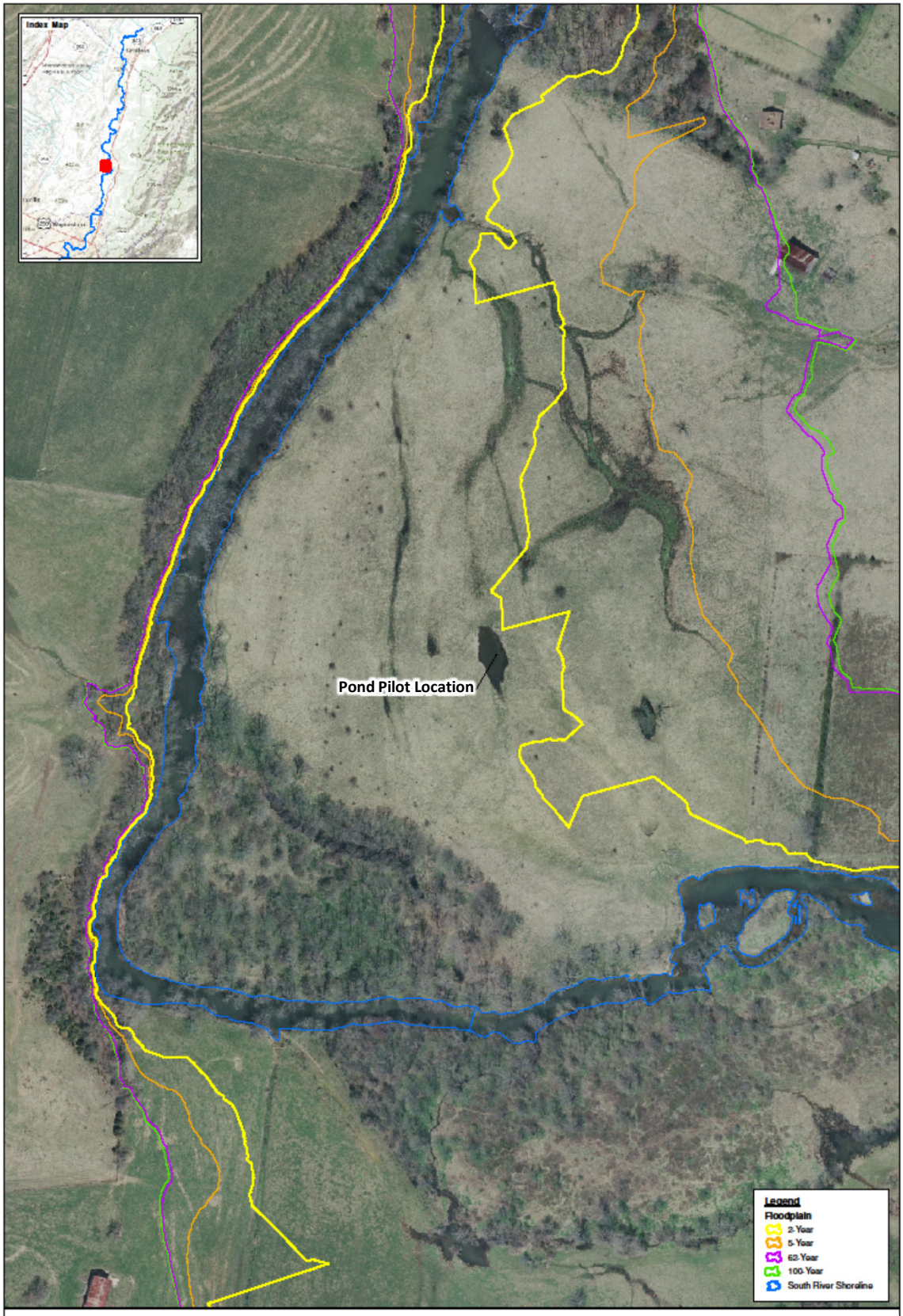
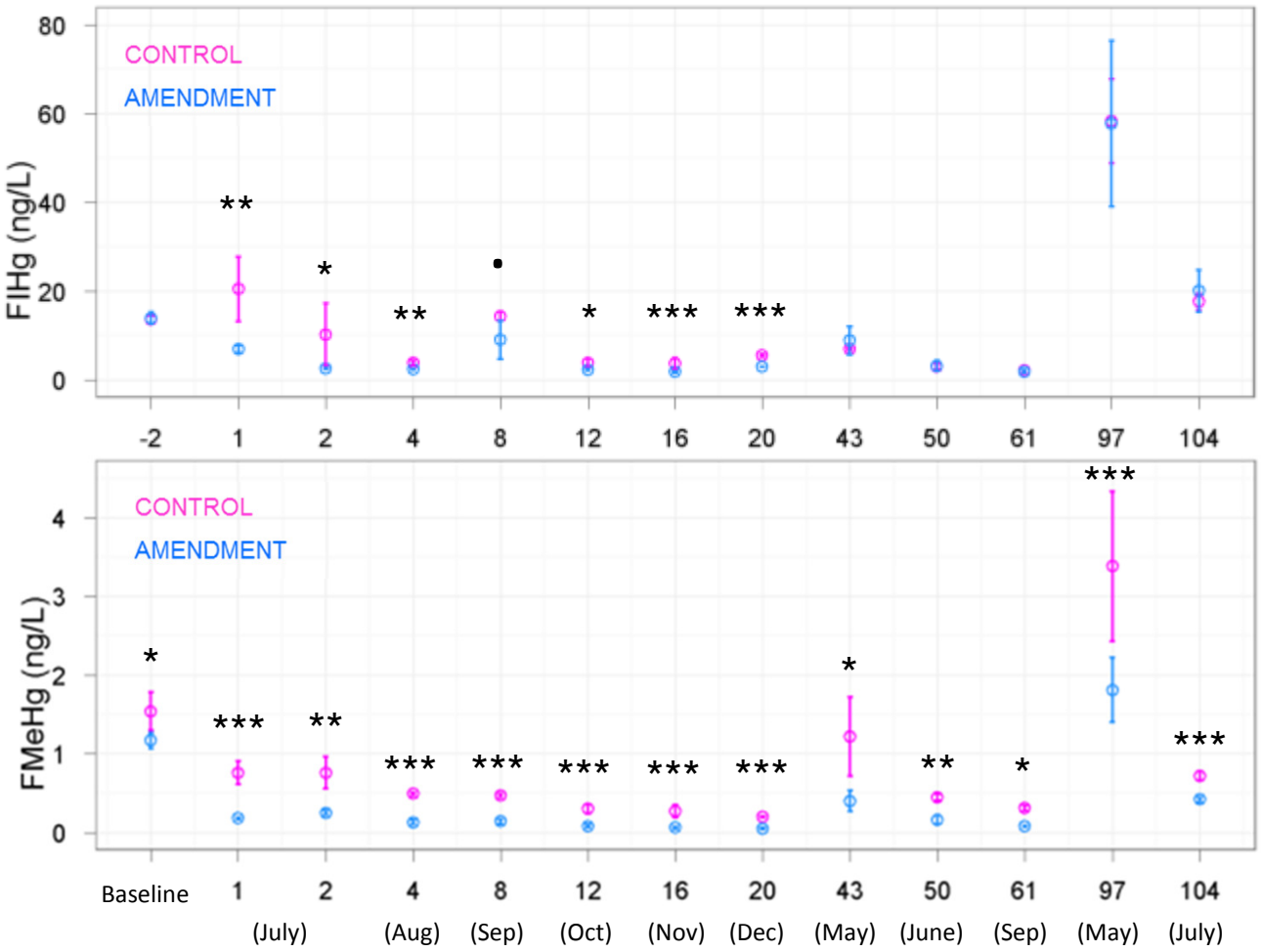


Figure 1
Pond Pilot Location
South River Pond Pilot Study:
Technical Briefing Paper

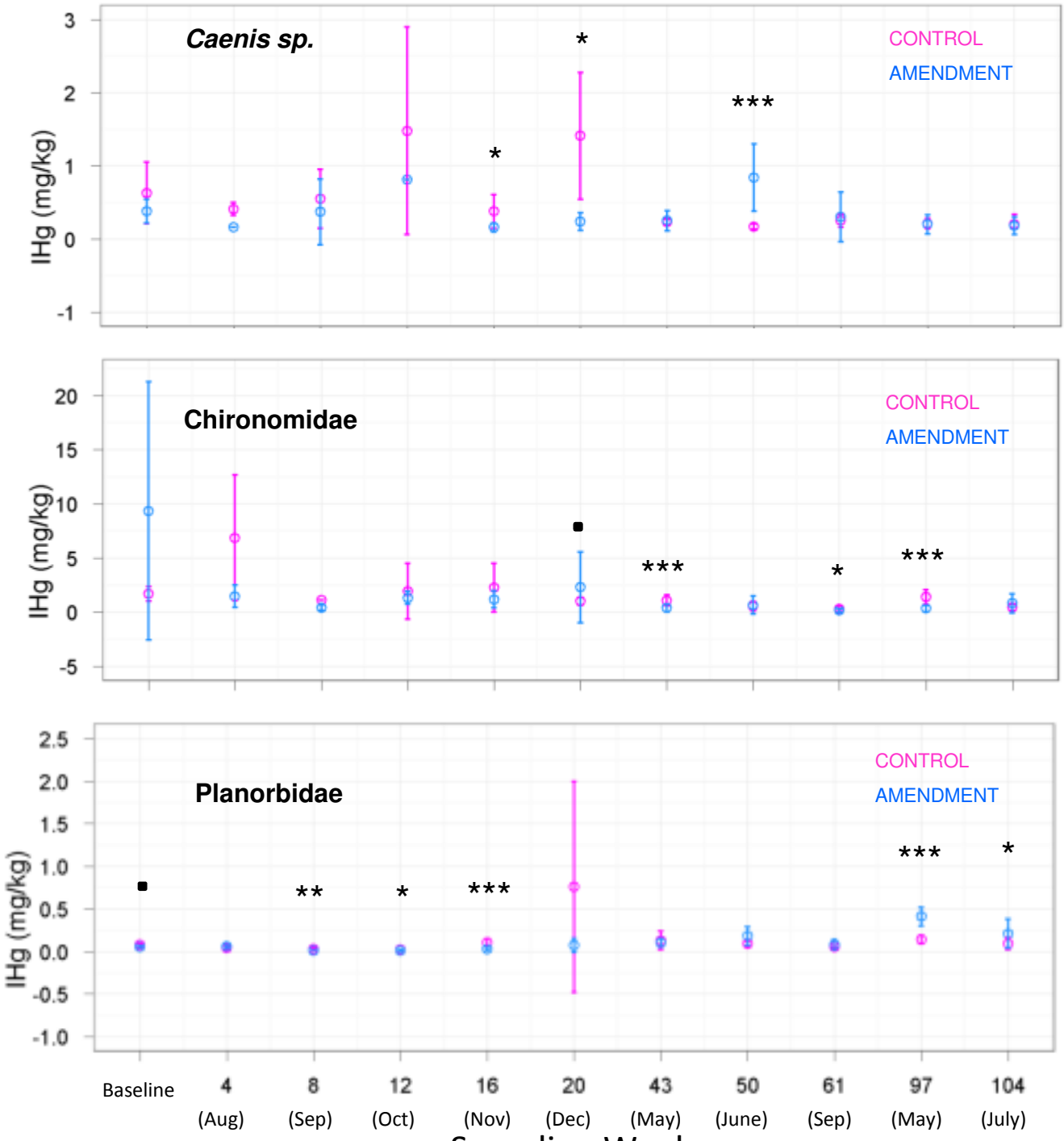
Figure 2
Filtered Surface Water Inorganic Mercury (IHg) and Methylmercury (MeHg) Monitoring Results
South River Pond Pilot Study:
Technical Briefing Paper



Note:
Surface water mixing occurred between cells on several occasions after slight failure of barrier beginning January, 2012.
Compared log-transformed concentrations between amended and control cells (one-tailed, two-sample t-test)

	■	*	**	***
p - value	<0.1	< 0.05	< 0.01	<0.001

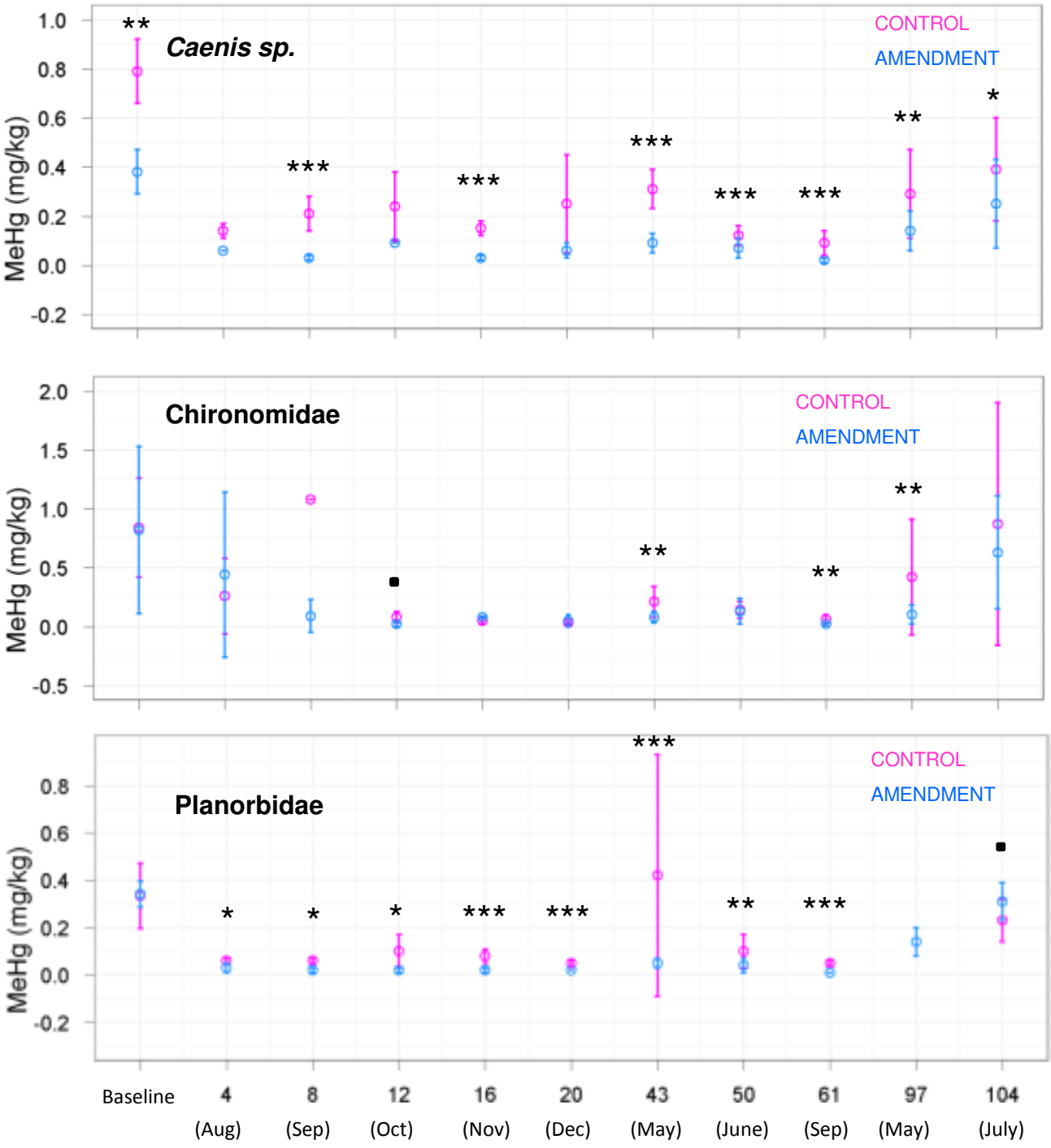
Figure 3
Benthic Invertebrate Tissue Inorganic Mercury (IHg) Monitoring Results
South River Pond Pilot Study:
Technical Briefing Paper



Note:
Due to lack of sample replicates, statistical tests were not conducted for *Caenis* at weeks 4 and 12, and Chironomidae at week 8.
Compared log-transformed concentrations between amended and control cells (one-tailed, two-sample t-test)

		*	**	***
p - value	<0.1	< 0.05	< 0.01	<0.001

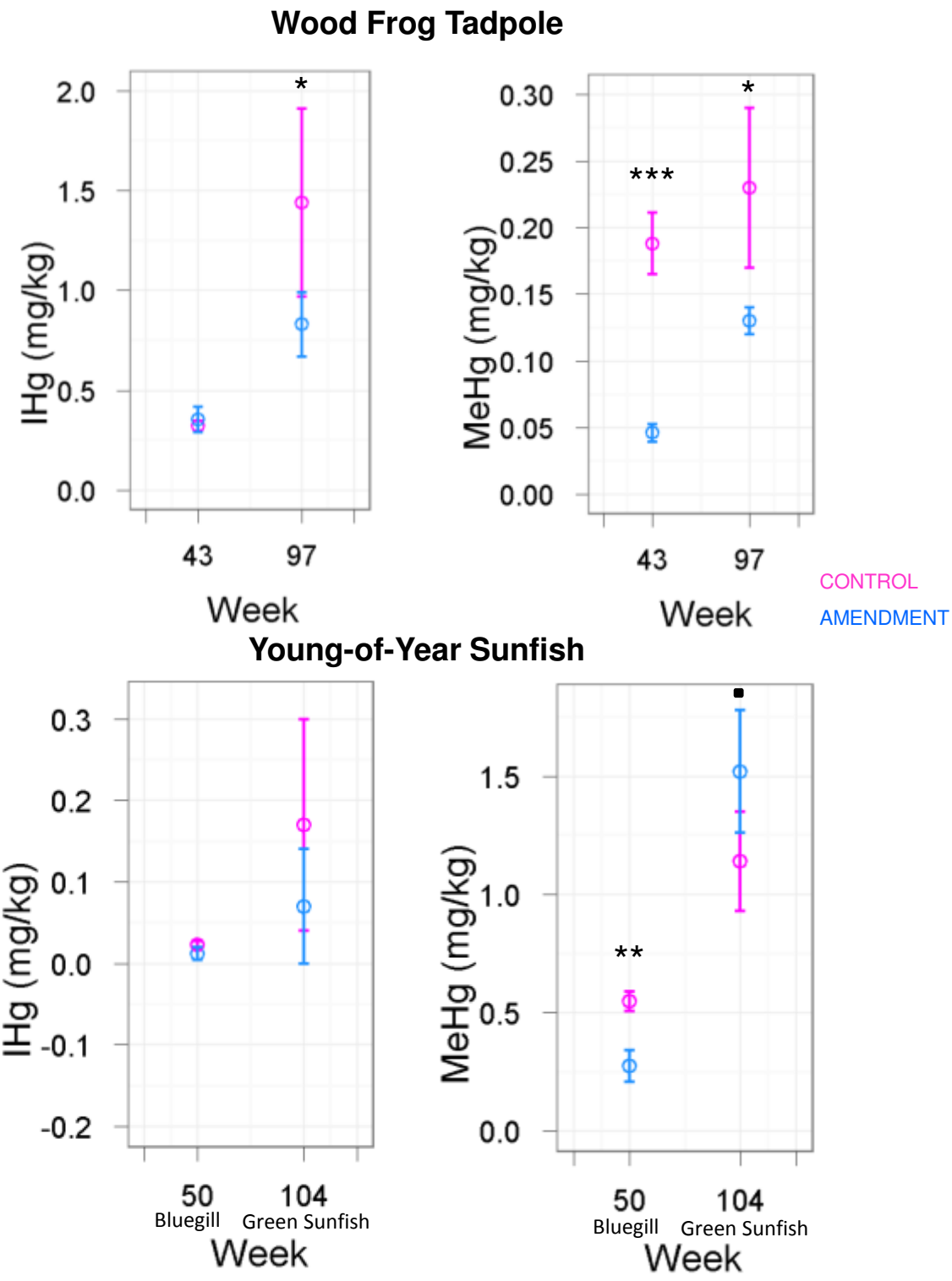
Figure 4
Benthic Invertebrate Tissue Methylmercury (MeHg) Monitoring Results
South River Pond Pilot Study:
Technical Briefing Paper



Note:
Due to lack of sample replicates, statistical tests were not conducted for *Caenis* at weeks 4 and 12, and Chironomidae at week 8.
Compared log-transformed concentrations between amended and control cells (one-tailed, two-sample t-test)

	■	*	**	***
p - value	<0.1	< 0.05	< 0.01	<0.001

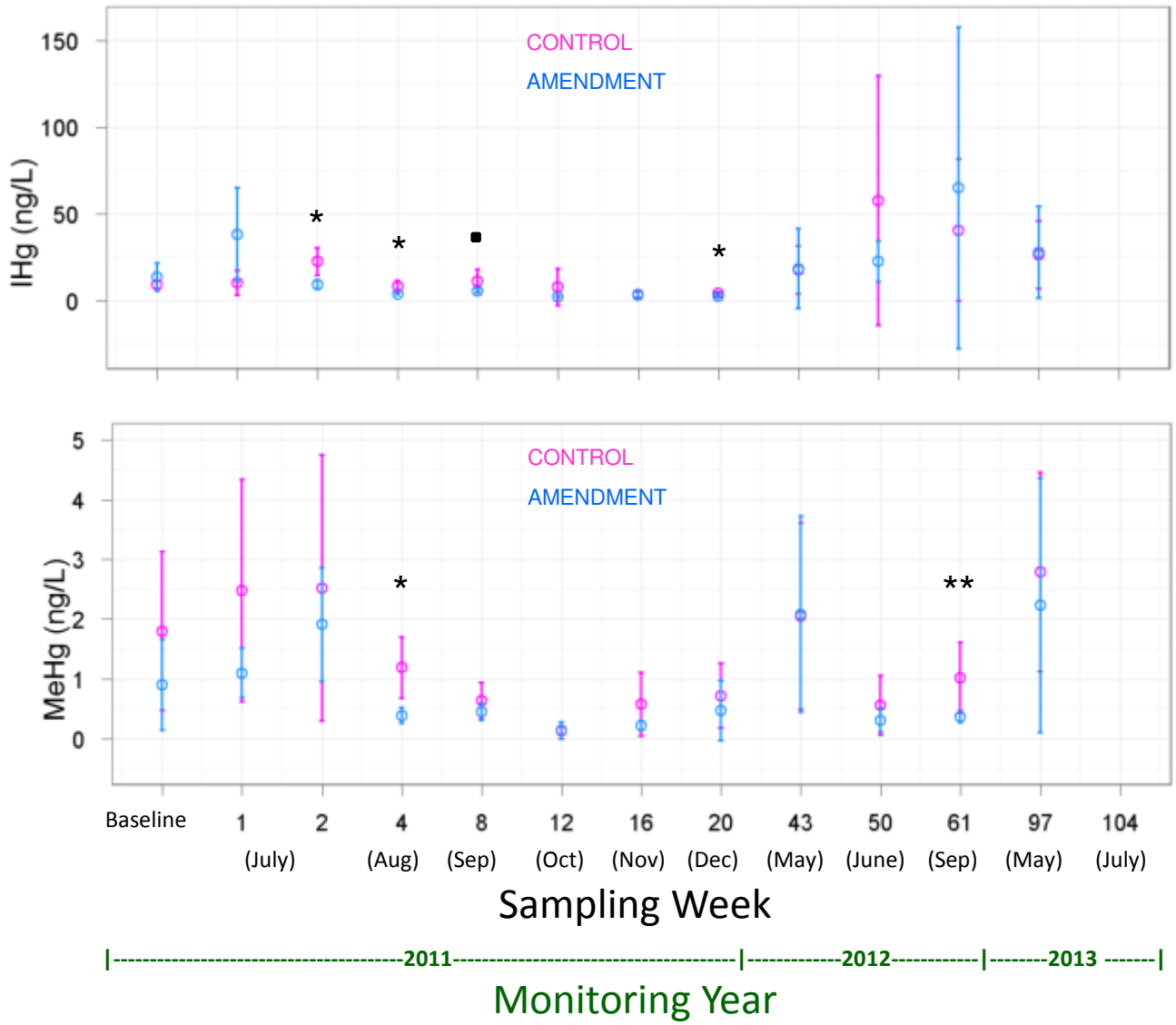
Figure 5
Wood Frog Tadpole and Young-of-Year Sunfish
Inorganic Mercury (IHg) and Methylmercury (MeHg) Monitoring Results
South River Pond Pilot Study:
Technical Briefing Paper



Note:
Compared log-transformed concentrations between amended and control cells (one-tailed, two-sample t-test)

	■	*	**	***
p - value	<0.1	< 0.05	< 0.01	<0.001

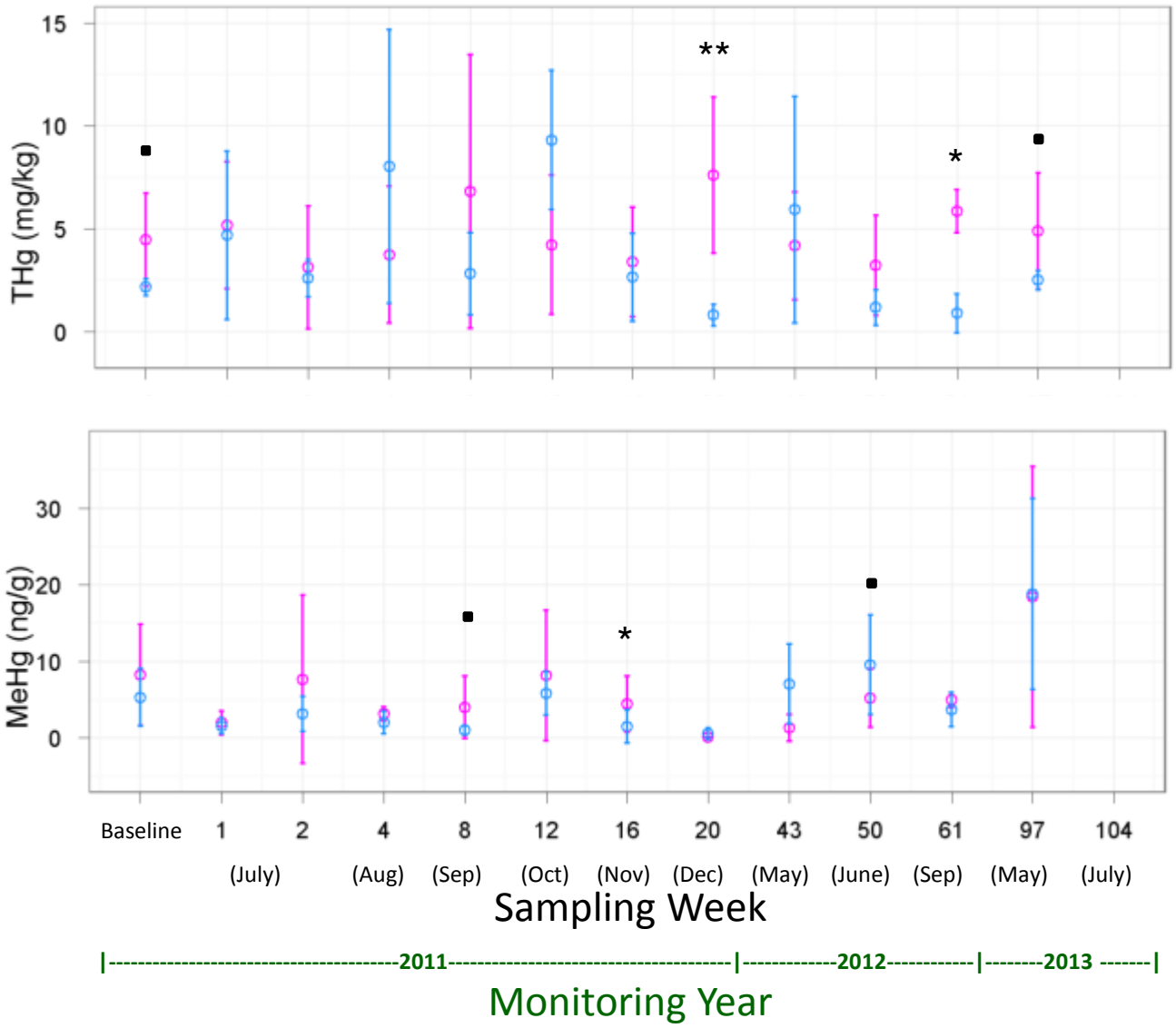
Figure 6
Pore Water Inorganic Mercury (IHg) and Methylmercury (MeHg) Monitoring Results
South River Pond Pilot Study:
Technical Briefing Paper



Note:
Compared log-transformed concentrations between amended and control cells (one-tailed, two-sample t-test)

	■	*	**	***
p - value	<0.1	< 0.05	< 0.01	<0.001

Figure 7
Sediment Inorganic Mercury (IHg) and Methylmercury (MeHg) Monitoring Results
South River Pond Pilot Study:
Technical Briefing Paper



Note:

Compared log-transformed concentrations between amended and control cells (one-tailed, two-sample t-test)

Sediment concentrations are grain-size normalized (<0.075mm)

	■	*	**	***
p - value	<0.1	< 0.05	< 0.01	<0.001

APPENDIX B
INTEGRATING GREEN AND SUSTAINABLE REMEDIATION PRACTICES

As discussed in the main body of this Remediation Proposal, the comparative evaluation of bank management area (BMA) remediation alternatives for the South River is focused on reducing potential exposure to mercury. In addition, a preliminary sustainability analysis was also performed as a component of this Remediation Proposal to examine and incorporate green and sustainable remediation practices into the evaluation of BMA remediation options. This sustainability analysis included evaluations of short- and long-term aspects of all activities, including the corrective action and future activities required such as maintenance and adaptive management. Table B-1 provides a preliminary description for each of the core elements considered in evaluating corrective action alternatives to incorporate green and sustainable remediation.

Table B-1
Sustainability Core Elements

Core Element	General Description
Energy Use	Evaluate the types and amounts of energy used to support corrective actions including fuel, electricity, and other sources (i.e., renewable energy sources).
Air Quality/ Greenhouse Gases	Evaluate the types and amounts of emissions that affect air quality, including greenhouse gases, and overall effects on the environment.
Water Quality and Quantity	Evaluate the short- and long-term effects of remediation options/activities on water resources, including the amount of water used and the potential effects on overall water quality.
Soil Quantity and Quality	Evaluate the short- and long-term effects of remediation options/activities on the amount of soil used or disturbed and the overall quality of soil.
Ecological Services	Evaluate the effects of remediation options/activities on ecological services related to physical, chemical, and biological functions and evaluate opportunities and options for offsetting these impacts by implementing environmental/habitat enhancement projects. This will include an examination of potential enhancements to maximize habitat value.
Human Services and Safety	Evaluate human services (use and non-use) that would be affected in the short-term and long-term by remediation activities.
Economics	Evaluate costs derived from the engineering estimates plus any additional measures needed to incorporate green and sustainable remediation practices.

The preliminary sustainability screening matrix for the BMA remediation alternatives described in the main body of the Remediation Proposal is provided in Table B-2. The matrix summarizes the potential effects that the alternative treatment approaches may have on the sustainability core elements listed in Table B-1. The magnitude of effect would

depend upon the area treated and site-specific project specifications (e.g., best management practices [BMPs] implemented and restoration approach). The matrix focuses on the anticipated direction of the effect the action would have on the core element. A qualitative effect score was given to each sustainability core element for each of the alternative treatment approaches, both in the short- and long-term. If the action is expected to have a positive effect, the qualitative effect score is "+"; expected negative effects are indicated with a "-"; and when no effect is expected the qualitative score is "0." Following the qualitative effect score is a brief statement summarizing the rationale for the score.

A more detailed sustainability analysis is anticipated to be completed during design, including evaluating the use of BMPs for soil/sediment management, equipment maintenance, and use of energy efficient equipment and clean fuels (i.e., renewable fuels).

Table B-2
Screening Matrix for Bank Remediation Option Sustainability Components

General Response Action	Potentially Applicable Remediation Technology	Description of Remediation Option	Sustainability Core Elements	Qualitative Score of Sustainability Element Short-Term	Qualitative Score of Sustainability Element Long-Term	Brief Description of Sustainable Component Result
Monitoring	Monitoring	Includes long-term bank monitoring to verify predicted natural recovery	Energy Use	0	0	Energy use would be required for transportation to areas in need of monitoring, but this would be comparatively minor in the short- and long-term.
			Air Quality/ Greenhouse Gasses	0	0	Air emissions would be largely unaffected by transportation to areas in need of monitoring both short- and long-term.
			Water Quality and Quantity	0	0	Water quality would be largely unaffected in the short and long term. However, monitoring may indicate a need for adaptive management that would address developing issues.
			Soil Quantity and Quality	0	0	Soil quality and quantity would remain largely unaffected in the short- and long-term. However, monitoring may indicate a need for adaptive management, which would address developing issues.
			Ecological Services	0	-	Ecological habitat/services would be unaffected in the short-term resulting in relatively low impact associated with monitoring but could increase in the long-term since the areas would not need to recover from disturbance.
			Human Services	0	-	Human services would be unaffected in the short-term, resulting in relatively high services, and long-term effects would be moderate, depending on the results of monitoring.
			Economics	+	-	Costs associated with monitoring are generally much less than any of the active alternatives that would require use of heavy equipment and soil management. Long-term costs could be slightly higher than more aggressive remedies depending on specific monitoring program elements.
Enhanced Vegetative Stabilization	Active and adaptive management of vegetation	Includes plant management and canopy management; at-risk tree management; and long-term bank monitoring and adaptive management	Energy Use	+	0	Short-term energy use would be relatively low. Long-term monitoring and maintenance could be more substantial than for more aggressive alternatives in the long-term.
			Air Quality/ Greenhouse Gasses	+	+	Short-term and long-term air effects would be relatively low.
			Water Quality and Quantity	0	0	Water quality would be largely unaffected in the short-term resulting in relatively low degree of relative degradation. Water quantity would be unaffected in both the short- and long- term.
			Soil Quantity and Quality	0	+	Soil quality and quantity would be largely unaffected in the short-term and improve in the long-term through a reduction in short-and long-term bank erosion.
			Ecological Services	+	+	There would be no substantial short-term changes in habitats and therefore ecological services would be relatively high. Bank habitat could be enhanced with low maintenance and use of native plants that provide ecological improvements in the long-term.
			Human Services	+	+	Human services would not be changed substantially in the short-term and are therefore relatively high. Bank habitats could be enhanced moderately to support recreational activities.

General Response Action	Potentially Applicable Remediation Technology	Description of Remediation Option	Sustainability Core Elements	Qualitative Score of Sustainability Element Short-Term	Qualitative Score of Sustainability Element Long-Term	Brief Description of Sustainable Component Result
			Economics	0	0	Short-term costs would be moderate and largely related to the types of equipment needed to complete the action. Long-term costs would be moderate due to monitoring and maintenance requirements.
Structural Stabilization	Slope reshaping; vegetation management; toe protection; monitoring	Includes bank reshaping as needed; slope stabilization focusing on green technologies (with use of plant and canopy management, and riprap or other hard stabilization); toe management; and long-term bank monitoring and adaptive management	Energy Use	0	-	Removal and transportation energy use could be relatively moderate in the short-term, and there would be some long-term need for maintenance of areas but low energy use.
			Air Quality/ Greenhouse Gasses	-	0	Use of machinery would result in moderate, short-term reduced air quality on a local level and contributions to greenhouse gas emissions. Additional emissions from required maintenance would be low to moderate in the long-term.
			Water Quality and Quantity	-	0	Disturbance of the bank, staging, and access areas could result in high-to-moderate short-term degradation of water quality. The water quality degradation could be minimized, but likely not eliminated, by the use of appropriate sediment control BMPs. Once the banks are stabilized, water quality would improve with time with relatively low potential for degradation. Water quantity would be unchanged both short- and long-term.
			Soil Quantity and Quality	-	+	Disturbance of the bank, staging, and access areas would have high-to-moderate short-term soil quality degradation. Once the banks are stabilized, erosion potential would be mitigated and soil quality would improve with time.
			Ecological Services	-	+	Habitat on banks, staging, and access areas would be highly or moderately degraded in the short-term, depending on how aggressive the reshaping and use of riprap is. Ecological services may be improved in the long-term, depending on revegetation and habitat restoration elements integrated into the alternative.
			Human Services	0	+	Human activities would decrease locally during remediation of the area, though decreases in services would be moderate. Habitat for game species (e.g., fish and wildlife) may improve in the long-term depending on the habitat restoration elements integrated into the alternative. Actions would reduce exposure and erosion potential, which would benefit human services in the long-term.
			Economics	-	0	Short-term costs would be moderate to high, largely related to the types of equipment needed to complete the action and soil management. Long-term costs would be less and related to any required monitoring and maintenance.
Removal and Disposal	Removal and disposal of bank soils	Includes removal of trees and vegetation along the banks, off-site landfill disposal, and bank contouring and revegetation	Energy Use	-	0	Removal and transportation by heavy machinery would require energy use substantially higher than less intrusive alternatives during construction. There would be low but long-term energy use for monitoring and adaptive management.
			Air Quality/ Greenhouse Gasses	-	0	Use of heavy machinery for removal and disposal would result in relatively high air emissions and greenhouse gas emissions on a local level and contribute to greenhouse gas emission, especially in the short-term during construction. Some longer term needs for monitoring and mechanical adaptive management will have minimal requirements for equipment use and relatively low emissions related to air quality and greenhouse gasses.
			Water Quality and Quantity	-	0	Large-scale disturbance of the bank, staging, and access areas and upland disposal would be substantial resulting in potential erosion and short-term degradation of water quality. The degradation of water quality can be minimized, but likely not eliminated by the use of appropriate sediment control BMPs. Water quantity would be relatively unchanged.
			Soil Quantity and Quality	-	+	Large-scale disturbance of the bank, staging, and access areas and upland disposal would have high potential for short-term soil degradation. Long-term soil quality in the banks would be improved once the banks are stabilized (though moderate degradation of soil in the area used for upland disposal of materials would continue in the long-term).

General Response Action	Potentially Applicable Remediation Technology	Description of Remediation Option	Sustainability Core Elements	Qualitative Score of Sustainability Element Short-Term	Qualitative Score of Sustainability Element Long-Term	Brief Description of Sustainable Component Result
			Ecological Services	-	-	Habitat degradation on the banks, staging, and access areas and the upland disposal area would be substantial in the short-term. Long-term impacts on ecological services would diminish over time as the bank, staging, and access areas are restored; however, recovery would take decades to restore large tree and/or forested areas impacted by the remediation. Habitat quality in the disposal area would be moderately degraded over the long-term. Habitat enhancement measures could help offset long-term impacts.
			Human Services	-	0	Human services would be substantially decreased in the short-term primarily due to ecological losses on banks, staging areas, access roads, and upland habitats that support recreational activities such as bird watching, fishing, and hunting. Once remediation is complete and the bank areas are stabilized, these impacts would lessen over time (e.g., decades) if enhancement measures are incorporated. Actions would reduce exposure and erosion potential that would benefit human services in the long-term.
			Economics	-	+	Short-term costs for the removal alternative would be substantial due to the need for heavy equipment and transportation/disposal of removed soils. Long-term costs would be relatively low and would be related to any required monitoring, which should be minimal, and habitat enhancement/restoration.

Notes:
+ = Net Gain/Benefit
0 = No Effect
- = Net Loss/Detriment

APPENDIX C
2012 AND 2013 BANK SAMPLING DATA

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-03	0.06	0.17	LB01-1	LB01-1 (16'-18')	0 - 2	4.8	48.2
LBH-03	0.06	0.17	LB01-1	LB01-1 (14'-16')	2 - 4	0.95	28.4
LBH-03	0.06	0.17	LB01-1	LB01-1 (12'-14')	4 - 6	0.61	27.7
LBH-03	0.06	0.17	LB01-1	LB01-1 (10'-12')	6 - 8	0.48	19.7
LBH-03	0.06	0.17	LB01-1	LB01-1 (8'-10')	8 - 10	0.24	16.7
LBH-03	0.06	0.17	LB01-1	LB01-1 (6'-8')	10 - 12	0.39	17.6
LBH-03	0.06	0.17	LB01-1	LB01-1 (4'-6')	12 - 14	0.61	18.3
LBH-03	0.06	0.17	LB01-1	LB01-1 (2'-4')	14 - 16	0.45	20.4
LBH-03	0.06	0.17	LB01-1	LB01-1 (0'-2')	16 - 18	0.80	31.1
LBH-04	0.17	0.27	LB01-2	LB01-2 (6.4'-8')	0 - 1.6	9.1	20.7
LBH-04	0.17	0.27	LB01-2	LB01-2 (4.8'-6.4')	1.6 - 3.2	14.9	19.6
LBH-04	0.17	0.27	LB01-2	LB01-2 (3.2'-4.8')	3.2 - 4.8	20.8	19.4
LBH-04	0.17	0.27	LB01-2	LB01-2 (1.6'-3.2')	4.8 - 6.4	352.0	19.0
LBH-04	0.17	0.27	LB01-2	LB01-2 (0'-1.6')	6.4 - 8	941.0	32.1
LBH-04	0.17	0.27	LB01-3	LB01-3 (10'-12')	0 - 2	5.6	18.9
LBH-04	0.17	0.27	LB01-3	LB01-3 (8'-10')	2 - 4	6.2	22.4
LBH-04	0.17	0.27	LB01-3	LB01-3 (6'-8')	4 - 6	4.7	22.1
LBH-04	0.17	0.27	LB01-3	LB01-3 (4'-6')	6 - 8	1.2	20.8
LBH-04	0.17	0.27	LB01-3	LB01-3 (2'-4')	8 - 10	4.7	31.2
LBH-04	0.17	0.27	LB01-3	LB01-3 (0'-2')	10 - 12	2.1	33.3
LBH-06	0.32	0.39	LB01-4	LB01-4 (14'-16')	0 - 2	0.43	4.5
LBH-06	0.32	0.39	LB01-4	LB01-4 (12'-14')	2 - 4	0.32	5.5
LBH-06	0.32	0.39	LB01-4	LB01-4 (10'-12')	4 - 6	0.75	14.1
LBH-06	0.32	0.39	LB01-4	LB01-4 (8'-10')	6 - 8	0.72	24.5
LBH-06	0.32	0.39	LB01-4	LB01-4 (6'-8')	8 - 10	0.79	27.5
LBH-06	0.32	0.39	LB01-4	LB01-4 (4'-6')	10 - 12	0.44	22.8
LBH-06	0.32	0.39	LB01-4	LB01-4 (2'-4')	12 - 14	0.26	30.0
LBH-06	0.32	0.39	LB01-4	LB01-4 (0'-2')	14 - 16	0.67	54.0
LBH-07	0.41	0.51	LBH-7-A	LBH-7-A (0'-2')	0 - 2	4.8	15.6
LBH-07	0.41	0.51	LBH-7-A	LBH-7-A (2'-4')	2 - 4	1.2	16.7
LBH-07	0.41	0.51	LBH-7-A	LBH-7-A (4'-6')	4 - 6	1.6	19.2
LBH-07	0.41	0.51	LBH-7-A	LBH-7-A (6'-8')	6 - 8	2.2	19.9
LBH-07	0.41	0.51	LBH-7-A	LBH-7-A (8'-10')	8 - 10	2.7	25.0
LBH-07	0.41	0.51	LBH-7-B	LBH-7-B (0'-1')	0 - 1	0.84	36.4
LBH-07	0.41	0.51	LBH-7-B	LBH-7-B (1'-2')	1 - 2	0.74	37.9
LBH-07	0.41	0.51	LBH-7-B	LBH-7-B (2'-3')	2 - 3	1.2	28.9
LBH-07	0.41	0.51	LBH-7-B	LBH-7-B (3'-4')	3 - 4	1.8	31.8
LBH-07	0.41	0.51	LBH-7-C	LBH-7-C (0'-1.2')	0 - 1.2	1.2	18.2
LBH-07	0.41	0.51	LBH-7-C	LBH-7-C (1.2'-2.4')	1.2 - 2.4	2.5	17.9
LBH-07	0.41	0.51	LBH-7-C	LBH-7-C (2.4'-3.6')	2.4 - 3.6	3.7	21.0
LBH-07	0.41	0.51	LBH-7-C	LBH-7-C (3.6'-4.8')	3.6 - 4.8	4.9	21.5
LBH-07	0.41	0.51	LBH-7-C	LBH-7-C (4.8'-6')	4.8 - 6	3.8	24.3
LBH-07	0.41	0.51	LBH-7-D	LBH - 7 - D (0'-2')	0 - 2	12.6	21.7
LBH-07	0.41	0.51	LBH-7-D	LBH - 7 - D (2'-4')	2 - 4	35.7	30.8
LBH-07	0.41	0.51	LBH-7-D	LBH - 7 - D (4'-6')	4-6	3.5	45.0
LBH-07	0.41	0.51	LBH-7-D	LBH - 7 - D (6'-8')	6 - 8	6.0	38.0
LBH-07	0.41	0.51	LBH-7-D	LBH - 7 - D (8'-10')	8 - 10	7.9	41.5
LBH-11	0.81	1.05	LBH-11-A	LBH-11-A (0'-2')	0 - 2	12.7	25.1
LBH-11	0.81	1.05	LBH-11-A	LBH-11-A (2'-4')	2 - 4	15.5	22.6
LBH-11	0.81	1.05	LBH-11-A	LBH-11-A (4'-6')	4 - 6	11.1	20.6
LBH-11	0.81	1.05	LBH-11-A	LBH-11-A (6'-8')	6 - 8	8.4	23.8
LBH-11	0.81	1.05	LBH-11-A	LBH-11-A (8'-10')	8 - 10	11.9	26.1
LBH-11	0.81	1.05	LBH-11-A	LBH-11-A (10'-12')	10 - 12	20.4	38.4

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2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-11	0.81	1.05	LBH-11-B	LBH-11-B (0'-2')	0 - 2	16.2	21.0
LBH-11	0.81	1.05	LBH-11-B	LBH-11-B (2'-4')	2 - 4	36.5	20.4
LBH-11	0.81	1.05	LBH-11-B	LBH-11-B (4'-6')	4 - 6	103.0	20.3
LBH-11	0.81	1.05	LBH-11-B	LBH-11-B (6'-8')	6 - 8	125.0	20.7
LBH-11	0.81	1.05	LBH-11-B	LBH-11-B (8'-10')	8 - 10	129.0	20.1
LBH-11	0.81	1.05	LBH-11-B	LBH-11-B (10'-12')	10 - 12	143.0	32.6
LBH-11	0.81	1.05	LBH-11-C	LBH-11-C (0'-2')	0 - 2	6.5	24.2
LBH-11	0.81	1.05	LBH-11-C	LBH-11-C (2'-4')	2 - 4	7.0	26.6
LBH-11	0.81	1.05	LBH-11-C	LBH-11-C (4'-6')	4 - 6	4.7	19.1
LBH-11	0.81	1.05	LBH-11-C	LBH-11-C (6'-8')	6 - 8	6.2	17.9
LBH-11	0.81	1.05	LBH-11-C	LBH-11-C (8'-10')	8 - 10	6.4	21.0
LBH-11	0.81	1.05	LBH-11-C	LBH-11-C (10'-12')	10 - 12	11.7	25.5
LBH-11	0.81	1.05	LBH-11-D	LBH-11-D (0'-2')	0 - 2	7.2	27.9
LBH-11	0.81	1.05	LBH-11-D	LBH-11-D (2'-4')	2 - 4	3.9	23.0
LBH-11	0.81	1.05	LBH-11-D	LBH-11-D (4'-6')	4 - 6	4.3	23.9
LBH-11	0.81	1.05	LBH-11-D	LBH-11-D (6'-8')	6 - 8	4.9	18.1
LBH-11	0.81	1.05	LBH-11-D	LBH-11-D (8'-10')	8 - 10	7.1	24.3
LBH-13	1.25	1.31	LBH-13-A	LBH-13-A (0'-2')	0 - 2	3.6	11.5
LBH-13	1.25	1.31	LBH-13-A	LBH-13-A (2'-4')	2 - 4	5.9	15.5
LBH-13	1.25	1.31	LBH-13-A	LBH-13-A (4'-6')	4 - 6	4.1	21.3
LBH-13	1.25	1.31	LBH-13-A	LBH-13-A (6'-8')	6 - 8	9.5	28.8
LBH-13	1.25	1.31	LBH-13-A	LBH-13-A (8'-10')	8 - 10	11.3	39.7
LBH-13	1.25	1.31	LBH-13-B	LBH-13-B (0'-1.6')	0 - 1.6	16.3	14.3
LBH-13	1.25	1.31	LBH-13-B	LBH-13-B (1.6'-3.2')	1.6 - 3.2	4.7	18.3
LBH-13	1.25	1.31	LBH-13-B	LBH-13-B (3.2'-4.8')	3.22 - 4.8	19.2	27.6
LBH-13	1.25	1.31	LBH-13-B	LBH-13-B (4.8'-6.4')	4.88 - 6.4	23.9	38.1
LBH-13	1.25	1.31	LBH-13-B	LBH-13-B (6.4'-8')	6.4 - 8	30.0	36.4
LBH-14	1.32	1.49	LB02-1	LB02-1 (8'-10')	0 - 2	20.2	18.9
LBH-14	1.32	1.49	LB02-1	LB02-1 (6'-8')	2 - 4	19.4	18.4
LBH-14	1.32	1.49	LB02-1	LB02-1 (4'-6')	4 - 6	22.3	16.7
LBH-14	1.32	1.49	LB02-1	LB02-1 (2'-4')	6 - 8	21.7	15.6
LBH-14	1.32	1.49	LB02-1	LB02-1 (0'-2')	8 - 10	14.9	29.4
LBH-15	1.49	1.60	LB02-2	LB02-2 (10'-12')	0 - 2	12.9	23.9
LBH-15	1.49	1.60	LB02-2	LB02-2 (8'-10')	2 - 4	9.7	20.3
LBH-15	1.49	1.60	LB02-2	LB02-2 (6'-8')	4 - 6	5.3	23.6
LBH-15	1.49	1.60	LB02-2	LB02-2 (4'-6')	6 - 8	6.7	28.2
LBH-15	1.49	1.60	LB02-2	LB02-2 (2'-4')	8 - 10	11.1	19.5
LBH-15	1.49	1.60	LB02-2	LB02-2 (0'-2')	10 - 12	11.9	25.0
LBH-15	1.49	1.60	LB03-1	LB03-1 (20'-22')	0 - 2	4.4	22.3
LBH-15	1.49	1.60	LB03-1	LB03-1 (18'-20')	2 - 4	5.3	19.9
LBH-15	1.49	1.60	LB03-1	LB03-1 (16'-18')	4 - 6	5.5	19.8
LBH-15	1.49	1.60	LB03-1	LB03-1 (14'-16')	6 - 8	3.4	21.3
LBH-15	1.49	1.60	LB03-1	LB03-1 (12'-14')	8 - 10	4.1	25.0
LBH-15	1.49	1.60	LB03-1	LB03-1 (10'-12')	10 - 12	5.7	23.0
LBH-15	1.49	1.60	LB03-1	LB03-1 (8'-10')	12 - 14	4.2	20.3
LBH-15	1.49	1.60	LB03-1	LB03-1 (6'-8')	14 - 16	5.4	26.9
LBH-15	1.49	1.60	LB03-1	LB03-1 (4'-6')	16 - 18	16.8	28.3
LBH-15	1.49	1.60	LB03-1	LB03-1 (2'-4')	18 - 20	9.3	24.4
LBH-15	1.49	1.60	LB03-1	LB03-1 (0'-2')	20 - 22	8.0	27.5
LBH-15	1.49	1.60	LB04-1	LB04-1 (18'-20')	0 - 2	3.2	22.1
LBH-15	1.49	1.60	LB04-1	LB04-1 (16'-18')	2 - 4	3.1	22.0
LBH-15	1.49	1.60	LB04-1	LB04-1 (14'-16')	4 - 6	6.0	24.1
LBH-15	1.49	1.60	LB04-1	LB04-1 (12'-14')	6 - 8	4.2	28.2

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2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-15	1.49	1.60	LB04-1	LB04-1 (10'-12')	8 - 10	3.3	30.1
LBH-15	1.49	1.60	LB04-1	LB04-1 (8'-10')	10 - 12	4.0	28.2
LBH-15	1.49	1.60	LB04-1	LB04-1 (6'-8')	12 - 14	5.2	28.1
LBH-15	1.49	1.60	LB04-1	LB04-1 (4'-6')	14 - 16	5.5	30.1
LBH-15	1.49	1.60	LB04-1	LB04-1 (2'-4')	16 - 18	7.8	30.8
LBH-15	1.49	1.60	LB04-1	LB04-1 (0'-2')	18 - 20	5.3	30.8
LBH-15	1.49	1.60	LB05-1	LB05-1 (10'-12')	0 - 2	2.1	26.4
LBH-15	1.49	1.60	LB05-1	LB05-1 (8'-10')	2 - 4	2.5	16.5
LBH-15	1.49	1.60	LB05-1	LB05-1 (6'-8')	4 - 6	2.1	15.9
LBH-15	1.49	1.60	LB05-1	LB05-1 (4'-6')	6 - 8	2.5	14.4
LBH-15	1.49	1.60	LB05-1	LB05-1 (2'-4')	8 - 10	2.2	22.0
LBH-15	1.49	1.60	LB05-1	LB05-1 (0'-2')	10 - 12	2.9	32.5
LBH-16	1.60	1.65	LB05-2	LB05-2 (20'-22')	0 - 2	3.4	28.3
LBH-16	1.60	1.65	LB05-2	LB05-2 (18'-20')	2 - 4	2.2	22.7
LBH-16	1.60	1.65	LB05-2	LB05-2 (16'-18')	4 - 6	1.4	13.1
LBH-16	1.60	1.65	LB05-2	LB05-2 (14'-16')	6 - 8	1.2	13.6
LBH-16	1.60	1.65	LB05-2	LB05-2 (12'-14')	8 - 10	2.8	13.3
LBH-16	1.60	1.65	LB05-2	LB05-2 (10'-12')	10 - 12	1.0	10.8
LBH-16	1.60	1.65	LB05-2	LB05-2 (8'-10')	12 - 14	2.2	22.7
LBH-16	1.60	1.65	LB05-2	LB05-2 (6'-8')	14 - 16	2.7	36.8
LBH-16	1.60	1.65	LB05-2	LB05-2 (4'-6')	16 - 18	2.1	38.2
LBH-16	1.60	1.65	LB05-2	LB05-2 (2'-4')	18 - 20	1.7	40.4
LBH-16	1.60	1.65	LB05-2	LB05-2 (0'-2')	20 - 22	1.3	21.7
LBH-16	1.60	1.65	LB05-3	LB05-3 (16'-18')	0 - 2	0.99	7.5
LBH-16	1.60	1.65	LB05-3	LB05-3 (14'-16')	2 - 4	2.2	10.3
LBH-16	1.60	1.65	LB05-3	LB05-3 (12'-14')	4 - 6	2.3	25.8
LBH-16	1.60	1.65	LB05-3	LB05-3 (10'-12')	6 - 8	2.9	27.3
LBH-16	1.60	1.65	LB05-3	LB05-3 (8'-10')	8 - 10	3.4	33.8
LBH-16	1.60	1.65	LB05-3	LB05-3 (6'-8')	10 - 12	3.4	35.0
LBH-16	1.60	1.65	LB05-3	LB05-3 (4'-6')	12 - 14	4.3	41.2
LBH-16	1.60	1.65	LB05-3	LB05-3 (2'-4')	14 - 16	3.4	33.3
LBH-16	1.60	1.65	LB05-3	LB05-3 (0'-2')	16 - 18	2.9	26.8
LBH-17	1.65	1.69	LB06-1	LB06-1 (10'-12')	0 - 2	2.4	16.6
LBH-17	1.65	1.69	LB06-1	LB06-1 (8'-10')	2 - 4	2.1	16.1
LBH-17	1.65	1.69	LB06-1	LB06-1 (6'-8')	4 - 6	3.1	20.4
LBH-17	1.65	1.69	LB06-1	LB06-1 (4'-6')	6 - 8	3.9	25.3
LBH-17	1.65	1.69	LB06-1	LB06-1 (2'-4')	8 - 10	4.1	36.2
LBH-17	1.65	1.69	LB06-1	LB06-1 (0'-2')	10 - 12	4.1	37.1
LBH-17	1.65	1.69	LB06-2	LB06-2 (10'-12')	0 - 2	0.94	14.4
LBH-17	1.65	1.69	LB06-2	LB06-2 (8'-10')	2 - 4	0.16	15.6
LBH-17	1.65	1.69	LB06-2	LB06-2 (6'-8')	4 - 6	0.07	19.8
LBH-17	1.65	1.69	LB06-2	LB06-2 (4'-6')	6 - 8	0.37	15.6
LBH-17	1.65	1.69	LB06-2	LB06-2 (2'-4')	8 - 10	0.87	19.3
LBH-17	1.65	1.69	LB06-2	LB06-2 (0'-2')	10 - 12	1.5	21.1
LBH-18	1.69	1.83	LB07-1	LB07-1 (12'-14')	0 - 2	1.9	19.9
LBH-18	1.69	1.83	LB07-1	LB07-1 (10'-12')	2 - 4	11.0	15.4
LBH-18	1.69	1.83	LB07-1	LB07-1 (8'-10')	4 - 6	1.3	17.8
LBH-18	1.69	1.83	LB07-1	LB07-1 (6'-8')	6 - 8	1.8	12.7
LBH-18	1.69	1.83	LB07-1	LB07-1 (4'-6')	8 - 10	2.7	13.2
LBH-18	1.69	1.83	LB07-1	LB07-1 (2'-4')	10 - 12	1.8	27.5
LBH-18	1.69	1.83	LB07-1	LB07-1 (0'-2')	12 - 14	1.7	37.3
LBH-18	1.69	1.83	LB07-2	LB07-2 (10'-12')	0 - 2	0.90	15.6
LBH-18	1.69	1.83	LB07-2	LB07-2 (8'-10')	2 - 4	1.6	22.3

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Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-18	1.69	1.83	LB07-2	LB07-2 (6'-8')	4 - 6	1.2	15.1
LBH-18	1.69	1.83	LB07-2	LB07-2 (4'-6')	6 - 8	1.1	13.3
LBH-18	1.69	1.83	LB07-2	LB07-2 (2'-4')	8 - 10	1.4	24.4
LBH-18	1.69	1.83	LB07-2	LB07-2 (0'-2')	10 - 12	10.4	26.7
LBH-18	1.69	1.83	LB08-1	LB08-1 (12'-14')	0 - 2	0.69	11.9
LBH-18	1.69	1.83	LB08-1	LB08-1 (10'-12')	2 - 4	2.3	39.1
LBH-18	1.69	1.83	LB08-1	LB08-1 (8'-10')	4 - 6	1.7	37.5
LBH-18	1.69	1.83	LB08-1	LB08-1 (6'-8')	6 - 8	1.5	33.2
LBH-18	1.69	1.83	LB08-1	LB08-1 (4'-6')	8 - 10	1.7	51.2
LBH-18	1.69	1.83	LB08-1	LB08-1 (2'-4')	10 - 12	1.5	38.8
LBH-18	1.69	1.83	LB08-1	LB08-1 (0'-2')	12 - 14	2.4	39.7
LBH-18	1.69	1.83	LB08-2	LB08-2 (16'-18')	0 - 2	0.41	9.3
LBH-18	1.69	1.83	LB08-2	LB08-2 (14'-16')	2 - 4	0.48	14.1
LBH-18	1.69	1.83	LB08-2	LB08-2 (12'-14')	4 - 6	0.59	6.6
LBH-18	1.69	1.83	LB08-2	LB08-2 (10'-12')	6 - 8	0.58	9.1
LBH-18	1.69	1.83	LB08-2	LB08-2 (8'-10')	8 - 10	0.71	10.8
LBH-18	1.69	1.83	LB08-2	LB08-2 (6'-8')	10 - 12	0.85	9.8
LBH-18	1.69	1.83	LB08-2	LB08-2 (4'-6')	12 - 14	0.78	8.0
LBH-18	1.69	1.83	LB08-2	LB08-2 (2'-4')	14 - 16	1.5	17.9
LBH-18	1.69	1.83	LB08-2	LB08-2 (0'-2')	16 - 18	1.9	40.6
LBH-19	1.83	1.89	LB08-3	LB08-3 (22'-24')	0 - 2	2.6	43.1
LBH-19	1.83	1.89	LB08-3	LB08-3 (20'-22')	2 - 4	2.8	37.9
LBH-19	1.83	1.89	LB08-3	LB08-3 (18'-20')	4 - 6	3.4	41.6
LBH-19	1.83	1.89	LB08-3	LB08-3 (16'-18')	6 - 8	4.0	40.7
LBH-19	1.83	1.89	LB08-3	LB08-3 (14'-16')	8 - 10	0.59	36.9
LBH-19	1.83	1.89	LB08-3	LB08-3 (12'-14')	10 - 12	2.7	42.4
LBH-19	1.83	1.89	LB08-3	LB08-3 (10'-12')	12 - 14	3.1	49.6
LBH-19	1.83	1.89	LB08-3	LB08-3 (8'-10')	14 - 16	3.9	52.0
LBH-19	1.83	1.89	LB08-3	LB08-3 (6'-8')	16 - 18	3.4	54.9
LBH-19	1.83	1.89	LB08-3	LB08-3 (4'-6')	18 - 20	2.5	48.4
LBH-19	1.83	1.89	LB08-3	LB08-3 (2'-4')	20 - 22	2.8	50.8
LBH-19	1.83	1.89	LB08-3	LB08-3 (0'-2')	22 - 24	2.4	43.3
LBH-19	1.83	1.89	LB09-1	LB09-1 (4.8'-6')	0 - 1.2	4.0	31.0
LBH-19	1.83	1.89	LB09-1	LB09-1 (3.6'-4.8')	1.2 - 2.4	47.1	22.1
LBH-19	1.83	1.89	LB09-1	LB09-1 (2.4'-3.6')	2.4 - 3.6	6.8	13.7
LBH-19	1.83	1.89	LB09-1	LB09-1 (1.2'-2.4')	3.6 - 4.8	2.4	16.1
LBH-19	1.83	1.89	LB09-1	LB09-1 (0'-1.2')	4.8 - 6	3.5	25.9
LBH-19	1.83	1.89	LB09-2	LB09-2 (4.8'-6')	0 - 1.2	7.2	18.1
LBH-19	1.83	1.89	LB09-2	LB09-2 (3.6'-4.8')	1.2 - 2.4	32.6	15.9
LBH-19	1.83	1.89	LB09-2	LB09-2 (2.4'-3.6')	2.4 - 3.6	23.4	17.1
LBH-19	1.83	1.89	LB09-2	LB09-2 (1.2'-2.4')	3.6 - 4.8	2.3	19.1
LBH-19	1.83	1.89	LB09-2	LB09-2 (0'-1.2')	4.8 - 6	2.9	29.9
LBH-22	2.04	2.08	LB10-1	LB10-1 (4'-5')	0 - 1	0.12	21.6
LBH-22	2.04	2.08	LB10-1	LB10-1 (3'-4')	1 - 2	2.2	26.0
LBH-22	2.04	2.08	LB10-1	LB10-1 (2'-3')	2 - 3	0.58	27.9
LBH-22	2.04	2.08	LB10-1	LB10-1 (1'-2')	3 - 4	2.0	33.2
LBH-22	2.04	2.08	LB10-1	LB10-1 (0'-1')	4 - 5	2.5	38.0
LBH-24	2.19	2.71	LB11-1	LB11-1 (8'-10')	0 - 2	7.1	33.9
LBH-24	2.19	2.71	LB11-1	LB11-1 (6'-8')	2 - 4	7.0	35.6
LBH-24	2.19	2.71	LB11-1	LB11-1 (4'-6')	4 - 6	6.3	33.6
LBH-24	2.19	2.71	LB11-1	LB11-1 (2'-4')	6 - 8	5.7	35.8
LBH-24	2.19	2.71	LB11-1	LB11-1 (0'-2')	8 - 10	9.3	26.3
LBH-24	2.19	2.71	LB11-2	LB11-2 (6.4'-8')	0 - 1.6	10.7	26.2

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-24	2.19	2.71	LB11-2	LB11-2 (4.8'-6.4')	1.6 - 3.2	11.6	29.3
LBH-24	2.19	2.71	LB11-2	LB11-2 (3.2'-4.8')	3.2 - 4.8	22.9	21.5
LBH-24	2.19	2.71	LB11-2	LB11-2 (1.6'-3.2')	4.8 - 6.4	48.2	21.5
LBH-24	2.19	2.71	LB11-2	LB11-2 (0'-1.6')	6.4 - 8	120.0	37.1
LBH-24	2.19	2.71	LB11-3	LB11-3 (8'-10')	0 - 2	27.3	22.3
LBH-24	2.19	2.71	LB11-3	LB11-3 (6'-8')	2 - 4	72.6	23.5
LBH-24	2.19	2.71	LB11-3	LB11-3 (4'-6')	4 - 6	19.5	21.8
LBH-24	2.19	2.71	LB11-3	LB11-3 (2'-4')	6 - 8	32.3	25.4
LBH-24	2.19	2.71	LB11-3	LB11-3 (0'-2')	8 - 10	33.7	33.3
LBH-24	2.19	2.71	LB11-4	LB11-4 (10'-12')	0 - 2	10.7	21.5
LBH-24	2.19	2.71	LB11-4	LB11-4 (8'-10')	2 - 4	11.4	22.8
LBH-24	2.19	2.71	LB11-4	LB11-4 (6'-8')	4 - 6	8.3	21.7
LBH-24	2.19	2.71	LB11-4	LB11-4 (4'-6')	6 - 8	8.6	20.8
LBH-24	2.19	2.71	LB11-4	LB11-4 (2'-4')	8 - 10	18.0	17.7
LBH-24	2.19	2.71	LB11-4	LB11-4 (0'-2')	10 - 12	12.9	19.3
LBH-24	2.19	2.71	LB12-1	LB12-1(8-10)	0 - 2	9.1	22.0
LBH-24	2.19	2.71	LB12-1	LB12-1(6-8)	2 - 4	16.5	21.3
LBH-24	2.19	2.71	LB12-1	LB12-1(4-6)	4 - 6	31.1	24.3
LBH-24	2.19	2.71	LB12-1	LB12-1(2-4)	6 - 8	226.0	31.2
LBH-24	2.19	2.71	LB12-1	LB12-1(0-2)	8 - 10	184.0	30.1
LBH-25	2.71	2.80	LB12-2	LB12-2(4.8-6)	0 - 1.2	11.6	26.4
LBH-25	2.71	2.80	LB12-2	LB12-2(3.6-4.8)	1.2 - 2.4	11.7	30.3
LBH-25	2.71	2.80	LB12-2	LB12-2(2.4-3.6)	2.4 - 3.6	8.9	31.7
LBH-25	2.71	2.80	LB12-2	LB12-2(1.2-2.4)	3.6 - 4.8	11.3	24.5
LBH-25	2.71	2.80	LB12-2	LB12-2(0-1.2)	4.8 - 6	21.6	26.7
LBH-25	2.71	2.80	LB12-3	LB12-3(4-5)	0 - 1	6.7	20.2
LBH-25	2.71	2.80	LB12-3	LB12-3(3-4)	1 - 2	11.2	32.1
LBH-25	2.71	2.80	LB12-3	LB12-3(2-3)	2 - 3	19.1	27.4
LBH-25	2.71	2.80	LB12-3	LB12-3(1-2)	3 - 4	17.0	32.9
LBH-25	2.71	2.80	LB12-3	LB12-3(0-1)	4 - 5	15.5	41.5
LBH-27	2.90	3.07	LB13-1	LB13-1 (8'-10')	0 - 2	8.4	26.6
LBH-27	2.90	3.07	LB13-1	LB13-1 (6'-8')	2 - 4	9.6	21.9
LBH-27	2.90	3.07	LB13-1	LB13-1 (4'-6')	4 - 6	11.2	21.0
LBH-27	2.90	3.07	LB13-1	LB13-1 (2'-4')	6 - 8	118.0	23.3
LBH-27	2.90	3.07	LB13-1	LB13-1 (0'-2')	8 - 10	476.0	33.8
LBH-27	2.90	3.07	LB13-2	LB13-2 (4'-5')	0 - 1	0.26	18.0
LBH-27	2.90	3.07	LB13-2	LB13-2 (3'-4')	1 - 2	0.58	12.4
LBH-27	2.90	3.07	LB13-2	LB13-2 (2'-3')	2 - 3	6.8	17.6
LBH-27	2.90	3.07	LB13-2	LB13-2 (1'-2')	3 - 4	6.7	20.6
LBH-27	2.90	3.07	LB13-2	LB13-2 (0'-1')	4 - 5	2.0	21.8
LBH-27	2.90	3.07	LB13-3	LB13-3 (7.2'-9')	0 - 1.8	6.5	26.0
LBH-27	2.90	3.07	LB13-3	LB13-3 (5.4'-7.2')	1.8 - 3.6	13.7	27.2
LBH-27	2.90	3.07	LB13-3	LB13-3 (3.6'-5.4')	3.6 - 5.4	24.2	22.7
LBH-27	2.90	3.07	LB13-3	LB13-3 (1.8'-3.6')	5.4 - 7.2	13.1	41.7
LBH-27	2.90	3.07	LB13-3	LB13-3 (0'-1.8')	7.2 - 9	18.0	31.7
LBH-27	2.90	3.07	LB13-4	LB13-4 (8'-10')	0 - 2	10.2	27.9
LBH-27	2.90	3.07	LB13-4	LB13-4 (6'-8')	2 - 4	11.0	33.3
LBH-27	2.90	3.07	LB13-4	LB13-4 (4'-6')	4 - 6	13.2	33.0
LBH-27	2.90	3.07	LB13-4	LB13-4 (2'-4')	6 - 8	15.2	27.0
LBH-27	2.90	3.07	LB13-4	LB13-4 (0'-2')	8 - 10	143.0	32.5
LBH-27	2.90	3.07	LB14-1	LB14-1 (8'-10')	0 - 2	13.3	24.7
LBH-27	2.90	3.07	LB14-1	LB14-1 (6'-8')	2 - 4	18.4	25.4
LBH-27	2.90	3.07	LB14-1	LB14-1 (4'-6')	4 - 6	16.5	30.4

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-27	2.90	3.07	LB14-1	LB14-1 (2'-4')	6 - 8	21.6	30.5
LBH-27	2.90	3.07	LB14-1	LB14-1 (0'-2')	8 - 10	18.9	39.0
LBH-28	3.07	3.16	LB14-2	LB14-2 (3'-4')	0 - 1	23.1	19.7
LBH-28	3.07	3.16	LB14-2	LB14-2 (2'-3')	1 - 2	13.5	18.1
LBH-28	3.07	3.16	LB14-2	LB14-2 (1'-2')	2 - 3	5.8	24.6
LBH-28	3.07	3.16	LB14-2	LB14-2 (0'-1')	3 - 4	5.3	32.7
LBH-30	3.36	3.45	LB15-1	LB15-1 (4'-5')	0 - 1	10.9	11.4
LBH-30	3.36	3.45	LB15-1	LB15-1 (3'-4')	1 - 2	63.3	19.0
LBH-30	3.36	3.45	LB15-1	LB15-1 (2'-3')	2 - 3	5.2	14.1
LBH-30	3.36	3.45	LB15-1	LB15-1 (1'-2')	3 - 4	17.0	17.8
LBH-30	3.36	3.45	LB15-1	LB15-1 (0'-1')	4 - 5	12.1	27.6
LBH-30	3.36	3.45	LB15-2	LB15-2 (4.8'-6')	0 - 1.2	11.6	27.4
LBH-30	3.36	3.45	LB15-2	LB15-2 (3.6'-4.8')	1.2 - 2.4	11.4	23.5
LBH-30	3.36	3.45	LB15-2	LB15-2 (2.4'-3.6')	2.4 - 3.6	9.8	25.8
LBH-30	3.36	3.45	LB15-2	LB15-2 (1.2'-2.4')	3.6 - 4.8	11.8	32.1
LBH-30	3.36	3.45	LB15-2	LB15-2 (0'-1.2')	4.8 - 6	13.0	41.2
LBH-30	3.36	3.45	LB16-1	LB16-1 (4.8'-6')	0 - 1.2	8.5	13.2
LBH-30	3.36	3.45	LB16-1	LB16-1 (3.6'-4.8')	1.2 - 2.4	9.6	13.9
LBH-30	3.36	3.45	LB16-1	LB16-1 (2.4'-3.6')	2.4 - 3.6	7.3	16.3
LBH-30	3.36	3.45	LB16-1	LB16-1 (1.2'-2.4')	3.6 - 4.8	2.0	20.5
LBH-30	3.36	3.45	LB16-1	LB16-1 (0'-1.2')	4.8 - 6	7.2	24.9
LBH-31	3.45	3.53	LB16-2	LB16-2 (1'-2')	0 - 1	3.0	19.2
LBH-31	3.45	3.53	LB16-2	LB16-2 (0'-1')	1 - 2	2.7	26.5
LBH-31	3.45	3.53	LB16-3	LB16-3 (4.8'-6')	0 - 1.2	17.9	15.7
LBH-31	3.45	3.53	LB16-3	LB16-3 (3.6'-4.8')	1.2 - 2.4	11.3	18.4
LBH-31	3.45	3.53	LB16-3	LB16-3 (2.4'-3.6')	2.4 - 3.6	18.4	18.6
LBH-31	3.45	3.53	LB16-3	LB16-3 (1.2'-2.4')	3.6 - 4.8	8.9	19.0
LBH-31	3.45	3.53	LB16-3	LB16-3 (0'-1.2')	4.8 - 6	8.6	21.5
LBH-31	3.45	3.53	LB17-1	LB17-1 (4.8'-6')	0 - 1.2	12.5	4.7
LBH-31	3.45	3.53	LB17-1	LB17-1 (3.6'-4.8')	1.2 - 2.4	26.4	16.6
LBH-31	3.45	3.53	LB17-1	LB17-1 (2.4'-3.6')	2.4 - 3.6	16.9	9.8
LBH-31	3.45	3.53	LB17-1	LB17-1 (1.2'-2.4')	3.6 - 4.8	21.6	17.4
LBH-31	3.45	3.53	LB17-1	LB17-1 (0'-1.2')	4.8 - 6	87.7	25.5
LBH-31	3.45	3.53	LB17-2	LB17-2 (14'-16')	0 - 2	6.2	9.9
LBH-31	3.45	3.53	LB17-2	LB17-2 (12'-14')	2 - 4	9.4	16.3
LBH-31	3.45	3.53	LB17-2	LB17-2 (10'-12')	4 - 6	6.8	8.3
LBH-31	3.45	3.53	LB17-2	LB17-2 (8'-10')	6 - 8	5.2	14.3
LBH-31	3.45	3.53	LB17-2	LB17-2 (6'-8')	8 - 10	9.2	35.7
LBH-31	3.45	3.53	LB17-2	LB17-2 (4'-6')	10 - 12	4.5	20.2
LBH-31	3.45	3.53	LB17-2	LB17-2 (2'-4')	12 - 14	3.4	19.4
LBH-31	3.45	3.53	LB17-2	LB17-2 (0'-2')	14 - 16	3.1	31.8
LBH-32	3.53	3.69	LB17-3	LB17-3 (4'-5')	0 - 1	15.4	13.7
LBH-32	3.53	3.69	LB17-3	LB17-3 (3'-4')	1 - 2	6.4	21.6
LBH-32	3.53	3.69	LB17-3	LB17-3 (2'-3')	2 - 3	13.4	23.7
LBH-32	3.53	3.69	LB17-3	LB17-3 (1'-2')	3 - 4	8.6	26.8
LBH-32	3.53	3.69	LB17-3	LB17-3 (0'-1')	4 - 5	11.5	31.3
LBH-32	3.53	3.69	LB18-1	LB18-1 (6.4'-8')	0 - 1.6	10.4	15.6
LBH-32	3.53	3.69	LB18-1	LB18-1 (4.8'-6.4')	1.6 - 3.2	9.0	20.4
LBH-32	3.53	3.69	LB18-1	LB18-1 (3.2'-4.8')	3.2 - 4.8	12.9	20.1
LBH-32	3.53	3.69	LB18-1	LB18-1 (1.6'-3.2')	4.8 - 6.4	32.2	23.0
LBH-32	3.53	3.69	LB18-1	LB18-1 (0'-1.6')	6.4 - 8	16.5	33.6
LBH-32	3.53	3.69	LB18-2	LB18-2 (6.4'-8')	0 - 1.6	10.4	27.0
LBH-32	3.53	3.69	LB18-2	LB18-2 (4.8'-6.4')	1.6 - 3.2	16.1	33.6

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-32	3.53	3.69	LB18-2	LB18-2 (3.2'-4.8')	3.2 - 4.8	12.9	26.9
LBH-32	3.53	3.69	LB18-2	LB18-2 (1.6'-3.2')	4.8 - 6.4	15.3	35.7
LBH-32	3.53	3.69	LB18-2	LB18-2 (0'-1.6')	6.4 - 8	13.2	35.6
LBH-32	3.53	3.69	LB18-3	LB18-3 (4'-5')	0 - 1	9.8	16.7
LBH-32	3.53	3.69	LB18-3	LB18-3 (3'-4')	1 - 2	7.4	16.6
LBH-32	3.53	3.69	LB18-3	LB18-3 (2'-3')	2 - 3	10.2	24.0
LBH-32	3.53	3.69	LB18-3	LB18-3 (1'-2')	3 - 4	7.2	31.8
LBH-32	3.53	3.69	LB18-3	LB18-3 (0'-1')	4 - 5	7.9	30.0
LBH-33	3.69	3.80	LB18-4	LB18-4 (3'-4')	0 - 1	10.9	28.4
LBH-33	3.69	3.80	LB18-4	LB18-4 (2'-3')	1 - 2	9.9	26.2
LBH-33	3.69	3.80	LB18-4	LB18-4 (1'-2')	2 - 3	11.3	33.0
LBH-33	3.69	3.80	LB18-4	LB18-4 (0'-1')	3 - 4	11.3	29.6
LBH-34	3.80	3.91	LB19-1	LB19-1 (4'-5')	0 - 1	3.8	20.3
LBH-34	3.80	3.91	LB19-1	LB19-1 (3'-4')	1 - 2	4.9	26.7
LBH-34	3.80	3.91	LB19-1	LB19-1 (2'-3')	2 - 3	5.4	29.1
LBH-34	3.80	3.91	LB19-1	LB19-1 (1'-2')	3 - 4	5.0	33.6
LBH-34	3.80	3.91	LB19-1	LB19-1 (0'-1')	4 - 5	9.9	36.9
LBH-34	3.80	3.91	LB19-2	LB19-2 (4'-5')	0 - 1	0.58	8.6
LBH-34	3.80	3.91	LB19-2	LB19-2 (3'-4')	1 - 2	2.1	11.7
LBH-34	3.80	3.91	LB19-2	LB19-2 (2'-3')	2 - 3	2.8	16.4
LBH-34	3.80	3.91	LB19-2	LB19-2 (1'-2')	3 - 4	4.7	23.8
LBH-34	3.80	3.91	LB19-2	LB19-2 (0'-1')	4 - 5	5.7	27.9
LBH-34	3.80	3.91	LB20-1	LB20-1 (4'-5')	0 - 1	2.8	14.1
LBH-34	3.80	3.91	LB20-1	LB20-1 (3'-4')	1 - 2	2.5	15.0
LBH-34	3.80	3.91	LB20-1	LB20-1 (2'-3')	2 - 3	4.0	18.0
LBH-34	3.80	3.91	LB20-1	LB20-1 (1'-2')	3 - 4	1.1	16.1
LBH-34	3.80	3.91	LB20-1	LB20-1 (0'-1')	4 - 5	0.80	20.8
LBH-37	4.05	4.14	LB21-1	LB21-1 (4'-5')	0 - 1	136.0	26.4
LBH-37	4.05	4.14	LB21-1	LB21-1 (3'-4')	1 - 2	258.0	25.7
LBH-37	4.05	4.14	LB21-1	LB21-1 (2'-3')	2 - 3	188.0	26.1
LBH-37	4.05	4.14	LB21-1	LB21-1 (1'-2')	3 - 4	37.4	31.8
LBH-37	4.05	4.14	LB21-1	LB21-1 (0'-1')	4 - 5	28.4	30.2
LBH-37	4.05	4.14	LB22-1	LB22-1 (4'-5')	0 - 1	2.6	15.4
LBH-37	4.05	4.14	LB22-1	LB22-1 (3'-4')	1 - 2	0.57	18.0
LBH-37	4.05	4.14	LB22-1	LB22-1 (2'-3')	2 - 3	1.7	18.1
LBH-37	4.05	4.14	LB22-1	LB22-1 (1'-2')	3 - 4	1.7	21.4
LBH-37	4.05	4.14	LB22-1	LB22-1 (0'-1')	4 - 5	2.7	15.6
LBH-37	4.05	4.14	LB22-2	LB22-2 (4'-5')	0 - 1	0.51	18.8
LBH-37	4.05	4.14	LB22-2	LB22-2 (3'-4')	1 - 2	0.06	17.4
LBH-37	4.05	4.14	LB22-2	LB22-2 (2'-3')	2 - 3	0.57	22.4
LBH-37	4.05	4.14	LB22-2	LB22-2 (1'-2')	3 - 4	0.38	25.8
LBH-37	4.05	4.14	LB22-2	LB22-2 (0'-1')	4 - 5	0.01	26.5
LBH-37	4.05	4.14	LB23-1	LB23-1 (10'-12')	0 - 2	9.0	19.0
LBH-37	4.05	4.14	LB23-1	LB23-1 (8'-10')	2 - 4	12.3	18.8
LBH-37	4.05	4.14	LB23-1	LB23-1 (6'-8')	4 - 6	7.9	19.3
LBH-37	4.05	4.14	LB23-1	LB23-1 (4'-6')	6 - 8	9.2	17.9
LBH-37	4.05	4.14	LB23-1	LB23-1 (2'-4')	8 - 10	4.8	16.8
LBH-37	4.05	4.14	LB23-1	LB23-1 (0'-2')	10 - 12	3.2	18.7
LBH-38	4.14	4.39	LB24-1	LB24-1 (8'-10')	0 - 2	8.6	31.7
LBH-38	4.14	4.39	LB24-1	LB24-1 (6'-8')	2 - 4	8.5	27.8
LBH-38	4.14	4.39	LB24-1	LB24-1 (4'-6')	4 - 6	11.6	24.9
LBH-38	4.14	4.39	LB24-1	LB24-1 (2'-4')	6 - 8	18.3	28.8
LBH-38	4.14	4.39	LB24-1	LB24-1 (0'-2')	8 - 10	10.7	39.9

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-38	4.14	4.39	LB25-1	LB25-1 (6.4'-8')	0 - 1.6	0.16	20.2
LBH-38	4.14	4.39	LB25-1	LB25-1 (4.8'-6.4')	1.6 - 3.2	2.4	22.8
LBH-38	4.14	4.39	LB25-1	LB25-1 (3.2'-4.8')	3.2 - 4.8	0.13	19.2
LBH-38	4.14	4.39	LB25-1	LB25-1 (1.6'-3.2')	4.8 - 6.4	0.42	21.1
LBH-38	4.14	4.39	LB25-1	LB25-1 (0'-1.6')	6.4 - 8	1.7	23.6
LBH-38	4.14	4.39	LB26-1	LB26-1 (8'-10')	0 - 2	2.3	22.4
LBH-38	4.14	4.39	LB26-1	LB26-1 (6'-8')	2 - 4	0.11	17.6
LBH-38	4.14	4.39	LB26-1	LB26-1 (4'-6')	4 - 6	1.0	18.6
LBH-38	4.14	4.39	LB26-1	LB26-1 (2'-4')	6 - 8	1.3	20.3
LBH-38	4.14	4.39	LB26-1	LB26-1 (0'-2')	8 - 10	0.19	21.8
LBH-38	4.14	4.39	LB26-2	LB26-2 (8'-10')	0 - 2	0.88	21.0
LBH-38	4.14	4.39	LB26-2	LB26-2 (6'-8')	2 - 4	4.8	28.5
LBH-38	4.14	4.39	LB26-2	LB26-2 (4'-6')	4 - 6	0.99	20.2
LBH-38	4.14	4.39	LB26-2	LB26-2 (2'-4')	6 - 8	0.09	15.0
LBH-38	4.14	4.39	LB26-2	LB26-2 (0'-2')	8 - 10	0.11	15.3
LBH-38	4.14	4.39	LB26-3	LB26-3 (6.4'-8')	0 - 1.6	0.10	20.4
LBH-38	4.14	4.39	LB26-3	LB26-3 (4.8'-6.4')	1.6 - 3.2	0.50	22.0
LBH-38	4.14	4.39	LB26-3	LB26-3 (3.2'-4.8')	3.2 - 4.8	1.9	23.7
LBH-38	4.14	4.39	LB26-3	LB26-3 (1.6'-3.2')	4.8 - 6.4	5.0	30.8
LBH-38	4.14	4.39	LB26-3	LB26-3 (0'-1.6')	6.4 - 8	4.5	33.0
LBH-38	4.14	4.39	LB27-1	LB27-1 (6.4'-8')	0 - 1.6	8.0	20.5
LBH-38	4.14	4.39	LB27-1	LB27-1 (4.8'-6.4')	1.6 - 3.2	52.2	20.9
LBH-38	4.14	4.39	LB27-1	LB27-1 (3.2'-4.8')	3.2 - 4.8	52.5	22.7
LBH-38	4.14	4.39	LB27-1	LB27-1 (1.6'-3.2')	4.8 - 6.4	28.8	23.6
LBH-38	4.14	4.39	LB27-1	LB27-1 (0'-1.6')	6.4 - 8	110.0	31.9
LBH-38	4.14	4.39	LB27-2	LB27-2 (8'-10')	0 - 2	15.0	30.9
LBH-38	4.14	4.39	LB27-2	LB27-2 (6'-8')	2 - 4	13.8	34.4
LBH-38	4.14	4.39	LB27-2	LB27-2 (4'-6')	4 - 6	11.2	30.9
LBH-38	4.14	4.39	LB27-2	LB27-2 (2'-4')	6 - 8	12.6	29.6
LBH-38	4.14	4.39	LB27-2	LB27-2 (0'-2')	8 - 10	12.4	31.9
LBH-38	4.14	4.39	LB28-1	LB28-1 (4.8'-6')	0 - 1.2	4.1	21.7
LBH-38	4.14	4.39	LB28-1	LB28-1 (3.6'-4.8')	1.2 - 2.4	1.1	19.1
LBH-38	4.14	4.39	LB28-1	LB28-1 (2.4'-3.6')	2.4 - 3.6	1.2	19.6
LBH-38	4.14	4.39	LB28-1	LB28-1 (1.2'-2.4')	3.6 - 4.8	1.4	19.9
LBH-38	4.14	4.39	LB28-1	LB28-1 (0'-1.2')	4.8 - 6	0.27	23.3
LBH-38	4.14	4.39	LB28-2	LB28-2 (4.8'-6')	0 - 1.2	8.3	24.5
LBH-38	4.14	4.39	LB28-2	LB28-2 (3.6'-4.8')	1.2 - 2.4	163.0	23.6
LBH-38	4.14	4.39	LB28-2	LB28-2 (2.4'-3.6')	2.4 - 3.6	57.7	21.1
LBH-38	4.14	4.39	LB28-2	LB28-2 (1.2'-2.4')	3.6 - 4.8	15.6	19.7
LBH-38	4.14	4.39	LB28-2	LB28-2 (0'-1.2')	4.8 - 6	9.4	26.7
LBH-39	4.39	4.71	LB28-3	LB28-3 (8'-10')	0 - 2	10.2	24.0
LBH-39	4.39	4.71	LB28-3	LB28-3 (6'-8')	2 - 4	7.4	21.2
LBH-39	4.39	4.71	LB28-3	LB28-3 (4'-6')	4 - 6	9.7	29.2
LBH-39	4.39	4.71	LB28-3	LB28-3 (2'-4')	6 - 8	12.6	31.0
LBH-39	4.39	4.71	LB28-3	LB28-3 (0'-2')	8 - 10	8.2	28.9
LBH-39	4.39	4.71	LB28-4	LB28-4 (8'-10')	0 - 2	38.9	28.3
LBH-39	4.39	4.71	LB28-4	LB28-4 (6'-8')	2 - 4	75.5	29.1
LBH-39	4.39	4.71	LB28-4	LB28-4 (4'-6')	4 - 6	57.4	30.1
LBH-39	4.39	4.71	LB28-4	LB28-4 (2'-4')	6 - 8	17.9	33.6
LBH-39	4.39	4.71	LB28-4	LB28-4 (0'-2')	8 - 10	8.2	32.4
LBH-39	4.39	4.71	LB29-1	LB29-1 (8'-10')	0 - 2	15.0	32.6
LBH-39	4.39	4.71	LB29-1	LB29-1 (6'-8')	2 - 4	11.8	30.6
LBH-39	4.39	4.71	LB29-1	LB29-1 (4'-6')	4 - 6	27.4	25.8

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
LBH-39	4.39	4.71	LB29-1	LB29-1 (2'-4')	6 - 8	16.3	24.1
LBH-39	4.39	4.71	LB29-1	LB29-1 (0'-2')	8 - 10	170.0	33.6
LBH-39	4.39	4.71	LB29-2	LB29-2 (4.8'-6')	0 - 1.2	23.0	29.8
LBH-39	4.39	4.71	LB29-2	LB29-2 (3.6'-4.8')	1.2 - 2.4	30.9	26.0
LBH-39	4.39	4.71	LB29-2	LB29-2 (2.4'-3.6')	2.4 - 3.6	142.0	23.6
LBH-39	4.39	4.71	LB29-2	LB29-2 (1.2'-2.4')	3.6 - 4.8	323.0	25.9
LBH-39	4.39	4.71	LB29-2	LB29-2 (0'-1.2')	4.8 - 6	362.0	33.9
LBH-39	4.39	4.71	LB29-3	LB29-3 (5.6'-7')	0 - 1.4	23.6	18.9
LBH-39	4.39	4.71	LB29-3	LB29-3 (4.2'-5.6')	1.4 - 2.8	24.9	22.9
LBH-39	4.39	4.71	LB29-3	LB29-3 (2.8'-4.2')	2.8 - 4.2	23.4	21.8
LBH-39	4.39	4.71	LB29-3	LB29-3 (1.4'-2.8')	4.2 - 5.6	16.2	24.0
LBH-39	4.39	4.71	LB29-3	LB29-3 (0'-1.4')	5.6 - 7	30.9	31.3
LBH-39	4.39	4.71	LB29-4	LB29-4 (6.4'-8')	0 - 1.6	14.2	21.7
LBH-39	4.39	4.71	LB29-4	LB29-4 (4.8'-6.4')	1.6 - 3.2	14.8	20.3
LBH-39	4.39	4.71	LB29-4	LB29-4 (3.2'-4.8')	3.2 - 4.8	16.8	20.2
LBH-39	4.39	4.71	LB29-4	LB29-4 (1.6'-3.2')	4.8 - 6.4	16.8	19.7
LBH-39	4.39	4.71	LB29-4	LB29-4 (0'-1.6')	6.4 - 8	14.1	29.0
LBH-41	4.83	4.94	LB30-1	LB30-1 (5.6'-7')	0 - 1.4	11.5	25.1
LBH-41	4.83	4.94	LB30-1	LB30-1 (4.2'-5.6')	1.4 - 2.8	13.7	23.4
LBH-41	4.83	4.94	LB30-1	LB30-1 (2.8'-4.2')	2.8 - 4.2	13.4	26.9
LBH-41	4.83	4.94	LB30-1	LB30-1 (1.4'-2.8')	4.2 - 5.6	10.4	34.9
LBH-41	4.83	4.94	LB30-1	LB30-1 (0'-1.4')	5.6 - 7	12.4	42.2
LBH-41	4.83	4.94	LB30-2	LB30-2 (8'-10')	0 - 2	28.0	32.1
LBH-41	4.83	4.94	LB30-2	LB30-2 (6'-8')	2 - 4	18.0	24.7
LBH-41	4.83	4.94	LB30-2	LB30-2 (4'-6')	4 - 6	14.0	39.9
LBH-41	4.83	4.94	LB30-2	LB30-2 (2'-4')	6 - 8	11.0	37.1
LBH-41	4.83	4.94	LB30-2	LB30-2 (0'-2')	8 - 10	14.1	40.5
RBH-03	0.16	0.31	RB01-1	RB01-1 (14'-16')	0 - 2	45.9	33.6
RBH-03	0.16	0.31	RB01-1	RB01-1 (12'-14')	2 - 4	19.3	32.6
RBH-03	0.16	0.31	RB01-1	RB01-1 (10'-12')	4 - 6	5.8	41.0
RBH-03	0.16	0.31	RB01-1	RB01-1 (8'-10')	6 - 8	3.9	39.9
RBH-03	0.16	0.31	RB01-1	RB01-1 (6'-8')	8 - 10	4.7	44.1
RBH-03	0.16	0.31	RB01-1	RB01-1 (4'-6')	10 - 12	1.6	43.9
RBH-03	0.16	0.31	RB01-1	RB01-1 (2'-4')	12 - 14	2.3	47.3
RBH-03	0.16	0.31	RB01-1	RB01-1 (0'-2')	14 - 16	1.0	49.8
RBH-04	0.31	0.38	RBH-4-C	RBH-4-C (0'-2')	12 - 14	5.2	29.2
RBH-04	0.31	0.38	RBH-4-C	RBH-4-C (2'-4')	10 - 12	3.1	33.8
RBH-04	0.31	0.38	RBH-4-C	RBH-4-C (4'-6')	8 - 10	1.3	29.7
RBH-04	0.31	0.38	RBH-4-C	RBH-4-C (6'-8')	6 - 8	1.2	31.8
RBH-04	0.31	0.38	RBH-4-C	RBH-4-C (8'-10')	4 - 6	4.0	33.7
RBH-04	0.31	0.38	RBH-4-C	RBH-4-C (10'-12')	2 - 4	0.94	34.2
RBH-04	0.31	0.38	RBH-4-C	RBH-4-C (12'-14')	0 - 2	1.5	39.6
RBH-04	0.31	0.38	RBH-4-B	RBH-4-B (0'-2')	8 - 10	3.2	37.1
RBH-04	0.31	0.38	RBH-4-B	RBH-4-B (2'-4')	6 - 8	2.6	30.1
RBH-04	0.31	0.38	RBH-4-B	RBH-4-B (4'-6')	4 - 6	3.3	23.6
RBH-04	0.31	0.38	RBH-4-B	RBH-4-B (6'-8')	2 - 4	2.2	27.7
RBH-04	0.31	0.38	RBH-4-B	RBH-4-B (8'-10')	0 - 2	2.6	31.9
RBH-04	0.31	0.38	RBH-4-A	RBH - 4 - A (0'-2')	8 - 10	1.1	25.1
RBH-04	0.31	0.38	RBH-4-A	RBH - 4 - A (2'-4')	6 - 8	1.5	13.2
RBH-04	0.31	0.38	RBH-4-A	RBH - 4 - A (4'-6')	4 - 6	0.98	12.0
RBH-04	0.31	0.38	RBH-4-A	RBH - 4 - A (6'-8')	2 - 4	1.1	14.0
RBH-04	0.31	0.38	RBH-4-A	RBH - 4 - A (8'-10')	0 - 2	1.4	24.7
RBH-06	0.51	0.81	RB01-2	RB01-2 (16'-18')	0 - 2	55.7	19.1

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-06	0.51	0.81	RB01-2	RB01-2 (14'-16')	2 - 4	3.0	24.5
RBH-06	0.51	0.81	RB01-2	RB01-2 (12'-14')	4 - 6	2.3	22.2
RBH-06	0.51	0.81	RB01-2	RB01-2 (10'-12')	6 - 8	1.2	19.1
RBH-06	0.51	0.81	RB01-2	RB01-2 (8'-10')	8 - 10	1.3	20.5
RBH-06	0.51	0.81	RB01-2	RB01-2 (6'-8')	10 - 12	2.2	23.1
RBH-06	0.51	0.81	RB01-2	RB01-2 (4'-6')	12 - 14	0.53	17.6
RBH-06	0.51	0.81	RB01-2	RB01-2 (2'-4')	14 - 16	0.48	21.0
RBH-06	0.51	0.81	RB01-2	RB01-2 (0'-2')	16 - 18	0.69	31.5
RBH-06	0.51	0.81	RB01-3	RB01-3 (10'-12')	0 - 2	4.6	21.3
RBH-06	0.51	0.81	RB01-3	RB01-3 (8'-10')	2 - 4	3.8	22.4
RBH-06	0.51	0.81	RB01-3	RB01-3 (6'-8')	4 - 6	3.6	21.6
RBH-06	0.51	0.81	RB01-3	RB01-3 (4'-6')	6 - 8	5.1	20.0
RBH-06	0.51	0.81	RB01-3	RB01-3 (2'-4')	8 - 10	4.0	24.4
RBH-06	0.51	0.81	RB01-3	RB01-3 (0'-2')	10 - 12	2.6	27.8
RBH-06	0.51	0.81	RB01-4	RB01-4 (22'-24')	0 - 2	0.76	35.7
RBH-06	0.51	0.81	RB01-4	RB01-4 (20'-22')	2 - 4	0.81	14.4
RBH-06	0.51	0.81	RB01-4	RB01-4 (18'-20')	4 - 6	2.7	21.5
RBH-06	0.51	0.81	RB01-4	RB01-4 (16'-18')	6 - 8	0.63	13.1
RBH-06	0.51	0.81	RB01-4	RB01-4 (14'-16')	8 - 10	0.89	11.6
RBH-06	0.51	0.81	RB01-4	RB01-4 (12'-14')	10 - 12	1.0	19.0
RBH-06	0.51	0.81	RB01-4	RB01-4 (10'-12')	12 - 14	0.94	20.3
RBH-06	0.51	0.81	RB01-4	RB01-4 (8'-10')	14 - 16	1.8	21.7
RBH-06	0.51	0.81	RB01-4	RB01-4 (6'-8')	16 - 18	0.63	27.3
RBH-06	0.51	0.81	RB01-4	RB01-4 (4'-6')	18 - 20	0.95	16.9
RBH-06	0.51	0.81	RB01-4	RB01-4 (2'-4')	20 - 22	0.97	27.2
RBH-06	0.51	0.81	RB01-4	RB01-4 (0'-2')	22 - 24	0.70	27.7
RBH-06	0.51	0.81	RB02-1	RB02-1 (10'-12')	0 - 2	3.7	22.6
RBH-06	0.51	0.81	RB02-1	RB02-1 (8'-10')	2 - 4	4.9	19.2
RBH-06	0.51	0.81	RB02-1	RB02-1 (6'-8')	4 - 6	2.1	7.9
RBH-06	0.51	0.81	RB02-1	RB02-1 (4'-6')	6 - 8	2.1	11.9
RBH-06	0.51	0.81	RB02-1	RB02-1 (2'-4')	8 - 10	5.4	13.8
RBH-06	0.51	0.81	RB02-1	RB02-1 (0'-2')	10 - 12	4.9	31.0
RBH-07	0.81	0.92	RBH-7-A	RBH-7-A (0'-1')	3 - 4	1.2	42.8
RBH-07	0.81	0.92	RBH-7-A	RBH-7-A (1'-2')	2 - 3	1.3	24.2
RBH-07	0.81	0.92	RBH-7-A	RBH-7-A (2'-3')	1 - 2	4.3	26.2
RBH-07	0.81	0.92	RBH-7-A	RBH-7-A (3'-4')	0 - 1	2.3	24.8
RBH-07	0.81	0.92	RBH-7-B	RBH-7-B (0'-1.6')	6.4 - 8	1.3	27.4
RBH-07	0.81	0.92	RBH-7-B	RBH-7-B (1.6'-3.2')	4.8 - 6.4	1.2	30.0
RBH-07	0.81	0.92	RBH-7-B	RBH-7-B (3.2'-4.8')	3.2 - 4.8	0.97	42.2
RBH-07	0.81	0.92	RBH-7-B	RBH-7-B (4.8'-6.4')	1.6 - 3.2	0.73	45.5
RBH-07	0.81	0.92	RBH-7-B	RBH-7-B (6.4'-8')	0 - 1.6	0.81	36.1
RBH-07	0.81	0.92	RBH-7-C	RBH-7-C (0'-1')	4 - 5	29.3	33.3
RBH-07	0.81	0.92	RBH-7-C	RBH-7-C (1'-2')	3 - 4	18.6	23.2
RBH-07	0.81	0.92	RBH-7-C	RBH-7-C (2'-3')	2 - 3	8.8	23.0
RBH-07	0.81	0.92	RBH-7-C	RBH-7-C (3'-4')	1 - 2	5.6	25.4
RBH-07	0.81	0.92	RBH-7-C	RBH-7-C (4'-5')	0 - 1	4.2	29.1
RBH-07	0.81	0.92	RBH-7-D	RBH-7-D (0'-1.6')	6.4 - 8	2.3	14.2
RBH-07	0.81	0.92	RBH-7-D	RBH-7-D (1.6'-3.2')	4.8 - 6.4	4.4	13.9
RBH-07	0.81	0.92	RBH-7-D	RBH-7-D (3.2'-4.8')	3.2 - 4.8	7.7	18.5
RBH-07	0.81	0.92	RBH-7-D	RBH-7-D (4.8'-6.4')	1.6 - 3.2	2.2	26.9
RBH-07	0.81	0.92	RBH-7-D	RBH-7-D (6.4'-8')	0 - 1.6	1.4	28.7
RBH-08	0.92	1.05	RB03-1	RB03-1 (8'-10')	0 - 2	1.5	11.7
RBH-08	0.92	1.05	RB03-1	RB03-1 (6'-8')	2 - 4	1.6	22.9

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2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-08	0.92	1.05	RB03-1	RB03-1 (4'-6')	4 - 6	1.5	22.0
RBH-08	0.92	1.05	RB03-1	RB03-1 (2'-4')	6 - 8	2.3	29.4
RBH-08	0.92	1.05	RB03-1	RB03-1 (0'-2')	8 - 10	2.0	35.4
RBH-10	1.15	1.20	RB03-2	RB03-2 (16'-18')	0 - 2	0.97	19.6
RBH-10	1.15	1.20	RB03-2	RB03-2 (14'-16')	2 - 4	0.72	25.1
RBH-10	1.15	1.20	RB03-2	RB03-2 (12'-14')	4 - 6	0.80	22.0
RBH-10	1.15	1.20	RB03-2	RB03-2 (10'-12')	6 - 8	0.01	20.5
RBH-10	1.15	1.20	RB03-2	RB03-2 (8'-10')	8 - 10	0.93	37.5
RBH-10	1.15	1.20	RB03-2	RB03-2 (6'-8')	10 - 12	0.97	46.4
RBH-10	1.15	1.20	RB03-2	RB03-2 (4'-6')	12 - 14	1.2	40.9
RBH-10	1.15	1.20	RB03-2	RB03-2 (2'-4')	14 - 16	0.67	33.0
RBH-10	1.15	1.20	RB03-2	RB03-2 (0'-2')	16 - 18	1.0	36.7
RBH-11	1.20	1.33	RB03-3	RB03-3 (12'-14')	0 - 2	5.5	27.6
RBH-11	1.20	1.33	RB03-3	RB03-3 (10'-12')	2 - 4	12.5	21.0
RBH-11	1.20	1.33	RB03-3	RB03-3 (8'-10')	4 - 6	12.0	26.5
RBH-11	1.20	1.33	RB03-3	RB03-3 (6'-8')	6 - 8	13.9	34.2
RBH-11	1.20	1.33	RB03-3	RB03-3 (4'-6')	8 - 10	8.3	35.0
RBH-11	1.20	1.33	RB03-3	RB03-3 (2'-4')	10 - 12	3.4	29.7
RBH-11	1.20	1.33	RB03-3	RB03-3 (0'-2')	12 - 14	2.6	36.5
RBH-12	1.33	1.41	RBH-12-A	RBH-12-A (0'-2')	8 - 10	12.8	17.7
RBH-12	1.33	1.41	RBH-12-A	RBH-12-A (2'-4')	6 - 8	103.0	19.7
RBH-12	1.33	1.41	RBH-12-A	RBH-12-A (4'-6')	4 - 6	119.0	18.7
RBH-12	1.33	1.41	RBH-12-A	RBH-12-A (6'-8')	2 - 4	11.2	19.4
RBH-12	1.33	1.41	RBH-12-A	RBH-12-A (8'-10')	0 - 2	16.0	25.1
RBH-12	1.33	1.41	RBH-12-B	RBH-12-B (0'-2')	8 - 10	35.5	18.2
RBH-12	1.33	1.41	RBH-12-B	RBH-12-B (2'-4')	6 - 8	74.9	17.4
RBH-12	1.33	1.41	RBH-12-B	RBH-12-B (4'-6')	4 - 6	14.4	15.4
RBH-12	1.33	1.41	RBH-12-B	RBH-12-B (6'-8')	2 - 4	4.2	19.2
RBH-12	1.33	1.41	RBH-12-B	RBH-12-B (8'-10')	0 - 2	6.1	23.4
RBH-12	1.33	1.41	RBH-12-C	RBH-12-C (0'-2')	8 - 10	8.5	17.3
RBH-12	1.33	1.41	RBH-12-C	RBH-12-C (2'-4')	6 - 8	46.0	19.4
RBH-12	1.33	1.41	RBH-12-C	RBH-12-C (4'-6')	4 - 6	7.6	14.5
RBH-12	1.33	1.41	RBH-12-C	RBH-12-C (6'-8')	2 - 4	2.8	16.5
RBH-12	1.33	1.41	RBH-12-C	RBH-12-C (8'-10')	0 - 2	5.0	41.8
RBH-13	1.41	1.49	RB03-4	RB03-4 (4.8'-6')	0 - 1.2	13.1	29.6
RBH-13	1.41	1.49	RB03-4	RB03-4 (3.6'-4.8')	1.2 - 2.4	12.4	20.6
RBH-13	1.41	1.49	RB03-4	RB03-4 (2.4'-3.6')	2.4 - 3.6	18.1	23.2
RBH-13	1.41	1.49	RB03-4	RB03-4 (1.2'-2.4')	3.6 - 4.8	41.9	24.1
RBH-13	1.41	1.49	RB03-4	RB03-4 (0'-1.2')	4.8 - 6	817.0	33.7
RBH-14	1.49	1.58	RB04-1	RB04-1 (10'-12')	0 - 2	2.6	27.0
RBH-14	1.49	1.58	RB04-1	RB04-1 (8'-10')	2 - 4	2.9	28.1
RBH-14	1.49	1.58	RB04-1	RB04-1 (6'-8')	4 - 6	3.5	27.7
RBH-14	1.49	1.58	RB04-1	RB04-1 (4'-6')	6 - 8	5.2	26.0
RBH-14	1.49	1.58	RB04-1	RB04-1 (2'-4')	8 - 10	2.9	35.2
RBH-14	1.49	1.58	RB04-1	RB04-1 (0'-2')	10 - 12	4.8	38.8
RBH-14	1.49	1.58	RB05-1	RB05-1 (10'-12')	0 - 2	2.1	25.0
RBH-14	1.49	1.58	RB05-1	RB05-1 (8'-10')	2 - 4	8.2	27.5
RBH-14	1.49	1.58	RB05-1	RB05-1 (6'-8')	4 - 6	2.4	27.7
RBH-14	1.49	1.58	RB05-1	RB05-1 (4'-6')	6 - 8	4.9	26.2
RBH-14	1.49	1.58	RB05-1	RB05-1 (2'-4')	8 - 10	6.0	20.0
RBH-14	1.49	1.58	RB05-1	RB05-1 (0'-2')	10 - 12	3.9	48.9
RBH-14	1.49	1.58	RB05-2	RB05-2 (8'-10')	0 - 2	2.4	33.4
RBH-14	1.49	1.58	RB05-2	RB05-2 (6'-8')	2 - 4	3.0	33.8

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-14	1.49	1.58	RB05-2	RB05-2 (4'-6')	4 - 6	2.4	27.4
RBH-14	1.49	1.58	RB05-2	RB05-2 (2'-4')	6 - 8	2.4	25.2
RBH-14	1.49	1.58	RB05-2	RB05-2 (0'-2')	8 - 10	1.6	24.7
RBH-15	1.58	1.62	RBH-15-A	RBH-15-A (0'-2')	8 - 10	1.0	12.2
RBH-15	1.58	1.62	RBH-15-A	RBH-15-A (2'-4')	6 - 8	0.58	12.6
RBH-15	1.58	1.62	RBH-15-A	RBH-15-A (4'-6')	4 - 6	2.4	16.9
RBH-15	1.58	1.62	RBH-15-A	RBH-15-A (6'-8')	2 - 4	0.68	11.7
RBH-15	1.58	1.62	RBH-15-A	RBH-15-A (8'-10')	0 - 2	0.97	14.3
RBH-15	1.58	1.62	RBH-15-B	RBH-15-B (0'-2')	8 - 10	0.03	12.2
RBH-15	1.58	1.62	RBH-15-B	RBH-15-B (2'-4')	6 - 8	0.08	11.4
RBH-15	1.58	1.62	RBH-15-B	RBH-15-B (4'-6')	4 - 6	0.23	11.4
RBH-15	1.58	1.62	RBH-15-B	RBH-15-B (6'-8')	2 - 4	1.1	11.9
RBH-15	1.58	1.62	RBH-15-B	RBH-15-B (8'-10')	0 - 2	1.6	22.8
RBH-16	1.62	1.65	RBH-16-A	RBH-16-A (0'-1')	3 - 4	1.8	12.0
RBH-16	1.62	1.65	RBH-16-A	RBH-16-A (1'-2')	2 - 3	2.4	10.8
RBH-16	1.62	1.65	RBH-16-A	RBH-16-A (2'-3')	1 - 2	0.89	11.0
RBH-16	1.62	1.65	RBH-16-A	RBH-16-A (3'-4')	0 - 1	1.1	15.0
RBH-17	1.65	1.72	RB06-1	RB06-1 (18'-20')	0 - 2	1.8	21.2
RBH-17	1.65	1.72	RB06-1	RB06-1 (16'-18')	2 - 4	1.3	18.0
RBH-17	1.65	1.72	RB06-1	RB06-1 (14'-16')	4 - 6	1.1	10.5
RBH-17	1.65	1.72	RB06-1	RB06-1 (12'-14')	6 - 8	1.2	16.2
RBH-17	1.65	1.72	RB06-1	RB06-1 (10'-12')	8 - 10	1.4	9.5
RBH-17	1.65	1.72	RB06-1	RB06-1 (8'-10')	10 - 12	1.5	22.4
RBH-17	1.65	1.72	RB06-1	RB06-1 (6'-8')	12 - 14	2.4	26.1
RBH-17	1.65	1.72	RB06-1	RB06-1 (4'-6')	14 - 16	0.76	11.2
RBH-17	1.65	1.72	RB06-1	RB06-1 (2'-4')	16 - 18	0.97	16.4
RBH-17	1.65	1.72	RB06-1	RB06-1 (0'-2')	18 - 20	1.7	33.1
RBH-17	1.65	1.72	RB06-2	RB06-2 (8'-10')	0 - 2	3.7	22.8
RBH-17	1.65	1.72	RB06-2	RB06-2 (6'-8')	2 - 4	4.2	22.6
RBH-17	1.65	1.72	RB06-2	RB06-2 (4'-6')	4 - 6	2.7	20.9
RBH-17	1.65	1.72	RB06-2	RB06-2 (2'-4')	6 - 8	3.1	28.4
RBH-17	1.65	1.72	RB06-2	RB06-2 (0'-2')	8 - 10	1.9	23.1
RBH-18	1.72	1.82	RB07-2	RB07-2 (6.4'-8')	0 - 1.6	29.0	14.3
RBH-18	1.72	1.82	RB07-2	RB07-2 (4.8'-6.4')	1.6 - 3.2	0.72	7.2
RBH-18	1.72	1.82	RB07-2	RB07-2 (3.2'-4.8')	3.2 - 4.8	2.2	9.9
RBH-18	1.72	1.82	RB07-2	RB07-2 (1.6'-3.2')	4.8 - 6.4	0.24	15.4
RBH-18	1.72	1.82	RB07-2	RB07-2 (0'-1.6')	6.4 - 8	0.01	19.9
RBH-18	1.72	1.82	RB07-1	RB07-1 (6.4'-8)	0 - 1.6	3.8	17.8
RBH-18	1.72	1.82	RB07-1	RB07-1 (4.8'-6.4)	1.6 - 3.2	6.8	5.8
RBH-18	1.72	1.82	RB07-1	RB07-1 (3.2'-4.8)	3.2 - 4.8	10.8	13.2
RBH-18	1.72	1.82	RB07-1	RB07-1 (1.6'-3.2)	4.8 - 6.4	7.8	12.6
RBH-18	1.72	1.82	RB07-1	RB07-1 (0'-1.6)	6.4 - 8	1.9	20.8
RBH-18	1.72	1.82	RB07-3	RB07-3 (5.6'-7')	0 - 1.4	5.3	30.4
RBH-18	1.72	1.82	RB07-3	RB07-3 (4.2'-5.6')	1.4 - 2.8	4.9	27.2
RBH-18	1.72	1.82	RB07-3	RB07-3 (2.8'-4.2')	2.8 - 4.2	22.2	19.4
RBH-18	1.72	1.82	RB07-3	RB07-3 (1.4'-2.8')	4.2 - 5.6	11.7	23.2
RBH-18	1.72	1.82	RB07-3	RB07-3 (0'-1.4')	5.6 - 7	12.0	26.4
RBH-19	1.82	1.88	RB08-1	RB08-1 (7.2'-9')	0 - 1.8	24.6	10.5
RBH-19	1.82	1.88	RB08-1	RB08-1 (5.4'-7.2')	1.8 - 3.6	0.56	6.5
RBH-19	1.82	1.88	RB08-1	RB08-1 (3.6'-5.4')	3.6 - 5.4	0.37	7.4
RBH-19	1.82	1.88	RB08-1	RB08-1 (1.8'-3.6')	5.4 - 7.2	3.5	4.5
RBH-19	1.82	1.88	RB08-1	RB08-1 (0'-1.8')	7.2 - 9	1.2	8.9
RBH-19	1.82	1.88	RB08-2	RB08-2 (6.4'-7')	0 - 0.6	17.4	6.6

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-19	1.82	1.88	RB08-2	RB08-2 (4.8'-6.4')	0.6 - 2.2	1.4	11.1
RBH-19	1.82	1.88	RB08-2	RB08-2 (3.2'-4.8')	2.2 - 3.8	3.0	10.8
RBH-19	1.82	1.88	RB08-2	RB08-2 (1.6'-3.2')	3.8 - 5.4	0.93	16.0
RBH-19	1.82	1.88	RB08-2	RB08-2 (0'-1.6')	5.4 - 7	1.1	18.8
RBH-19	1.82	1.88	RB08-3	RB08-3 (4.8'-6')	0 - 1.2	0.68	9.9
RBH-19	1.82	1.88	RB08-3	RB08-3 (3.6'-4.8')	1.2 - 2.4	0.66	12.6
RBH-19	1.82	1.88	RB08-3	RB08-3 (2.4'-3.6')	2.4 - 3.6	0.13	11.0
RBH-19	1.82	1.88	RB08-3	RB08-3 (1.2'-2.4')	3.6 - 4.8	0.87	14.4
RBH-19	1.82	1.88	RB08-3	RB08-3 (0'-1.2')	4.8 - 6	2.3	20.5
RBH-20	1.88	1.93	RB09-1	RB09-1 (6.4'-8')	0 - 1.6	38.6	14.7
RBH-20	1.88	1.93	RB09-1	RB09-1 (4.8'-6.4')	1.6 - 3.2	2.9	16.6
RBH-20	1.88	1.93	RB09-1	RB09-1 (3.2'-4.8')	3.2 - 4.8	6.7	13.5
RBH-20	1.88	1.93	RB09-1	RB09-1 (1.6'-3.2')	4.8 - 6.4	8.4	17.0
RBH-20	1.88	1.93	RB09-1	RB09-1 (0'-1.6')	6.4 - 8	5.3	31.3
RBH-20	1.88	1.93	RB09-2	RB09-2 (14'-16')	0 - 2	20.1	18.3
RBH-20	1.88	1.93	RB09-2	RB09-2 (12'-14')	2 - 4	20.4	19.6
RBH-20	1.88	1.93	RB09-2	RB09-2 (10'-12')	4 - 6	55.1	18.8
RBH-20	1.88	1.93	RB09-2	RB09-2 (8'-10')	6 - 8	120.0	21.8
RBH-20	1.88	1.93	RB09-2	RB09-2 (6'-8')	8 - 10	15.2	24.1
RBH-20	1.88	1.93	RB09-2	RB09-2 (4'-6')	10 - 12	6.0	23.5
RBH-20	1.88	1.93	RB09-2	RB09-2 (2'-4')	12 - 14	4.3	19.0
RBH-20	1.88	1.93	RB09-2	RB09-2 (0'-2')	14 - 16	7.4	35.3
RBH-21	1.93	2.00	RBH-21-A	RBH-21-A (0'-1.6')	6.4 - 8	9.4	11.7
RBH-21	1.93	2.00	RBH-21-A	RBH-21-A (1.6'-3.2')	4.8 - 6.4	9.6	15.1
RBH-21	1.93	2.00	RBH-21-A	RBH-21-A (3.2'-4.8')	3.2 - 4.8	18.0	16.9
RBH-21	1.93	2.00	RBH-21-A	RBH-21-A (4.8'-6.4')	1.6 - 3.2	16.1	26.5
RBH-21	1.93	2.00	RBH-21-A	RBH-21-A (6.4'-8')	0 - 1.6	13.9	23.1
RBH-21	1.93	2.00	RBH-21-B	RBH-21-B (0'-1.2')	4.8 - 6	3.8	9.7
RBH-21	1.93	2.00	RBH-21-B	RBH-21-B (1.2'-2.4')	3.6 - 4.8	9.9	16.3
RBH-21	1.93	2.00	RBH-21-B	RBH-21-B (4.8'-6')	0 - 1.2	6.4	28.6
RBH-22	2.00	2.08	RB10-1	RB10-1 (8'-10')	0 - 2	7.1	23.0
RBH-22	2.00	2.08	RB10-1	RB10-1 (6'-8')	2 - 4	12.6	18.8
RBH-22	2.00	2.08	RB10-1	RB10-1 (4'-6')	4 - 6	4.8	18.4
RBH-22	2.00	2.08	RB10-1	RB10-1 (2'-4')	6 - 8	7.7	18.8
RBH-22	2.00	2.08	RB10-1	RB10-1 (0'-2')	8 - 10	2.1	15.9
RBH-22	2.00	2.08	RB10-2	RB10-2 (12'-14')	0 - 2	2.8	10.7
RBH-22	2.00	2.08	RB10-2	RB10-2 (10'-12')	2 - 4	0.52	16.8
RBH-22	2.00	2.08	RB10-2	RB10-2 (8'-10')	4 - 6	4.2	17.4
RBH-22	2.00	2.08	RB10-2	RB10-2 (6'-8')	6 - 8	3.2	19.5
RBH-22	2.00	2.08	RB10-2	RB10-2 (4'-6')	8 - 10	1.8	14.8
RBH-22	2.00	2.08	RB10-2	RB10-2 (2'-4')	10 - 12	1.6	9.2
RBH-22	2.00	2.08	RB10-2	RB10-2 (0'-2')	12 - 14	0.79	7.7
RBH-22	2.00	2.08	RB10-3	RB10-3 (12'-14')	0 - 2	2.8	13.3
RBH-22	2.00	2.08	RB10-3	RB10-3 (10'-12')	2 - 4	3.4	10.9
RBH-22	2.00	2.08	RB10-3	RB10-3 (8'-10')	4 - 6	1.9	8.0
RBH-22	2.00	2.08	RB10-3	RB10-3 (6'-8')	6 - 8	1.5	8.7
RBH-22	2.00	2.08	RB10-3	RB10-3 (4'-6')	8 - 10	1.9	10.3
RBH-22	2.00	2.08	RB10-3	RB10-3 (2'-4')	10 - 12	1.5	8.4
RBH-22	2.00	2.08	RB10-3	RB10-3 (0'-2')	12 - 14	3.0	8.9
RBH-23	2.08	2.19	RB11-1	RB11-1 (4.8'-6')	0 - 1.2	8.6	26.6
RBH-23	2.08	2.19	RB11-1	RB11-1 (3.6'-4.8')	1.2 - 2.4	7.4	40.5
RBH-23	2.08	2.19	RB11-1	RB11-1 (2.4'-3.6')	2.4 - 3.6	4.4	29.9
RBH-23	2.08	2.19	RB11-1	RB11-1 (1.2'-2.4')	3.6 - 4.8	8.9	28.2

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-23	2.08	2.19	RB11-1	RB11-1 (0'-1.2')	4.8 - 6	8.7	48.5
RBH-23	2.08	2.19	RB11-2	RB11-2 (5.6'-7')	0 - 1.4	5.7	32.2
RBH-23	2.08	2.19	RB11-2	RB11-2 (4.2'-5.6')	1.4 - 2.8	7.8	32.7
RBH-23	2.08	2.19	RB11-2	RB11-2 (2.8'-4.2')	2.8 - 4.2	4.6	36.0
RBH-23	2.08	2.19	RB11-2	RB11-2 (1.4'-2.8')	4.2 - 5.6	2.6	26.5
RBH-23	2.08	2.19	RB11-2	RB11-2 (0'-1.4')	5.6 - 7	4.6	31.4
RBH-24	2.19	2.71	RB11-3	RB11-3 (16'-18')	0 - 2	5.1	12.6
RBH-24	2.19	2.71	RB11-3	RB11-3 (14'-16')	2 - 4	4.0	18.0
RBH-24	2.19	2.71	RB11-3	RB11-3 (12'-14')	4 - 6	3.8	14.9
RBH-24	2.19	2.71	RB11-3	RB11-3 (10'-12')	6 - 8	5.5	20.9
RBH-24	2.19	2.71	RB11-3	RB11-3 (8'-10')	8 - 10	4.0	17.9
RBH-24	2.19	2.71	RB11-3	RB11-3 (6'-8')	10 - 12	5.3	19.0
RBH-24	2.19	2.71	RB11-3	RB11-3 (4'-6')	12 - 14	5.4	24.8
RBH-24	2.19	2.71	RB11-3	RB11-3 (2'-4')	14 - 16	4.6	24.7
RBH-24	2.19	2.71	RB11-3	RB11-3 (0'-2')	16 - 18	7.2	30.5
RBH-24	2.19	2.71	RB11-4	RB11-4 (4'-5')	0 - 1	4.7	11.1
RBH-24	2.19	2.71	RB11-4	RB11-4 (3'-4')	1 - 2	8.7	21.2
RBH-24	2.19	2.71	RB11-4	RB11-4 (2'-3')	2 - 3	8.2	24.1
RBH-24	2.19	2.71	RB11-4	RB11-4 (1'-2')	3 - 4	8.4	24.4
RBH-24	2.19	2.71	RB11-4	RB11-4 (0'-1')	4 - 5	6.7	42.8
RBH-24	2.19	2.71	RB12-1	RB12-1 (8'-10')	0 - 2	16.2	21.3
RBH-24	2.19	2.71	RB12-1	RB12-1 (6'-8')	2 - 4	214.0	14.4
RBH-24	2.19	2.71	RB12-1	RB12-1 (4'-6')	4 - 6	103.0	18.2
RBH-24	2.19	2.71	RB12-1	RB12-1 (2'-4')	6 - 8	119.0	20.6
RBH-24	2.19	2.71	RB12-1	RB12-1 (0'-2')	8 - 10	35.8	24.5
RBH-24	2.19	2.71	RB12-2	RB12-2 (8'-10')	0 - 2	11.7	21.8
RBH-24	2.19	2.71	RB12-2	RB12-2 (6'-8')	2 - 4	12.4	23.4
RBH-24	2.19	2.71	RB12-2	RB12-2 (4'-6')	4 - 6	23.4	22.1
RBH-24	2.19	2.71	RB12-2	RB12-2 (2'-4')	6 - 8	17.8	23.5
RBH-24	2.19	2.71	RB12-2	RB12-2 (0'-2')	8 - 10	16.0	30.6
RBH-24	2.19	2.71	RB12-3	RB12-3 (6.4'-7')	0 - 0.6	8.4	23.8
RBH-24	2.19	2.71	RB12-3	RB12-3 (4.8'-6.4')	0.6 - 2.2	47.3	22.5
RBH-24	2.19	2.71	RB12-3	RB12-3 (3.2'-4.8')	2.2 - 3.8	231.0	25.6
RBH-24	2.19	2.71	RB12-3	RB12-3 (1.6'-3.2')	3.8 - 5.4	41.2	22.3
RBH-24	2.19	2.71	RB12-3	RB12-3 (0'-1.6')	5.4 - 7	5.6	23.9
RBH-24	2.19	2.71	RB13-1	RB13-1 (5.6'-7')	0 - 1.4	16.7	21.3
RBH-24	2.19	2.71	RB13-1	RB13-1 (4.2'-5.6')	1.4 - 2.8	186.0	20.4
RBH-24	2.19	2.71	RB13-1	RB13-1 (2.8'-4.2')	2.8 - 4.2	118.0	25.8
RBH-24	2.19	2.71	RB13-1	RB13-1 (1.4'-2.8')	4.2 - 5.6	2.1	17.2
RBH-24	2.19	2.71	RB13-1	RB13-1 (0'-1.4')	5.6 - 7	5.3	24.3
RBH-25	2.71	2.82	RB14-1	RB14-1 (12'-14')	0 - 2	7.0	25.8
RBH-25	2.71	2.82	RB14-1	RB14-1 (10'-12')	2 - 4	5.5	25.6
RBH-25	2.71	2.82	RB14-1	RB14-1 (8'-10')	4 - 6	6.1	24.9
RBH-25	2.71	2.82	RB14-1	RB14-1 (6'-8')	6 - 8	10.8	29.5
RBH-25	2.71	2.82	RB14-1	RB14-1 (4'-6')	8 - 10	7.5	18.1
RBH-25	2.71	2.82	RB14-1	RB14-1 (2'-4')	10 - 12	1.6	13.9
RBH-25	2.71	2.82	RB14-1	RB14-1 (0'-2')	12 - 14	5.8	19.7
RBH-25	2.71	2.82	RB14-2	RB14-2 (12'-14')	0 - 2	4.9	27.2
RBH-25	2.71	2.82	RB14-2	RB14-2 (10'-12')	2 - 4	7.5	24.5
RBH-25	2.71	2.82	RB14-2	RB14-2 (8'-10')	4 - 6	6.5	20.5
RBH-25	2.71	2.82	RB14-2	RB14-2 (6'-8')	6 - 8	8.6	24.0
RBH-25	2.71	2.82	RB14-2	RB14-2 (4'-6')	8 - 10	6.8	19.1
RBH-25	2.71	2.82	RB14-2	RB14-2 (2'-4')	10 - 12	5.0	18.5

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-25	2.71	2.82	RB14-2	RB14-2 (0'-2')	12 - 14	2.2	18.1
RBH-25	2.71	2.82	RB14-3	RB14-3 (6.4'-8')	0 - 1.6	8.5	24.7
RBH-25	2.71	2.82	RB14-3	RB14-3 (4.8'-6.4')	1.6 - 3.2	9.8	25.2
RBH-25	2.71	2.82	RB14-3	RB14-3 (3.2'-4.8')	3.2 - 4.8	16.9	23.5
RBH-25	2.71	2.82	RB14-3	RB14-3 (1.6'-3.2')	4.8 - 6.4	26.0	23.8
RBH-25	2.71	2.82	RB14-3	RB14-3 (0'-1.6')	6.4 - 8	246.0	30.9
RBH-25	2.71	2.82	RB15-1	RB15-1 (8'-10')	0 - 2	9.9	32.5
RBH-25	2.71	2.82	RB15-1	RB15-1 (6'-8')	2 - 4	12.4	26.6
RBH-25	2.71	2.82	RB15-1	RB15-1 (4'-6')	4 - 6	7.6	22.8
RBH-25	2.71	2.82	RB15-1	RB15-1 (2'-4')	6 - 8	8.3	24.6
RBH-25	2.71	2.82	RB15-1	RB15-1 (0'-2')	8 - 10	10.9	35.5
RBH-26	2.82	2.90	RB16-1	RB16-1 (10'-12')	0 - 2	8.9	28.1
RBH-26	2.82	2.90	RB16-1	RB16-1 (8'-10')	2 - 4	15.8	19.0
RBH-26	2.82	2.90	RB16-1	RB16-1 (6'-8')	4 - 6	14.3	18.3
RBH-26	2.82	2.90	RB16-1	RB16-1 (4'-6')	6 - 8	53.6	21.5
RBH-26	2.82	2.90	RB16-1	RB16-1 (2'-4')	8 - 10	274.0	27.9
RBH-26	2.82	2.90	RB16-1	RB16-1 (0'-2')	10 - 12	176.0	29.1
RBH-26	2.82	2.90	RB16-2	RB16-2 (5.6'-7')	0 - 1.4	11.3	22.0
RBH-26	2.82	2.90	RB16-2	RB16-2 (4.2'-5.6')	1.4 - 2.8	8.8	15.2
RBH-26	2.82	2.90	RB16-2	RB16-2 (2.8'-4.2')	2.8 - 4.2	8.7	14.4
RBH-26	2.82	2.90	RB16-2	RB16-2 (1.4'-2.8')	4.2 - 5.6	13.7	21.2
RBH-26	2.82	2.90	RB16-2	RB16-2 (0'-1.4')	5.6 - 7	22.7	32.7
RBH-26	2.82	2.90	RB16-3	RB16-3 (10'-12')	0 - 2	8.4	24.2
RBH-26	2.82	2.90	RB16-3	RB16-3 (8'-10')	2 - 4	7.0	17.4
RBH-26	2.82	2.90	RB16-3	RB16-3 (6'-8')	4 - 6	10.5	23.5
RBH-26	2.82	2.90	RB16-3	RB16-3 (4'-6')	6 - 8	10.7	33.4
RBH-26	2.82	2.90	RB16-3	RB16-3 (2'-4')	8 - 10	7.5	31.3
RBH-26	2.82	2.90	RB16-3	RB16-3 (0'-2')	10 - 12	9.3	29.0
RBH-28	3.07	3.16	RB17-1	RB17-1 (22'-24')	0 - 2	4.8	14.3
RBH-28	3.07	3.16	RB17-1	RB17-1 (20'-22')	2 - 4	4.9	15.6
RBH-28	3.07	3.16	RB17-1	RB17-1 (18'-20')	4 - 6	6.6	27.2
RBH-28	3.07	3.16	RB17-1	RB17-1 (16'-18')	6 - 8	9.0	25.5
RBH-28	3.07	3.16	RB17-1	RB17-1 (14'-16')	8 - 10	6.2	20.7
RBH-28	3.07	3.16	RB17-1	RB17-1 (12'-14')	10 - 12	6.7	23.0
RBH-28	3.07	3.16	RB17-1	RB17-1 (10'-12')	12 - 14	7.0	22.0
RBH-28	3.07	3.16	RB17-1	RB17-1 (8'-10')	14 - 16	7.8	21.4
RBH-28	3.07	3.16	RB17-1	RB17-1 (6'-8')	16 - 18	5.1	19.9
RBH-28	3.07	3.16	RB17-1	RB17-1 (4'-6')	18 - 20	2.8	11.4
RBH-28	3.07	3.16	RB17-1	RB17-1 (2'-4')	20 - 22	4.7	28.1
RBH-28	3.07	3.16	RB17-1	RB17-1 (0'-2')	22 - 24	7.6	34.5
RBH-28	3.07	3.16	RB17-2	RB17-2 (22'-24')	0 - 2	7.1	17.3
RBH-28	3.07	3.16	RB17-2	RB17-2 (20'-22')	2 - 4	8.2	18.5
RBH-28	3.07	3.16	RB17-2	RB17-2 (18'-20')	4 - 6	7.1	19.5
RBH-28	3.07	3.16	RB17-2	RB17-2 (16'-18')	6 - 8	4.1	13.1
RBH-28	3.07	3.16	RB17-2	RB17-2 (14'-16')	8 - 10	6.8	24.1
RBH-28	3.07	3.16	RB17-2	RB17-2 (12'-14')	10 - 12	7.9	24.1
RBH-28	3.07	3.16	RB17-2	RB17-2 (10'-12')	12 - 14	4.0	9.7
RBH-28	3.07	3.16	RB17-2	RB17-2 (8'-10')	14 - 16	4.4	13.5
RBH-28	3.07	3.16	RB17-2	RB17-2 (6'-8')	16 - 18	5.4	12.9
RBH-28	3.07	3.16	RB17-2	RB17-2 (4'-6')	18 - 20	4.2	12.3
RBH-28	3.07	3.16	RB17-2	RB17-2 (2'-4')	20 - 22	3.3	7.6
RBH-28	3.07	3.16	RB17-2	RB17-2 (0'-2')	22 - 24	4.5	26.3
RBH-28	3.07	3.16	RB18-1	RB18-1 (6.4'-8')	0 - 1.6	23.5	19.0

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-28	3.07	3.16	RB18-1	RB18-1 (4.8'-6.4')	1.6 - 3.2	40.6	17.1
RBH-28	3.07	3.16	RB18-1	RB18-1 (3.2'-4.8')	3.2 - 4.8	26.8	14.8
RBH-28	3.07	3.16	RB18-1	RB18-1 (1.6'-3.2')	4.8 - 6.4	29.6	19.6
RBH-28	3.07	3.16	RB18-1	RB18-1 (0'-1.6')	6.4 - 8	23.7	20.4
RBH-29	3.16	3.36	RB18-2	RB18-2 (6.4'-8')	0 - 1.6	7.9	23.4
RBH-29	3.16	3.36	RB18-2	RB18-2 (4.8'-6.4')	1.6 - 3.2	5.4	19.5
RBH-29	3.16	3.36	RB18-2	RB18-2 (3.2'-4.8')	3.2 - 4.8	0.91	11.7
RBH-29	3.16	3.36	RB18-2	RB18-2 (1.6'-3.2')	4.8 - 6.4	6.3	23.5
RBH-29	3.16	3.36	RB18-2	RB18-2 (0'-1.6')	6.4 - 8	3.6	21.8
RBH-29	3.16	3.36	RB19-1	RB19-1 (6.4'-8')	0 - 1.6	17.9	24.0
RBH-29	3.16	3.36	RB19-1	RB19-1 (4.8'-6.4')	1.6 - 3.2	25.8	21.2
RBH-29	3.16	3.36	RB19-1	RB19-1 (3.2'-4.8')	3.2 - 4.8	1.6	19.8
RBH-29	3.16	3.36	RB19-1	RB19-1 (1.6'-3.2')	4.8 - 6.4	2.1	21.1
RBH-29	3.16	3.36	RB19-1	RB19-1 (0'-1.6')	6.4 - 8	3.2	21.8
RBH-30	3.36	3.45	RB19-2	RB19-2 (8'-10')	0 - 2	16.2	29.3
RBH-30	3.36	3.45	RB19-2	RB19-2 (6'-8')	2 - 4	13.8	30.4
RBH-30	3.36	3.45	RB19-2	RB19-2 (4'-6')	4 - 6	11.9	26.2
RBH-30	3.36	3.45	RB19-2	RB19-2 (2'-4')	6 - 8	8.0	19.5
RBH-30	3.36	3.45	RB19-2	RB19-2 (0'-2')	8 - 10	9.7	25.6
RBH-30	3.36	3.45	RB19-3	RB19-3 (12'-14')	0 - 2	7.1	19.5
RBH-30	3.36	3.45	RB19-3	RB19-3 (10'-12')	2 - 4	7.1	24.4
RBH-30	3.36	3.45	RB19-3	RB19-3 (8'-10')	4 - 6	6.6	19.0
RBH-30	3.36	3.45	RB19-3	RB19-3 (6'-8')	6 - 8	6.5	19.5
RBH-30	3.36	3.45	RB19-3	RB19-3 (4'-6')	8 - 10	12.7	21.3
RBH-30	3.36	3.45	RB19-3	RB19-3 (2'-4')	10 - 12	9.5	23.4
RBH-30	3.36	3.45	RB19-3	RB19-3 (0'-2')	12 - 14	13.7	26.7
RBH-30	3.36	3.45	RB19-4	RB19-4 (12'-14')	0 - 2	8.7	23.0
RBH-30	3.36	3.45	RB19-4	RB19-4 (10'-12')	2 - 4	10.9	20.7
RBH-30	3.36	3.45	RB19-4	RB19-4 (8'-10')	4 - 6	12.0	22.0
RBH-30	3.36	3.45	RB19-4	RB19-4 (6'-8')	6 - 8	11.3	21.5
RBH-30	3.36	3.45	RB19-4	RB19-4 (4'-6')	8 - 10	17.0	24.6
RBH-30	3.36	3.45	RB19-4	RB19-4 (2'-4')	10 - 12	15.5	21.5
RBH-30	3.36	3.45	RB19-4	RB19-4 (0'-2')	12 - 14	14.6	24.6
RBH-32	3.53	3.69	RB20-1	RB20-1 (4'-5')	0 - 1	0.11	24.3
RBH-32	3.53	3.69	RB20-1	RB20-1 (3'-4')	1 - 2	0.17	23.1
RBH-32	3.53	3.69	RB20-1	RB20-1 (2'-3')	2 - 3	0.03	22.1
RBH-32	3.53	3.69	RB20-1	RB20-1 (1'-2')	3 - 4	0.04	23.0
RBH-32	3.53	3.69	RB20-1	RB20-1 (0'-1')	4 - 5	0.04	26.0
RBH-32	3.53	3.69	RB21-1	RB21-1 (3'-4')	0 - 1	0.02	22.5
RBH-32	3.53	3.69	RB21-1	RB21-1 (2'-3')	1 - 2	0.13	21.4
RBH-32	3.53	3.69	RB21-1	RB21-1 (1'-2')	2 - 3	0.08	23.7
RBH-32	3.53	3.69	RB21-1	RB21-1 (0'-1')	3 - 4	0.09	28.4
RBH-32	3.53	3.69	RB21-2	RB21-2 (6.4'-8')	0 - 1.6	0.06	21.0
RBH-32	3.53	3.69	RB21-2	RB21-2 (4.8'-6.4')	1.6 - 3.2	0.02	20.6
RBH-32	3.53	3.69	RB21-2	RB21-2 (3.2'-4.8')	3.2 - 4.8	1.7	28.7
RBH-32	3.53	3.69	RB21-2	RB21-2 (1.6'-3.2')	4.8 - 6.4	1.5	33.8
RBH-32	3.53	3.69	RB21-2	RB21-2 (0'-1.6')	6.4 - 8	2.9	40.3
RBH-32	3.53	3.69	RB22-1	RB22-1 (4'-5')	0 - 1	0.33	22.0
RBH-32	3.53	3.69	RB22-1	RB22-1 (3'-4')	1 - 2	3.9	23.0
RBH-32	3.53	3.69	RB22-1	RB22-1 (2'-3')	2 - 3	0.88	24.1
RBH-32	3.53	3.69	RB22-1	RB22-1 (1'-2')	3 - 4	1.4	24.7
RBH-32	3.53	3.69	RB22-1	RB22-1 (0'-1')	4 - 5	2.8	35.6
RBH-32	3.53	3.69	RB22-2	RB22-2 (4.8'-6')	0 - 1.2	0.29	17.7

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-32	3.53	3.69	RB22-2	RB22-2 (3.6'-4.8')	1.2 - 2.4	0.56	20.4
RBH-32	3.53	3.69	RB22-2	RB22-2 (2.4'-3.6')	2.4 - 3.6	0.38	21.1
RBH-32	3.53	3.69	RB22-2	RB22-2 (1.2'-2.4')	3.6 - 4.8	0.24	27.1
RBH-32	3.53	3.69	RB22-2	RB22-2 (0'-1.2')	4.8 - 6	0.62	28.3
RBH-33	3.69	3.80	RB23-1	RB23-1 (8'-10')	0 - 2	11.1	28.3
RBH-33	3.69	3.80	RB23-1	RB23-1 (6'-8')	2 - 4	7.1	25.1
RBH-33	3.69	3.80	RB23-1	RB23-1 (4'-6')	4 - 6	7.1	25.7
RBH-33	3.69	3.80	RB23-1	RB23-1 (2'-4')	6 - 8	7.8	26.1
RBH-33	3.69	3.80	RB23-1	RB23-1 (0'-2')	8 - 10	7.2	33.4
RBH-33	3.69	3.80	RB23-2	RB23-2 (10'-12')	0 - 2	5.2	23.7
RBH-33	3.69	3.80	RB23-2	RB23-2 (8'-10')	2 - 4	11.3	24.2
RBH-33	3.69	3.80	RB23-2	RB23-2 (6'-8')	4 - 6	7.4	22.7
RBH-33	3.69	3.80	RB23-2	RB23-2 (4'-6')	6 - 8	14.7	24.8
RBH-33	3.69	3.80	RB23-2	RB23-2 (2'-4')	8 - 10	30.3	32.7
RBH-33	3.69	3.80	RB23-2	RB23-2 (0'-2')	10 - 12	12.1	33.8
RBH-34	3.80	3.91	RB24-1	RB24-1 (10'-12')	0 - 2	23.9	29.8
RBH-34	3.80	3.91	RB24-1	RB24-1 (8'-10')	2 - 4	14.5	25.5
RBH-34	3.80	3.91	RB24-1	RB24-1 (6'-8')	4 - 6	25.3	28.2
RBH-34	3.80	3.91	RB24-1	RB24-1 (4'-6')	6 - 8	14.8	25.5
RBH-34	3.80	3.91	RB24-1	RB24-1 (2'-4')	8 - 10	19.4	16.6
RBH-34	3.80	3.91	RB24-1	RB24-1 (0'-2')	10 - 12	41.3	24.0
RBH-34	3.80	3.91	RB24-2	RB24-2 (10'-12')	0 - 2	11.5	27.5
RBH-34	3.80	3.91	RB24-2	RB24-2 (8'-10')	2 - 4	15.4	26.9
RBH-34	3.80	3.91	RB24-2	RB24-2 (6'-8')	4 - 6	11.4	27.3
RBH-34	3.80	3.91	RB24-2	RB24-2 (4'-6')	6 - 8	15.9	26.2
RBH-34	3.80	3.91	RB24-2	RB24-2 (2'-4')	8 - 10	27.1	25.9
RBH-34	3.80	3.91	RB24-2	RB24-2 (0'-2')	10 - 12	18.7	27.4
RBH-34	3.80	3.91	RB24-3	RB24-3 (8'-10')	0 - 2	11.1	30.1
RBH-34	3.80	3.91	RB24-3	RB24-3 (6'-8')	2 - 4	28.2	24.7
RBH-34	3.80	3.91	RB24-3	RB24-3 (4'-6')	4 - 6	53.3	21.8
RBH-34	3.80	3.91	RB24-3	RB24-3 (2'-4')	6 - 8	77.5	26.4
RBH-34	3.80	3.91	RB24-3	RB24-3 (0'-2')	8 - 10	37.4	28.0
RBH-34	3.80	3.91	RB25-1	RB25-1 (14'-16')	0 - 2	8.9	19.9
RBH-34	3.80	3.91	RB25-1	RB25-1 (12'-14')	2 - 4	7.1	18.3
RBH-34	3.80	3.91	RB25-1	RB25-1 (10'-12')	4 - 6	10.2	19.2
RBH-34	3.80	3.91	RB25-1	RB25-1 (8'-10')	6 - 8	15.2	24.9
RBH-34	3.80	3.91	RB25-1	RB25-1 (6'-8')	8 - 10	6.0	27.0
RBH-34	3.80	3.91	RB25-1	RB25-1 (4'-6')	10 - 12	10.8	35.9
RBH-34	3.80	3.91	RB25-1	RB25-1 (2'-4')	12 - 14	4.9	32.9
RBH-34	3.80	3.91	RB25-1	RB25-1 (0'-2')	14 - 16	5.9	31.1
RBH-34	3.80	3.91	RB25-2	RB25-2 (18'-20')	0 - 2	48.1	30.3
RBH-34	3.80	3.91	RB25-2	RB25-2 (16'-18')	2 - 4	39.5	30.0
RBH-34	3.80	3.91	RB25-2	RB25-2 (14'-16')	4 - 6	31.9	32.0
RBH-34	3.80	3.91	RB25-2	RB25-2 (12'-14')	6 - 8	29.7	31.5
RBH-34	3.80	3.91	RB25-2	RB25-2 (10'-12')	8 - 10	22.7	30.3
RBH-34	3.80	3.91	RB25-2	RB25-2 (8'-10')	10 - 12	20.6	36.8
RBH-34	3.80	3.91	RB25-2	RB25-2 (6'-8')	12 - 14	21.1	41.5
RBH-34	3.80	3.91	RB25-2	RB25-2 (4'-6')	14 - 16	20.6	43.9
RBH-34	3.80	3.91	RB25-2	RB25-2 (2'-4')	16 - 18	14.5	41.6
RBH-34	3.80	3.91	RB25-2	RB25-2 (0'-2')	18 - 20	13.1	34.0
RBH-37	4.04	4.14	RB26-1	RB26-1 (8'-10')	0 - 2	10.8	22.8
RBH-37	4.04	4.14	RB26-1	RB26-1 (6'-8')	2 - 4	11.1	21.8
RBH-37	4.04	4.14	RB26-1	RB26-1 (4'-6')	4 - 6	8.6	22.1

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2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-37	4.04	4.14	RB26-1	RB26-1 (2'-4')	6 - 8	9.7	24.4
RBH-37	4.04	4.14	RB26-1	RB26-1 (0'-2')	8 - 10	5.7	26.6
RBH-38	4.14	4.39	RB27-1	RB27-1 (6.4'-8')	0 - 1.6	10.0	9.4
RBH-38	4.14	4.39	RB27-1	RB27-1 (4.8'-6.4')	1.6 - 3.2	3.3	11.1
RBH-38	4.14	4.39	RB27-1	RB27-1 (3.2'-4.8')	3.2 - 4.8	0.30	5.4
RBH-38	4.14	4.39	RB27-1	RB27-1 (1.6'-3.2')	4.8 - 6.4	0.89	11.4
RBH-38	4.14	4.39	RB27-1	RB27-1 (0'-1.6')	6.4 - 8	1.8	19.4
RBH-38	4.14	4.39	RB27-2	RB27-2 (10'-12')	0 - 2	6.7	8.6
RBH-38	4.14	4.39	RB27-2	RB27-2 (8'-10')	2 - 4	6.9	10.2
RBH-38	4.14	4.39	RB27-2	RB27-2 (6'-8')	4 - 6	8.4	13.0
RBH-38	4.14	4.39	RB27-2	RB27-2 (4'-6')	6 - 8	7.4	12.0
RBH-38	4.14	4.39	RB27-2	RB27-2 (2'-4')	8 - 10	7.3	19.8
RBH-38	4.14	4.39	RB27-2	RB27-2 (0'-2')	10 - 12	14.8	24.8
RBH-38	4.14	4.39	RB27-3	RB27-3 (22'-24')	0 - 2	3.2	15.1
RBH-38	4.14	4.39	RB27-3	RB27-3 (20'-22')	2 - 4	3.3	10.9
RBH-38	4.14	4.39	RB27-3	RB27-3 (18'-20')	4 - 6	3.6	13.6
RBH-38	4.14	4.39	RB27-3	RB27-3 (16'-18')	6 - 8	4.1	13.0
RBH-38	4.14	4.39	RB27-3	RB27-3 (14'-16')	8 - 10	3.6	11.0
RBH-38	4.14	4.39	RB27-3	RB27-3 (12'-14')	10 - 12	6.8	14.9
RBH-38	4.14	4.39	RB27-3	RB27-3 (10'-12')	12 - 14	6.2	15.6
RBH-38	4.14	4.39	RB27-3	RB27-3 (8'-10')	14 - 16	8.5	16.4
RBH-38	4.14	4.39	RB27-3	RB27-3 (6'-8')	16 - 18	8.6	17.5
RBH-38	4.14	4.39	RB27-3	RB27-3 (4'-6')	18 - 20	15.0	27.2
RBH-38	4.14	4.39	RB27-3	RB27-3 (2'-4')	20 - 22	3.8	22.4
RBH-38	4.14	4.39	RB27-3	RB27-3 (0'-2')	22 - 24	2.1	16.7
RBH-38	4.14	4.39	RB27-4	RB27-4 (12'-14')	0 - 2	485.0	21.0
RBH-38	4.14	4.39	RB27-4	RB27-4 (10'-12')	2 - 4	57.2	17.7
RBH-38	4.14	4.39	RB27-4	RB27-4 (8'-10')	4 - 6	18.9	26.3
RBH-38	4.14	4.39	RB27-4	RB27-4 (6'-8')	6 - 8	5.9	13.1
RBH-38	4.14	4.39	RB27-4	RB27-4 (4'-6')	8 - 10	7.7	17.8
RBH-38	4.14	4.39	RB27-4	RB27-4 (2'-4')	10 - 12	6.8	32.1
RBH-38	4.14	4.39	RB27-4	RB27-4 (0'-2')	12 - 14	6.3	27.4
RBH-39	4.39	4.71	RB28-1	RB28-1 (6.4'-8')	0 - 1.6	10.8	22.6
RBH-39	4.39	4.71	RB28-1	RB28-1 (4.8'-6.4')	1.6 - 3.2	19.0	23.7
RBH-39	4.39	4.71	RB28-1	RB28-1 (3.2'-4.8')	3.2 - 4.8	42.4	22.1
RBH-39	4.39	4.71	RB28-1	RB28-1 (1.6'-3.2')	4.8 - 6.4	6.3	21.2
RBH-39	4.39	4.71	RB28-1	RB28-1 (0'-1.6')	6.4 - 8	0.18	12.5
RBH-39	4.39	4.71	RB28-2	RB28-2 (14'-16')	0 - 2	2.6	18.4
RBH-39	4.39	4.71	RB28-2	RB28-2 (12'-14')	2 - 4	5.0	23.1
RBH-39	4.39	4.71	RB28-2	RB28-2 (10'-12')	4 - 6	8.1	25.4
RBH-39	4.39	4.71	RB28-2	RB28-2 (8'-10')	6 - 8	7.9	23.4
RBH-39	4.39	4.71	RB28-2	RB28-2 (6'-8')	8 - 10	8.9	24.4
RBH-39	4.39	4.71	RB28-2	RB28-2 (4'-6')	10 - 12	13.8	27.3
RBH-39	4.39	4.71	RB28-2	RB28-2 (2'-4')	12 - 14	10.5	28.4
RBH-39	4.39	4.71	RB28-2	RB28-2 (0'-2')	14 - 16	17.4	39.1
RBH-39	4.39	4.71	RB28-3	RB28-3 (18'-20')	0 - 2	3.0	19.5
RBH-39	4.39	4.71	RB28-3	RB28-3 (16'-18')	2 - 4	3.2	21.3
RBH-39	4.39	4.71	RB28-3	RB28-3 (14'-16')	4 - 6	0.62	23.1
RBH-39	4.39	4.71	RB28-3	RB28-3 (12'-14')	6 - 8	0.31	25.8
RBH-39	4.39	4.71	RB28-3	RB28-3 (10'-12')	8 - 10	1.5	22.7
RBH-39	4.39	4.71	RB28-3	RB28-3 (8'-10')	10 - 12	3.6	27.8
RBH-39	4.39	4.71	RB28-3	RB28-3 (6'-8')	12 - 14	5.6	37.6
RBH-39	4.39	4.71	RB28-3	RB28-3 (4'-6')	14 - 16	9.4	36.4

Table C-1
2012 and 2013 Bank Sampling Data

Station	RRM Start	RRM End	Transect ID	Sample ID	Bank Interval (feet below top of bank)	THG (mg/kg)	Percent Moisture
RBH-39	4.39	4.71	RB28-3	RB28-3 (2'-4')	16 - 18	11.4	45.7
RBH-39	4.39	4.71	RB28-3	RB28-3 (0'-2')	18 - 20	10.3	48.9
RBH-39	4.39	4.71	RB28-4	RB28-4 (10'-12')	0 - 2	6.6	31.6
RBH-39	4.39	4.71	RB28-4	RB28-4 (8'-10')	2 - 4	12.7	33.0
RBH-39	4.39	4.71	RB28-4	RB28-4 (6'-8')	4 - 6	142.0	25.7
RBH-39	4.39	4.71	RB28-4	RB28-4 (4'-6')	6 - 8	64.9	31.7
RBH-39	4.39	4.71	RB28-4	RB28-4 (2'-4')	8 - 10	28.1	38.3
RBH-39	4.39	4.71	RB28-4	RB28-4 (0'-2')	10 - 12	17.5	46.2
RBH-40	4.71	4.83	RB29-1	RB29-1 (4'-5')	0 - 1	0.09	11.2
RBH-40	4.71	4.83	RB29-1	RB29-1 (3'-4')	1 - 2	0.05	10.0
RBH-40	4.71	4.83	RB29-1	RB29-1 (2'-3')	2 - 3	0.04	13.6
RBH-40	4.71	4.83	RB29-1	RB29-1 (1'-2')	3 - 4	0.93	24.2
RBH-40	4.71	4.83	RB29-1	RB29-1 (0'-1')	4 - 5	1.7	31.9
RBH-40	4.71	4.83	RB29-2	RB29-2 (18'-20')	0 - 2	0.83	20.8
RBH-40	4.71	4.83	RB29-2	RB29-2 (16'-18')	2 - 4	1.7	20.8
RBH-40	4.71	4.83	RB29-2	RB29-2 (14'-16')	4 - 6	0.70	20.0
RBH-40	4.71	4.83	RB29-2	RB29-2 (12'-14')	6 - 8	1.3	23.9
RBH-40	4.71	4.83	RB29-2	RB29-2 (10'-12')	8 - 10	2.3	24.3
RBH-40	4.71	4.83	RB29-2	RB29-2 (8'-10')	10 - 12	3.9	31.5
RBH-40	4.71	4.83	RB29-2	RB29-2 (6'-8')	12 - 14	1.1	19.4
RBH-40	4.71	4.83	RB29-2	RB29-2 (4'-6')	14 - 16	0.43	19.3
RBH-40	4.71	4.83	RB29-2	RB29-2 (2'-4')	16 - 18	0.22	18.0
RBH-40	4.71	4.83	RB29-2	RB29-2 (0'-2')	18 - 20	0.09	16.9
RBH-40	4.71	4.83	RB29-3	RB29-3 (4'-5')	0 - 1	2.5	39.5
RBH-40	4.71	4.83	RB29-3	RB29-3 (3'-4')	1 - 2	4.8	35.9
RBH-40	4.71	4.83	RB29-3	RB29-3 (2'-3')	2 - 3	3.1	38.8
RBH-40	4.71	4.83	RB29-3	RB29-3 (1'-2')	3 - 4	3.2	39.5
RBH-40	4.71	4.83	RB29-3	RB29-3 (0'-1')	4 - 5	3.7	39.0
RBH-41	4.83	4.94	RB30-1	RB30-1 (4'-5')	0 - 1	20.9	23.8
RBH-41	4.83	4.94	RB30-1	RB30-1 (3'-4')	1 - 2	32.3	14.5
RBH-41	4.83	4.94	RB30-1	RB30-1 (2'-3')	2 - 3	2.4	21.7
RBH-41	4.83	4.94	RB30-1	RB30-1 (1'-2')	3 - 4	8.0	28.9
RBH-41	4.83	4.94	RB30-1	RB30-1 (0'-1')	4 - 5	15.8	34.5
RBH-41	4.83	4.94	RB30-2	RB30-2 (5.6'-7')	0 - 1.4	8.7	27.9
RBH-41	4.83	4.94	RB30-2	RB30-2 (4.2'-5.6')	1.4 - 2.8	10.0	29.2
RBH-41	4.83	4.94	RB30-2	RB30-2 (2.8'-4.2')	2.8 - 4.2	15.4	30.0
RBH-41	4.83	4.94	RB30-2	RB30-2 (1.4'-2.8')	4.2 - 5.6	72.1	31.2
RBH-41	4.83	4.94	RB30-2	RB30-2 (0'-1.4')	5.6 - 7	8.8	38.9

APPENDIX D
MONITORING PROTOCOLS

South River Remediation Proposal
List of Protocols

SRAT-1	Biological Sampling Guidelines for Avian Tissue Analysis
SRBC-1	Biological Sampling Guidelines for Riparian, Wetland, and Aquatic Vegetation Community Assessment
SRBF-1	Biological Sampling Guidelines for Fish Tissue Analysis
SRBI-1	Biological Sampling Guidelines for Clam (*Corbicula*) Tissue Collection
SRBI-2	Biological Sampling Guidelines for Aquatic Macroinvertebrate Tissue Collection
SRBI-3	Guidelines for Macroinvertebrate Community Sampling and Laboratory Analyses
SRBS-1	Biological Sampling Guidelines for Spider Tissue Analysis
SRDA-1	Data Analysis for the Long-Term Monitoring Plan
SRET-1	Biological Sampling Guidelines for Earthworm Tissue Collection
SRSE-1	Guidelines for Sampling Size-Classified Sediments Using a Beckson pump
SRSE-2	Guidelines for Sampling Sediment Deposits
SRSW-1	Guidelines for Sampling Water Using a Diaphragm Pump
SRTI-1	Biological Sampling Guidelines for Aquatic Vegetation Tissue Collection
SRTR-1	Baseline and Performance Monitoring at Transects

Protocol SRAT-1
Biological Sampling Guidelines for Avian Tissue Analysis

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

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., tree swallow) potentially foraging in the South River watershed.

Equipment

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

- Nest boxes
- Mist nets, or other avian nets or traps
- Trowels
- 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

Samples of avian blood for THg analyses will be collected from tree swallows using two approaches, listed below:

- Nest box sampling: Preferred sampling approach establishes nesting habitat where adult birds can be captured and sampled during the nesting period when foraging range is most restricted; and
- Mist net sampling: Contingency sampling approach that involves the deployment of nylon mist nets to capture birds if an adequate sample size cannot be captured during nest box sampling.

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.

Nest Box Sampling

Nest boxes will be placed along the South River shoreline, and that of a reference river, 25 – 50 meters apart with entrance holes oriented toward the river. Potential nest box locations will be selected to avoid areas of known disturbance, including houses with minimal buffer area along the shoreline, boat launches, docks, and fishing areas. The selection of locations will be determined in the field based on local site conditions and accessibility. The position of installed nest boxes will be recorded using a geographical positioning system (GPS) unit with sub-meter accuracy.

Nest boxes will be monitored on a weekly basis in the spring to evaluate adult activity and the nesting cycle. In June, monitoring will be increased to every three to four days. Adult birds will not be captured for blood sampling until all eggs have hatched or it is determined the un-hatched egg(s) are not viable.

The primary collection method will be to temporarily capture each adult tree swallow at their respective nest box. Adult female tree swallow will be targeted preferentially for blood sampling; however, adult male birds will also be sampled if captured. Several standard methods for capture will be used including a temporary trap door (Friedman et al., 2008), small net, and towel. Captured birds will be briefly placed into a standard avian holding bag for weighing; a small towel will be used to handle the bird after release from the holding bag. One bird will be captured, processed (data collection and blood sample collection), and released at a time; no

birds will be kept in holding pens or closed containers to avoid stress. Each bird will be processed and released in the immediate vicinity of the nest box from which it is collected.

Mist Net Sampling

Mist net sampling may be used as a contingency sampling approach to supplement the nest box sampling if the target number of tree swallows cannot be collected from nest boxes. Mist net sampling may also be considered if additional target species are identified for collection.

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 URS 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.

URS 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.

1.0 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 SRBC-1:
Biological Sampling Guidelines for
Riparian, Wetland, and Aquatic Vegetation Community Assessment

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

Phase I Scope of Work Summary

Baseline vegetation assessments will be conducted to characterize habitat types along the study and reference areas. A combination of aerial photo interpretation and field surveys will be used to identify vegetation community structures for each habitat type and ultimately generate the following information:

- Riparian vegetation habitat type maps along the study and reference areas
- Wetland type maps (both floodplain and in-stream wetland features) and wetland type and overall acreage inundated by various categories of storm events along the floodplain in the study area
- Aquatic vegetation maps depicting relative coverage along the study area and reference areas
- Vegetation species list for riparian, wetland, and aquatic habitat types

The initial assessment will be performed using aerial photographs. Major vegetation types in the riparian zone (e.g., forest, shrub/scrub, agricultural vegetation) will be delineated using GIS. A survey to ground truth these habitats and develop a species list for each habitat type will be conducted at the descriptive sampling stations. Habitat types will be field verified by trained ecologists using a quadrat sampling. The survey of riparian and aquatic vegetation communities will assess the quality/complexity of riparian vegetation, as well the spatial coverage of aquatic vegetation in the study and reference areas. The field survey will be conducted in late summer at the presumed maximum extent of coverage.

RIPARIAN, WETLAND, AND AQUATIC VEGETATION COMMUNITY SAMPLING GUIDELINES

This method describes the baseline vegetation assessments that will be conducted to characterize habitat types along the study and reference areas. The method is based on the US Army Corps of Engineers *Wetlands Delineation Manual* (USACE 1987).

Equipment

The following equipment/supplies may be used to conduct the riparian, wetland, and aquatic vegetation community field surveys:

- Boat and motor
- Field notebook/data sheets
- Pencils and waterproof and permanent marking pens
- Sampling location maps
- GPS unit
- Camera
- Species reference guides, as necessary
- Appropriate health and safety equipment

Initial Aerial Photograph Assessment

For the initial riparian, wetland and aquatic vegetation community assessments, aerial photographs and map interpretation will be used to generate the following information:

- Riparian corridor vegetation characterization and cover type maps for the entire study and reference areas
- Wetland type characterization, maps (both floodplain and in-stream wetland features), and wetland type acreages inundated during various categories of storm flood events
- Aquatic vegetation characterization and maps depicting relative coverage along the study and reference areas

Using the Virginia Natural Heritage database and regional floras, a vegetation species list will be generated for riparian, wetland, and aquatic habitat types (VANHP, 2005).

Ground Truthing Procedures

A boat may be required to reach the designated sample locations. Health and safety procedures for conducting work over water are detailed in the health and safety plan and will be followed as a required component of the sampling.

The following procedures will be used during the riparian community ground truthing:

- Where possible given access restrictions, ground truthing will be conducted within the 100-year floodplain.
- Sampling locations will be selected based on accessibility.

- At each sample location, three vegetative strata will be assessed (trees, sapling/shrub, and herbaceous) using a nested approach.
- For trees, a 30-foot radius sample area will be evaluated.
- All trees [greater than 3-inch diameter at breast height (DBH)] will be identified and recorded on field data sheets.
- For saplings/shrubs, a 10-foot radius sample plot nested within the above 30-foot plot will be assessed.
- All saplings and shrubs will be identified and recorded on field data sheets. A sapling or shrub is any woody plant having a height over 3.2 feet and a stem diameter of less than 3.0 inches, exclusive of woody vines.
- For the herbaceous layer, a 1.64-foot radius nested sample plot will be evaluated from within the above 10-foot plot.
- All nonwoody and woody plants less than 3.2 feet will be identified and recorded as herbaceous species on field data sheets.

The following procedures will be used during the wetland community ground truthing:

- Trained wetland scientists will locate and evaluate wetland areas identified from wetland maps, soil surveys, and aerial photograph interpretation.
- Wetlands will be surveyed using the nested sample approach described above.
- Initial wetlands classification will be evaluated and revised in the field, as necessary.

The following procedures will be used during the aquatic vegetation community ground truthing:

- Trained aquatic biologists will float the length of the river completing a visual inspection of the aquatic coverage.
- Documentation will be made to estimate the aerial extent of coverage and the community species composition of these areas.
- Sufficient detail regarding the estimated coverage and extent of each aquatic vegetative community will be colleted to enable the mapping of this data in the project GIS database.

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.

References

USACE, Environmental Laboratory. 1987. *Corps of Engineers Wetlands Delineation Manual*. Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 100 pp.

VANHP. 2005. Online Information on Virginia's Natural Communities, Rare, Threatened & Endangered Animals and Plants [online]. Available from World Wide Web: (http://www.dcr.virginia.gov/dnh/nhrinfo.htm).

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

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

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

Before each sampling event, 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 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 the South River Science Team (SRST) Safety Program (SRST 2006).

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.

Non-Lethal Fish Tissue Analysis

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.
- Rinse fish tissue with DI water or distilled water to remove surface mucus.
- Dry fish tissue with Kimwipe or other lint-free wipe.
- 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.

For the following steps, a second person should be utilized in order to minimize time out of the water and stress on the fish.

- One person will remove the tissue plug from the dermal punch using clean forceps.
- The same person will 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 wet ice.
- The second person will apply wound dressing to the wound created by the dermal punch to minimize the potential for bacterial infection.
- Next, this person will insert a pre-recorded PIT tag from the scale envelope into the fish at just below the posterior insertion of the dorsal fin.
- The PIT tag number will be recorded on the field data sheet.

- The fish will then be released back into the stream.
- Decontaminate forceps and scalpel after every sample.
- Complete appropriate COC forms and ship overnight to the laboratory for processing and analysis.

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

Lethal Fish Tissue Analysis

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
- Rinse fish with deionized water or distilled water to remove surface mucus.
- Dry fish with Kimwipe or other lint-free wipe.
- Place selected fish in a plastic bag and place on dry ice.
- Decontaminate measuring board and tray for weighting after every sample.
- Complete appropriate COC forms and ship overnight to the laboratory for processing and analysis.
- The analytical laboratory will prepare the filet for analysis of total mercury (USEPA Method 1631) and methylmercury (USEPA Method 1630).

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.

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 Phase I system characterization. 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 (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 URS 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.

URS 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 SRST Safety Program (SRST 2006):

- 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.

Protocol SRBF-2:
Fish Population Study Guidelines

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

Fish 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 conduct the fish community surveys:

- Boat and motor
- Electrofishing equipment, including tote-barge electrofisher, boat electrofisher, and/or backpack electrofisher
- Block nets
- Insulated dip nets
- Insulated gloves
- Insulated chest waders
- Buckets for holding fish
- Live wells for holding fish during processing
- Measuring board
- Electronic scale
- Water quality meter
- Sample containers
- 70% reagent alcohol
- Field notebook/data sheets
- Pencils and waterproof and permanent marking pens
- Sampling location maps
- GPS unit
- 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 and an electrofisher. All equipment 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 URS personnel properly trained in these procedures, and calibration data will be documented in the field logbook data sheet. Electrofishing settings and output range during sampling will also be recorded.

Sample Collection Procedures

A boat may be required to reach the designated sample locations. Caution will be used when conducting sampling from the boat. Health and safety procedures for conducting the work over water are detailed in the health and safety plan. These procedures will be followed as a required component of the sampling.

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

- Using GPS and maps, confirm station location prior to sampling.
- Inspect the reach to determine if sampling from a boat will be required, and follow protocols outlined below for boat sampling if sections of the river are too deep to sample by wading.
- Set up block nets (where possible) if suitable natural blocks are not present.
- Wear polarized glasses to reduce surface glare while sampling (crewmembers only).

The following procedures will be used for tote-barge/backpack electrofishing:

- One or two netters will follow each anode/backpack and be responsible for collecting, transporting, and caring for fish obtained. The field crew leader will determine sampling reach based on field conditions.
- Each sampling reach will contain at least one, riffle-pool habitat unit.
- Starting with a shallow riffle or other suitable block, field teams will shock using pulsed DC (direct current) upstream and in a sweeping bank-to-bank manor to maximize area coverage.
- All wadeable habitats will be sampled via a minimum of a three-pass depletion approach. At least one hour between each pass with additional passes being required if sufficient reduction of target species is not obtained after three passes.
- Fish will be held in livewells or buckets for subsequent identification and enumeration.
- Block nets will be checked for additional stunned fish at the end of each shocking pass. Fish collected will be included for identification and enumeration.

The following procedures will be used for boat electrofisher:

- Using a boat electrofisher, one crew member will stand/sit in the bow of the boat and net stunned fish while the other crew member pilots the boat upstream in a sweeping bank-to-bank manner to sample all available habitats.
- Sampling will terminate at an upstream block, either natural or artificial.
- Fish will be held in livewells or buckets for subsequent identification and enumeration.

- Block nets will be checked for additional stunned fish at the end of the shocking pass. Fish collected will be included for identification and enumeration.

The following procedures will be used for fish data collection:

- All fish collected will be identified to species level and enumerated. Select fish (e.g. smallmouth bass, largemouth bass, and redbreast sunfish) will be measured and weighed, including age-0 fish for the bioaccumulation modeling effort. For the remaining species, a subsample of 25 individuals will be measured, weighed, and recorded on field data sheets.
- Samplers will record any morphological or histological abnormalities in the notes section of the data sheet.
- All fish will be returned to the water immediately downstream of the sampling reach and handled in a manor to avoid additional stress and physical harm. Any threatened or endangered species will be noted and released immediately. Any unidentifiable specimens collected during the study will be retained and preserved in 70% reagent alcohol.
- Water quality measurements will be collected and documented on the field sheets.
- In the field notebook/data sheets, information regarding the sample collection procedures must be recorded. This includes, but is not limited to, the method of fish capture, start time, end time, duration of sampling, maximum and mean stream widths, depth, substrate type, weather, and any other pertinent observations.

To the extent practical, consistent sampling techniques will be used among all sampling stations for consistency and comparability. However, if river sections are not wadeable, then community surveys will be performed using a boat electrofisher. It is also anticipated that a combination of these collection types may be necessary at various locations.

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.

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

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

Invertebrate clam (*Corbicula*) 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 clam tissue samples:

- Dip net
- 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
- Cyanoacrylate adhesive (Super Glue)
- 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 marking *Corbicula* that will be seeded:

- Dry *Corbicula* and remove any algae or detritus from the shell prior to marking
- Place a small dot of cyanoacrylate adhesive on the back of a color coded piece of plastic labeling tape or shellfish tag
- Immediately adhere the plastic label to the posterior edge of the *Corbicula* and press firmly for 5-10 seconds to ensure a secure bond.
- Check for a secure bond before placing in a water filled holding container
- Repeat the above steps using different color labeling tape for each location

The following procedures will be used for seeding *Corbicula*:

- Record seeding locations using GPS
- Place clams to be seeded within a marked area and record the number of clams seeded as well as tag color on field data sheets or field log.

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 and seeded clams:

- Locate seeded areas 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 which will be exchanged on a continual basis.
- Clams will be allowed to depurate for approximately 48 hours.
- After 48 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 Phase I system characterization. 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 URS 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.

URS 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

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

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
  - Emergence traps
  - Insect 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 deoionized (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.
- 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 which will be exchanged on a continual basis.

- 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 a subset of organisms will be measured and recorded on data sheets.
- 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.

The following procedures will be used when collecting adult aquatic insect tissue by passive emergence traps:

- Traps will be placed in habitats where target insects are likely to emerge.
- Traps will be anchored to the substrate with rebar pins.
- After a designated period of time has passed, traps will be checked and target insects will be separated into designated decontaminated containers.
- A subset of specimens will be measured for each taxa collected
- Organisms will be grouped into composited samples of 10 individuals each.
- Rinse specimens with DI or distilled water and blot using 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.
- In the field notebook/field data sheets, 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.

In the field notebook/field data sheets, note the type of sampler, depth, time of sampling, and relevant observations, including but not limited to weather, turbidity, approximate stream 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.

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 URS 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.

URS 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-3:
Guidelines for Macroinvertebrate
Community Sampling and Laboratory Analyses

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

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
- 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. 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

URS 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 health and safety plan. 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.

At each sampling location, three 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:

- Place a Surber sampler (500-µm mesh; sample area 1.0 ft^2) firmly on the substrate with the bag facing down stream.
- 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.
- Rinse the sampler with clean stream water, washing all organisms and debris into the back of the net.
- Sample two 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.
- Return samples to laboratory and complete log-in form.

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

URS 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 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.

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 possible 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

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

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.

Sampling will occur in study and reference areas along the South River. Whole body samples of spiders will be collected for the evaluation of mercury bioaccumulation in spiders. Ten (10) composite samples from each family will be targeted from each of the study and reference areas. Sampling will be performed in accordance with the conditions stated in applicable Virginia Department of Game and Inland Fisheries (VDGIF) scientific collection permit.

Equipment

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

- Boat and motor
- ☐ 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 in the riparian zone within 10 meters of the edge of the water. Traps will be set up in the early morning and monitored at least every four hours during the day. If necessary, traps will be left in place over night and checked the following morning until suitable numbers of spiders have been collected at each location.

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; 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.
- Every four hours, check traps for spiders. Remove spiders; place into sample containers and identify to family level.
- Record the number of spiders collected on field data sheets
- Place selected spiders in laboratory supplied containers and place on dry ice.
- Complete appropriate Chain-of-Custody forms and ship overnight to the laboratory for processing and analysis.

Procedures for collecting spiders using sweep nets:

- Locate site where sweep netting is to occur; the discretion of the Field Team leader will determine the exact sampling location.
- Visually scan overhanging vegetation for the presence of spiders. If present, capture using dip net and place into sample container.
- If no spiders can be visually located, attempt to beat vegetation to dislodge spiders and capture with dip net or sweep dip net through vegetation. Place all captured spiders into sample containers.
- Place selected spiders in laboratory supplied containers and place on dry ice.
- Record the number of spiders collected on field data sheets
- 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 URS 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.

URS 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 and MeHg

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
Periphyton	0.1 to 2.3	10	3	10	99	97	10
	5.2 to 11.8	10	3	10	100	99	12
	16 to 23.5	10	3	10	100	99	12
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
Earthworms	<0	10	3	5	65	76	89
	0.1 to 2.3	10	3	5	42	57	75
		10	3	10	100	100	100
	5.2 to 11.8	10	3	5	100	100	100
	16 to 23.5	10	3	5	63	75	88
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 SRET-1:
Biological Sampling Guidelines for
Earthworm Tissue Collection

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

Earthworm Tissue Sampling Procedures

Earthworm tissue sampling procedures for South River investigations are summarized in the following steps:

1. Collect soil at a depth interval 0 – 12 inches from subsample locations associated with composite soil sample locations.
2. Sort through the soil and remove approximately equal sample mass of earthworms from each subsample location.
3. Place specimens into sampling containers, freeze, and ship to the laboratory for analysis.

The detailed procedures for earthworm tissue collection are provided below.

Equipment

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

- ❑ Shovels, spade or hand trowel
- ❑ Tape measure
- ❑ Stainless steel sampling tools
- ❑ Stainless steel bowl
- ❑ Spade or shovel/Stainless steel trowel(s)
- ❑ Scale
- ❑ Sample bottles/vials and labels provided by the laboratory
- ❑ Sample container labels
- ❑ Distilled/deionized water
- ❑ Pencils and waterproof /permanent marking pens
- ❑ Ice chest, wet and dry ice
- ❑ Field notebook/field data sheets
- ❑ Chain-of-custody (COC) forms
- ❑ Custody seals
- ❑ Magnifying glass/hand lens
- ❑ Paper towels
- ❑ Lint-free wipes (Kimwipes or equivalent)
- ❑ Nitrile gloves
- ❑ Sampling location map
- ❑ Global positioning system (GPS)
- ❑ Camera
- ❑ 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. The following is a list of equipment/supplies that may be needed to perform decontamination:

- ❑ Decontamination supplies
- ❑ Brushes
- ❑ Wash tubs
- ❑ Buckets
- ❑ Sponges and paper towels
- ❑ Alconox
- ❑ Bleach
- ❑ Organic-free water DI or distilled water
- ❑ Hand-held sprayers or spray bottles
- ❑ Trash bags
- ❑ Plastic sheeting

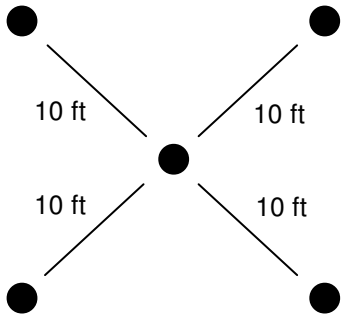
The following steps will be used to decontaminate the shovels, spades, and trowels:

1. Don appropriate personal protective equipment (PPE) and review health and safety procedures and plan.
2. Remove excess soil by scraping.
3. Wash using a brush in the plastic container holding Alconox and tap water. Equipment should be brushed until all soil is removed from the item being decontaminated.
4. Remove the item from the plastic container and rinse thoroughly with DI or distilled water.
5. Dry the item with a clean paper towel.

Following decontamination, the sampling equipment will be placed in a clean area and covered to prevent contact with the ground surface or other unclean surfaces. If the equipment is not to be used immediately, the equipment will be covered or wrapped in plastic sheeting or heavy-duty trash bags to minimize potential contamination.

Earthworm Tissue Sample Collection Procedures

Composite samples for earthworm tissue and soil will consist of subsamples from five (5) sample points distributed around randomly as follows:



After the collection of the composite soil sample, composite earthworm samples will be collected from the five (5) sample points by digging, as necessary, with a decontaminated shovel. The goal will be to collect approximately equal masses of earthworms from each sample point until at least 2.5 - 20 total grams of tissue are obtained for analysis. Gut contents of earthworms will be purged prior to shipment to the laboratory. The following sections describe the sampling procedures for the collection of earthworm samples using shovels, trowels, and scoops and depuration procedures.

This method involves the collection of earthworms from soil at or near the ground surface using tools such as spades, shovels, trowels, and scoops. The surface material is removed to the required depth and a stainless steel trowel or plastic scoop is used to collect the soil. The soil will be hand sorted and earthworms will be removed. To the extent practical, consistent sampling techniques are to be used among all sampling stations for consistency and comparability.

The following procedure describes the methodology for collecting earthworms:

1. Don appropriate PPE and review safety procedures with team.
2. Remove and discard sticks, rocks, vegetation and other debris from the sampling area using a pre-cleaned sampling tool.
3. At the prescribed soil subsample points, excavate soil to 12 inches below ground surface (bgs).
4. Place excavated soil into stainless steel trays or other appropriate containers.
5. Using gloved hands, sort through the soils and set aside any earthworms of similar species and size in a decontaminated stainless steel bowl or other appropriate clean sampling container.
6. Repeat the process to obtain sufficient numbers of earthworms totaling 2.5 - 20 grams of approximately equal mass from each subsample point for the composite sample for the sampling station.
7. Rinse each earthworm with distilled/deionized water.
8. Wipe or blot with lint-free wipes to remove excess water.
9. Place composite sample in clean laboratory-supplied sample containers (one per composite sample).
10. Freeze samples until ready for shipment to the designated analytical laboratory for tissue analyses.

11. Place samples in a cooler and pack securely with dry ice for shipment.

In the field notebook/field data sheets, note the depth of soil sorted, time of sampling, and relevant observations, including but not limited to weather or substrate type.

Sample Identification, Handling, and Chain-of-Custody

Samples will be identified, handled, and recorded as described below. Each sample container will have a sample label affixed to the outside, and documentation will be completed in waterproof ink. Each label will be marked using waterproof ink with the following information:

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

Sample containers will be packed in bubble wrap to minimize breakage and placed in plastic coolers. Ice will be placed around sample containers, and additional cushioning material will be added to the cooler, if necessary. A temperature blank will be included in each cooler. Paperwork will be placed in a sealable plastic bag and placed on top of the sample containers or taped to the inside lid of the cooler. The cooler will be sealed, and signed custody seals will be affixed to two sides of the cooler. Laboratory address labels will be placed on top of the cooler.

Sample coolers will be packaged and shipped as environmental samples in accordance with applicable federal and state regulations. Standard procedures applicable to the shipment of environmental samples to the analytical laboratory are outlined below:

- Environmental samples collected will be transported to the laboratory by field personnel, shipped through Federal Express or equivalent overnight service, or picked up by a laboratory courier. Shipments will be scheduled to meet holding time requirements.
- The laboratory will be notified prior to receipt of samples. If the number, type, or date of shipment changes due to site constraints or program changes, the laboratory will be informed in advance to allow adequate time to prepare.
- The transfer of custody of field collected samples will follow an established sample chain-of-custody (COC) program. The primary purpose of COC procedures is to ensure that sample traceability is maintained from collection through shipping, storage, and analysis to data reporting and disposal.
- Tracing sample possession will be accomplished by 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:

- Project name and number
- Sample number and identification of sampling point
- Sample media
- 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 prepared 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. A copy of each COC form will be retained by the sampling team for the project file. Bills of lading will also be retained as part of the chain-of-custody record.

Field Sampling and Project Documentation

All information pertinent to the investigation will be recorded in a bound Field Logbook and/or Field Data Sheets. Entries will include the following, as applicable:

- ❑ Project name and number;
- ❑ Sampler's and field personnel names;
- ❑ Date and time of sample collection;
- ❑ Observations at the sampling site such as weather conditions;
- ❑ Sample number, location, and depth;
- ❑ Sampling method;
- ❑ Analyses requested;
- ❑ Sampling media;
- ❑ Sample type (grab or composite); and
- ❑ Sample physical characteristics.
- ❑ Summary of daily tasks and information concerning sampling changes and scheduling modifications dictated by field conditions

Field investigation situations vary widely. No general rules can include every 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. At the completion of the field activities, the logbooks will be maintained in the central project file.

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. Although it is primarily intended for streams less than four feet deep, a modified method can be used to at least eight feet if the current is not too swift. 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.

- At sample site, install 0.5-m^2 frame over river bottom to be sampled. If bottom substrate is visible through the overlying water, photograph the sampling location with the edges of the frame nearly filling the camera viewfinder.
- Use a decontaminated pump to pump sediment and water from overlying substrate within the quadrat into one of the precleaned 5-gallon buckets. 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 4 gallons of water/sediment is in the 5-gallon bucket or the area of substrate defined by the quadrat is swept relatively clean of fine-grained material.
- After 4 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.
- Measure the volume of sand remaining in the first bucket and discard. If a more quantitative estimate of the dry weight of the coarse fraction is desired, collect a representative aliquot of the sand to determine percent water.
- 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.
- Pour the remaining settled sediment into a preweighed, wide-mouth glass sample jar, and weigh the jar to determine wet weight of the fine fraction.
- 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 Phase I system characterization. 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 URS 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.

URS 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 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 SRSE-2:
Guidelines for Sampling Sediment Deposits

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

This document defines the standard procedure for collecting bulk sediment samples for analytical chemistry, physical parameters, and other parameters. This Standard Operating Procedure (SOP) presents descriptions of equipment, field procedures, and QA/QC procedures necessary to collect sediment samples. 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:

- Plastic syringe core sampler
- Water quality meter
- Stakes to mark sampling locations
- Waders
- Powder-free Nitrile gloves
- Analysis-appropriate sample containers
- Sample bottle labels
- Stainless-steel bowls and spoons
- Appropriate decontamination supplies
    - Brushes
    - Wash tubs
    - Buckets
    - Sponges or paper towels
    - Formula 409 cleaner
    - Potable tap water
    - Organic free deionized (DI) water or distilled
    - Hand-held sprayers or spray bottles
    - Trash bags
    - Plastic sheeting
- Dry ice (if methylmercury analysis to be performed)
- DI or distilled water
- Sampling location maps

- Pencils and waterproof/permanent marking pens
- Global Positioning System (GPS) unit
- Camera
- Appropriate health and safety equipment
- Cooler with ice
- Label tape (clear)
- Paper towels
- Plastic sheeting
- Plastic bags
- Chain-of-Custody (COC) forms
- Custody seals

Decontamination Procedures

Before sampling begins, the sediment sampler, stainless-steel bowls, and spoons will be decontaminated. The equipment will be decontaminated between sampling locations. Core tubes will not be decontaminated since a new core tube will be used at each sampling location.

The following steps will be used to decontaminate sampling equipment:

- Don appropriate personal protective equipment (PPE) and review health and safety procedures.
- Gross quantities of the sampled medium found on equipment will be scraped off at the sampling site.
- Equipment that will not be damaged by water will be sprayed down with a solution containing Formula 409 along with potable water and scrubbed with a bristle brush or similar utensil. Equipment will be rinsed with DI or distilled water.

Following decontamination, the sampling equipment will be placed in a clean area and covered to prevent contact with the ground surface or other unclean surfaces. If the equipment is not to be used immediately, the equipment will be covered or wrapped in plastic sheeting or heavy-duty trash bags to minimize potential contamination.

Sediment Collection and Handling Procedures

In some areas a boat will be required in order to reach the designated sample locations. Caution will be used when conducting sampling from the boat. Health and safety procedures are detailed in the South River Science Team (SRST) Safety Program (SRST 2006).

Core Sampler

The procedures for collecting surface and subsurface sediment samples using a hand corer are provided below. A hand corer can be used to collect a relatively undisturbed sample that shows a profile of stratification. For offshore areas, a boat will be required in order to reach the designated sample locations. Caution will be used when conducting any sampling from a boat.

The following procedures will be used during this sampling activity:

- Position the boat at the sampling location using GPS unit, aerial photos, United States Geological Survey (USGS) quadrangle, and/or onshore landmarks.
- Record the sample location on a site map, and with the GPS unit in the field log book.
- Decontaminate sampling equipment.
- Don a clean pair of Nitrile gloves.
- Push core tube into surface of sediment.
- Measure length of core tube above surface of water.
- Manually push or hammer the core tube into the sediment to the appropriate depth.
- Remove air above sediment/water interface and cap top of core tube.
- Pull core tube out of sediment. As bottom of tube breaks water surface, cap bottom of core.
- Measure the sediment in the core tube to determine depth of penetration and recovery.
- Transfer (using a decontaminated spoon) each selected depth interval of sediment into separate stainless-steel bowls.
- Repeat the steps for pushing and retrieving the core tube to obtain a sufficient quantity of sediment for all chemical and physical analyses.
- Label sample jars.
- Homogenize the remaining sample and fill the sample bottles.
- Return unused sediment to the collection location.
- Store and document sample.
- Record applicable information on the Sample Collection Field Sheet and COC.

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. All field QA/QC samples are labeled with QA/QC identification numbers and sent to the laboratory with the other samples for analyses. The frequency of QA/QC samples is specified in the WP.

Field/Equipment Blank Samples

An equipment rinsate sample of sampling equipment is intended to check if decontamination procedures have been effective. A rinsate sample (also referred to as a "field blank") will be collected from the decontaminated sampling equipment before it is used to obtain the sample. Organic-free deionized water will be rinsed over the decontaminated sampling apparatus and transferred to the sample bottles. The same parameters that are being analyzed in the samples will be analyzed in the rinsate samples. The rinsate sample is assigned a QA/QC sample

identification number, stored in an iced cooler, and shipped to the laboratory along with the sediment/residue samples collected that day.

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 Phase I system characterization. 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 URS 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.

URS 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. All entries in logbooks will be made in waterproof ink. Corrections will consist of line-out deletions that are initialed and dated. 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 (grab or composite)
- Sample physical characteristics
- Sample preservation
- Observations at the sampling site (e.g., weather conditions)
- Unusual conditions
- Names and addresses of field contacts
- Names and responsibilities of field crew members
- Names and titles of any site visitors
- Location, description, and log of photographs (if taken)
- References for all maps and photographs
- Information concerning sampling changes, scheduling modifications, and change orders
- Summary of daily tasks and information concerning sampling changes, scheduling modifications, and change orders dictated by field conditions
- Signature and date by personnel responsible for observations

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. The logbooks will be kept in the field team member's possession or in a secure place during the investigation. Following the investigation, the logbooks will become a part of the final project file.

Sample Collection Field Sheet

Sample Collection Field Sheets will be completed for each sample by the sampling personnel (geologist, geological engineer, or geotechnical engineer). Most of the information required on the field sheet will have been completed at the conclusion of the sediment sampling task.

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 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 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 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. 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

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

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 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)

o Hydrochloric acid – high purity, pretested for mercury content, used to field preserve water samples (for mercury and methylmercury analysis).

- Note: Although field preservation of mercury samples is acceptable, it is preferable to ship samples immediately after collection so that they can be acidified by the laboratory within 48 hours of collection. Parker and Bloom (2005) provide detailed and current supporting scientific background for these recommendations regarding preservation and storage of water samples for mercury analysis.

o 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).

o Powder-free Nitrile gloves

o Pencils and waterproof/permanent marking pens

o Sampling location maps

o Global Positioning System (GPS) unit

o Camera

o Appropriate health and safety equipment

o Ziploc bags or similar dry storage materials

o Cooler

o Ice

o Paper towels

o Field notebook/field data sheets

o Chain-of-custody (COC) forms

o Custody seals

Decontamination Procedures

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

o 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.
- Filter
  The high capacity capsule filter may be used to filter more than one sample from the same waterbody provided the filter has not clogged and is first flushed with several liters of water from each location prior to collecting the sample for analysis. If filters are reused in this manner, the equipment blank (EQBLK) must be prepared using a filter that has been used at least once and preferably at several locations to collect samples prior to preparation of the blank.

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. However, when sampling anoxic waters from lake hypolimnia, excessive sulfide concentration in samples may require analytical adjustments (e.g., addition of a larger amount of bromine monochloride) to accommodate the interference. Record any field detection of hydrogen sulfide on the analytical request form.

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.

The following procedures may be used to collect discharge weighted samples (utilizing a modified equal-discharge-increment; USGS 2006) composite surface water samples at boundary transects upstream and downstream of Experimental Stations as described in the accompanying work plan:

- 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.
- Position a tape measure across the stream in the location to be sampled (Transect). String the tape from left to right when looking up stream.
- Measure discharge along transect according to SOP SRSD-1.
- Using a cumulative discharge curve or equivalent (USGS 2006), determine locations of the verticals (sampling locations) where cumulative discharges of 10, 30, 50, 70 & 90 percent occur.
- Go to the first vertical location on the tape, and collect five syringes by withdrawing the plunger slowly and steadily as the syringe is lowered through the water column. This should be done so that the syringe is completely filled by the time it reaches the bottom.
- Do not to disturb the substrate with the syringe.
- After five syringes have been collected at the first vertical, move on to the next vertical and repeat the previous two steps until all verticals have been sampled.
- It is imperative to keep syringes from different verticals separated so that they do not become mixed with syringes from other verticals which could skew analytical results.
- Transfer syringes into pre-labeled, lab provided sampling containers so that each bottle contains water from each of the five verticals, yielding three discharge weighted samples.

"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.
- "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" rebags 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 Phase I system characterization. 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 URS 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.

URS 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

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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

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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.

Protocol SRTI-1
Biological Sampling Guidelines:
Aquatic Vegetation Tissue Collection

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

AQUATIC VEGETATION TISSUE SAMPLING GUIDELINES

Vegetation 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 vegetation tissue samples:

- Boat and motor
- Field book/field datasheets
- GPS unit
- Electronic scale
- Tray for weighing
- Cinder blocks
- Stainless-steel scissors
- Distilled or deionized water
- Nitrile gloves
- Lint-free wipes (Kimwipes or equivalent)
- Sample containers from laboratory
- Sample container labels
- Cooler
- Dry ice
- Wet ice
- Chain-of-custody (COC) forms
- Paper towels
- Digital camera
- Waterproof marking pens/ink pens
- Plastic bags/Ziplock bags
- Decontamination supplies
- Appropriate health and safety equipment

Decontamination Procedures

Before each sample, the measuring board and tray for weighing will be thoroughly cleaned and rinsed with deionized or distilled water to prevent potential sample contamination. The following equipment/supplies may be needed to perform decontamination:

- Brushes
- Wash tubs
- Buckets
- Sponges and paper towels
- Formula 409 (low mercury content detergent)
- Organic-free water (deionized or distilled water)
- Hand-held sprayers or spray bottles
- Trash bags
- Plastic sheeting

Following decontamination, the equipment will be wrapped in clean plastic sheeting or trash bags to prevent contact with dust and unclean surfaces.

Aquatic Vegetation Collection Procedures

A boat may be required to reach the designated sample locations. Caution will be used when conducting sampling from the boat. Health and safety procedures for conducting the work are detailed in the HASP or the program.

The following procedures will be used for deployment of artificial substrates for macro-algal colonization:

- Two clean cinder blocks per station will be deployed two months prior to sampling.
- Cinder blocks are to be placed at sampling locations in shallow water near the toe of pools. Placement will be within areas of existing algae growth and in areas with generally open canopy cover.
- The position of each artificial substrate will be recorded using GPS unit at deployment.

The following procedures will be used for macro-algal tissue collection by hand:

- Locate artificial substrate via GPS.
- Remove sufficient macro-algae for a sample by hand.
- Rinse collected tissue with stream water to remove debris.

The following procedures will be used for macro-algal sample preparation:

- Inspect macro-algae for detritus and invertebrates and remove any if found.
- Record the weight of sample on the field data sheet.
- Rinse sample with deionized water or distilled water.
- Dry macro-algae with lint-free wipe.
- Place sample in laboratory supplied bottleware and place on dry ice.
- Decontaminate tray for weighting after every sample.
- Complete appropriate COC forms, and ship overnight to the laboratory for processing and analysis.

The following procedures will be used for vascular plant tissue collection by hand:

- Locate target vascular plant tissue within designated stream reach; if vascular plant tissue is absent, sample location will be omitted.
- Record a GPS location at sampling point.
- Remove the tops of five plants using scissors and hand protection (gloves).
- Vigorously rinse the plant tops in river water to remove debris.
- Place these into the collection tray for sample preparation.

The following procedures will be used for vascular plant tissue sample preparation**:**

- Rinse plant sample with deionized water or distilled water.
- Dry plant sample with Chem-wipe or other lint-free wipe.
- Place the sample on tared digital field balance.
- Record the mass of the plant sample on the field data sheet.
- Place sample in laboratory-supplied bottleware and place on dry ice.
- Decontaminate tray for weighing after every sample.
- Complete appropriate COC 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 data 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.

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 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 Phase I system characterization. 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 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 URS 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.

URS 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.

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 SRTR-1:
Baseline and Performance Monitoring at Transects

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

This document describes the site characterization methods that have been used to select transects in several South River efforts. This is the approach used as part of the monitoring effort in the Bank Pilot study for the South River Program. It includes guidance on collection of physical, and hydrological data along with habitat evaluation procedures. The specific scope may vary depending on the objective of transect identification; the protocol is divided by task into the following sections:

- Equipment
- Initial Station Location Selection
- Stream Morphology
- Transect Data Collection
  - Substrate Characterization
  - Habitat and Submerged Aquatic Vegetation
  - Hydraulic Head Pressure
  - Water velocity
- Soil and Sediment Sampling Total Mercury (Hg) delineation
- Field Log Book and Field Data Sheet

Equipment

The following equipment/supplies may be used to conduct the field surveys:

- Field notebook/data sheets
- Pencils and waterproof/permanent marking pens
- Sampling location maps
- Trimble Geo-XH global positioning system (GPS) with Zephyr antenna
- Camera
- 100- and 300- foot measuring tapes
- 2-foot rebar sections
- Hammer
- Pin flags
- Graduated sediment probe
- Laser level and survey rod

- Sontek FlowTracker Acoustic Doppler Velocimeter (ADV)
- Appropriate health and safety equipment

Initial Transect Station Location Selection

Upon arrival at a station location, the following methodology will be used to set up station transects:

- Establish the first transect centered on the targeted feature and mark each side of the transect with a pin flag. The pin flags will be on opposing banks so that the transect runs perpendicular to the stream.
- Use the GPS to document the location of the transect.
- Establish transects at approximately 100 foot intervals upstream and downstream of the central transect and document their locations on opposing streambanks with pin flags and the GPS.

Cross-Sectional Channel Morphology

1. Establish transect locations in accordance with methodology described above.
2. Document large woody debris, large boulders, and snags with GPS throughout the reach.
3. Transects should be perpendicular to stream channel plan form.
4. Endpoints of each transect should be 20-feet landward from top-of-bank on each bank.
5. Insert two bank erosion pins at each bank. Select an upper and lower position on bank to capture mass wasting or undercutting of bank. Document position and elevation of pins and initial lengths of exposure.
6. Document location of transect on both banks with GPS and field notebook for subsequent monitoring. Also mark location of each transect with pin flags for easy field orientation.
7. Set up laser level in central location such that all transects and features can be surveyed with minimal movement of laser level.
8. Establish point of reference for future surveys by setting a two-foot piece of rebar into ground and cap rebar slightly above ground surface. Record location of reference point with GPS and field notebook.
9. Establish the height of the instrument relative to reference point (this will allow all other elevations to be related to this single known point).
10. Collect position and elevation data along each transect at two-foot intervals. Include position and elevation of top-of-bank, edge of water, and toe-of-bank at each end of transect.
11. Along each transect, at each position/elevation data point, record depth to bottom if subaqueous, or note as subaerial.

12. At each bank on each transect:
    a. Record bank slope (and changes in slope) between top-of-bank and water's edge on each bank.
    b. Record erosion pin exposure.
    c. Visually describe bank condition regarding slope stability (evidence of slumping, undercutting); surface erosion (rills, gullies); and percent vegetative cover.
13. Document conditions at each transect with photographs.
14. Document all data on a Field Data Sheet

Grain Size Distribution

1. Along each transect, at each position/elevation data point, visually characterize the following soil/sediment data using a pocket-size grain sizing folder.
    a. Modal grain size: gravel (boulder, cobble, pebble, or granule); sand (coarse, medium or fine); or mud (silt and clay)
    b. Sorting (well sorted or poorly sorted)
2. Document all data on a Field Data Sheet.

Flow Characteristics

1. Select five locations on each transect for which position and elevation have been recorded to measure mean flow velocity with a Sontek FlowTracker Acoustic Doppler Velocimeter.
2. Where water depth is 2.5 feet or greater, measure velocity at 0.2d and 0.8d (d is the depth of water column) and average the two readings. Where water depth is less than 2.5 feet, measure velocity at 0.6 d.
3. Indicate time of day of each velocity measurement.
4. Document all data on a Field Data Sheet.

Habitat Evaluation

1. Vegetation sampling plots shall be located on the streambank as follows: one upstream of the pilot project, two within the pilot project, one downstream of the pilot project, and two on the opposite bank.
2. Establish sampling plot by setting a two-foot piece of rebar into ground; cap rebar slightly above ground surface. Record location of rebar with GPS and in field notebook.
3. The sampling plot shall be 1 square meter and the upper left corner of the plot shall contain the rebar with the upper edge of the plot parallel to the water's edge.
4. Document the total areal vegetative cover within the plot. Record, by stratum, the percent cover and dominant species.

5. Document any invasive species identified within the plot and the percent cover.
6. Count and record the number of planted trees along the top of bank. Calculate the total percent survivorship.
7. Document the location and extent of SAV. Identify, as possible, the species composition of each SAV bed.
8. Complete the selected Habitat Parameters from the Rapid Bioassessment Protocols: 1. Epifaunal Substrate/Available Cover; 2a. Embeddedness; 2b. Pool Substrate Characterization; 8. Bank Stability; and 9. Vegetative Protection.
9. Establish a permanent photograph location point on the bank opposite the pilot project by setting a two-foot piece of rebar into ground; cap rebar slightly above ground surface. Record location of rebar with GPS and in field notebook.
10. Using several photographs, document the entire pilot project. Also photograph the areas upstream and downstream of the pilot project. Take the same photographs at every monitoring event.
11. Document all data on a Field Data Sheet.

Soil and Sediment Collection

Pending different field activities soil and sediment samples may be collected. Detailed sampling guidelines for soil sampling are provided in SRSO-1. Detailed sampling guidelines for sediment sampling are provided in SRSE-1.

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

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