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July 13, 2015

Mr. Michael Liberati
DuPont Corporate Remediation Group
Chestnut Run Plaza 715-236
Wilmington, DE 19805
VIA ELECTRONIC MAIL

Re: Revised Final Ecological Risk Assessment Report and Ecological Retrospective Data Quality Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia
EPA ID# VAD003114832

Dear Mr. Liberati:

The Department of Environmental Quality, Office of Remediation Programs (DEQ) received revised Final Ecological Risk Assessment Report (ERA), Retrospective Data Quality Assessment Report, and Response to comments document, dated May 1, 2015. This revision was submitted as part of the conditional approval granted on April 10, 2015.

The ERA is considered part of the RCRA Facility Investigation (RFI) associated with the Former DuPont Waynesboro Plant (Facility) located in Waynesboro, Virginia, and the Corrective Action requirements of the Hazardous Waste Management Permit for the Facility.

The revised Final ERA portions of the RFI and associated documents have been reviewed and are hereby approved as part of the facility's Site-Wide Corrective Action.

If you have any questions, you may contact me at 804-698-4064 or by email at Vincent.Maiden@deq.virginia.gov.

Sincerely,

Vincent A. Maiden
Office of Remediation Programs

cc: Sonal Iyer, File – DEQ CO
Andrea Barbieri, EPA Region III (3LC50)
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Volume I of III

FINAL REPORT

Ecological Risk Assessment Report for Former DuPont Waynesboro Site Area of Concern (AOC) 4

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

Date: May 1, 2015 Project No.: 18986567.01440

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Acronym List

Acronym	Explanation
AOC	Area of Concern
bgs	Below Ground Surface
BHC	Delta Benzene Hexachloride
CCC	Criteria Continuous Concentration
CCME	Canadian Council of Ministers of the Environment
CMS	Corrective Measures Study
COPEC	Constituent of Potential Ecological Concern
CRG	Corporate Remediation Group
DOC	Dissolved Organic Carbon
DMIR	Daily Mercury Intake Rates
DRM	Dose Rate Models
DuPont	E.I. du Pont de Nemours and Company
ECSM	Ecological Conceptual Site Model
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ERAG	Ecological Risk Assessment Guidance
ESB	Equilibrium Partitioning Sediment Benchmarks
ESBTU	Equilibrium Sediment Benchmark Toxic Unit
ESV	Ecological Screening Value
FCV	Final Chronic Value
HRAD	Historical Release-Age Deposit
IHg	Inorganic Mercury
km^2	Square Kilometer
LiDAR	Light Detection and Ranging
LWD	Large Woody Debris
ME	Measurement Endpoint
m	Meter
MeHg	Methylmercury
mg/kg	Milligram per Kilogram
NELAC	National Laboratory Accreditation Conference
NFA	No Further Action
ng/g	Nanogram per Gram
ng/L	Nanogram per Liter
NOAEL	No-Observed-Adverse-Effect-Level
NRDA	Natural Resource Damage Assessment
NRDC	Natural Resources Defense Council
NRWQC	National Recommended Water Quality Criteria
^{o}C	Centigrade
OCPs	Organochlorine Pesticides
OWPC	Office of Waste Permitting and Compliance
PAH	Polycyclic Aromatic Hydrocarbon
PCA	Principal Components Analysis
PCCRARM	Presidential/Congressional Commission on Risk Assessment and Risk Management
PEC	Probable Effects Concentration
RBP	Rapid Bioassessment Protocols
RCRA	Resource Conservation and Recovery Act
RDQA	Retrospective Data Quality Assessment

RFI	RCRA Facility Investigation
SAV	Submerged Aquatic Vegetation
SERCC	Southeast Regional Climate Center
SFSR	South Fork Shenandoah River
SQT	Sediment Quality Triad
SRST	South River Science Team
SWMU	Solid Waste Management Unit
TEC	Threshold Effect Concentration
THg	Total Mercury
tPAH	Total Polycyclic Aromatic Hydrocarbon
UCL	Upper Confidence Limit of the Mean
UPL	Upper Prediction Limit
URS	URS Corporation
USGS	United States Geological Survey
VDEQ	Virginia Department of Environmental Quality
VAWQC	Virginia Water Quality Criteria
WOE	Weight of Evidence

Executive Summary

E.1 Introduction

This Ecological Risk Assessment (ERA) Report documents the results of an assessment of ecological risks due to mercury and other constituents in environmental media in an off-site portion of the former E.I. du Pont de Nemours and Company (DuPont) Plant (the site), in Waynesboro, Virginia. This off-site portion [Area of Concern (AOC 4)] includes the aquatic and riparian terrestrial systems (including the floodplain) along approximately 25 river miles of the South River downstream of the site and a segment of the South Fork Shenandoah River (SFSR) in Virginia. The South River watershed within AOC 4 is composed of agricultural, forested, and developed areas and provides ecological habitats to support various ecological receptors, including, benthic, aquatic, and terrestrial organisms and wildlife. Mercury was released to the South River system from the site between 1929 and 1950, during the period of its use in acetate flake and yarn production.

In February 2014, under the authority of Resource Conservation and Recovery Act (RCRA), Commonwealth of Virginia, Department of Environmental Quality (VDEQ) modified the Hazardous Waste Management Permit for Corrective Action (VAD003114832) for the site to include AOC 4. This ERA Report has been prepared pursuant to this February 2014 permit modification.

The ERA incorporates and relies on the extensive information (from numerous reports and publications, technical and non-technical) already available about conditions in AOC 4. Sections 1 and 2 of this report provide brief discussions of this information. Given the different purposes of the historical investigations, all analytical data may not be of equivalent quality and relevance to perform an ERA. Hence, in consultation with VDEQ, a Retrospective Data Quality Assessment (RDQA) was performed using a consistent process for available datasets to evaluate their usability for the ERA. The RDQA evaluated available documentation for the data sources with respect to data comparability, sample integrity, accompanying QA/QC elements, and overall representativeness and relevance of the datasets for the ERA.

The ERA integrated relevant physical, chemical, and biological data from several years of these various off-site investigations. The goals of this ERA were (1) to evaluate potential risks to ecological receptors within AOC 4 due to site-related constituents, including mercury and (2) to support remedial decision-making within AOC 4. The ERA followed the eight step process in the ERAGs. Summaries of the main steps and findings are provided in the subsequent sections.

E.2 Problem Formulation

The Problem Formulation presents information that is used to focus the evaluation of ecological risks in AOC 4. A screening-level ecological risk evaluation was performed in this section based on which an ecological conceptual site model (ECSM) was developed for the baseline ecological risk assessment (BERA) for AOC 4. AOC 4 was divided into 16 Assessment Reaches (see Section 3.0 for further discussion) including:

- A Reference Reach upstream of the plant site located between relative river mile (RRM) -2.7 to RRM -0.7;
- A Buffer Reach located between RRM -0.7 and RRM 0;
- Thirteen South River Study Reaches between RRM 0 and RRM 24; and
- A Study Reach on the South Fork Shenandoah River downstream of RRM 24.

The screening level evaluation compared constituent concentrations in surface water, sediment, and soil (within the 62-year floodplain) from AOC 4 to screening-level ecological benchmarks. From the various constituents [including trace metals and polycyclic aromatic hydrocarbons (PAHs)], mercury [total mercury (THg) and methylmercury (MeHg)] were retained as COPECs for BERA.

An ECSM was then developed to represent the current understanding of the source, fate, and transport of mercury within AOC 4, and the potential exposures of various ecological receptors to mercury within AOC 4. Based on mercury concentrations detected in various media and existing potential ecological habitats within AOC 4, the following exposure routes and exposure pathways were identified:

- Direct contact of organisms with soil, sediment, pore water, and surface water (e.g., aquatic and benthic invertebrates, fish, and soil invertebrates);
- Incidental ingestion of soil and sediment (e.g., sediment ingestion by mallard ducks and soil ingestion by short-tailed shrew); and
- Dietary ingestion of mercury containing food items by aquatic organisms, birds, and mammals.

Included in the exposure assessment was the aquatic-to-terrestrial trophic transfer pathway involving terrestrial birds (e.g., Tree swallow) feeding on invertebrates (e.g., emergent insects,) and invertebrates that prey on aquatic invertebrates (wolf spiders). Based on the potentially complete exposure routes and pathways identified in AOC 4, the following ecological receptor groups and focal receptors were selected for the BERA:

- Aquatic Receptors: Benthic macroinvertebrates and larval and emergent aquatic invertebrates, fish species [largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*)], and aquatic vegetation (submerged aquatic vegetation);
- Semi-Aquatic Receptors: Amphibians, piscivorous birds [belted kingfisher (*Megaceryle alcyon*)], omnivorous birds [mallard duck (*Anas platyrhynchos*)], piscivorous mammals [river otter (*Lontra canadensis*)]; and
- Terrestrial Receptors: Terrestrial vegetation, soil invertebrates (earthworms), invertivorous birds [Tree swallow (*Tachycineta bicolor*) – an aerial insectivore and American robin (*Turdus migratorius*) – a ground insectivore], carnivorous birds [Eastern screech owl (*Megascops asio*)], invertivorous mammals [Big brown bat (*Eptesicus fuscus*) – an aerial insectivore, short-tailed shrew (*Blarina brevicauda*) – a ground insectivore, and white-tailed deer (*Odocoileus virginianus*) – an herbivore].

Generally, overall population-level potential risks were evaluated the assessment endpoint for the above receptor groups and focal species based on measurement endpoints related population survival, growth, and reproduction. Individual level impacts were considered for the evaluation of potential risks to endangered and/or special status species.

E.3 Ecological Effects Analysis

The Ecological Effects Analysis focused on evaluating ecotoxicological data on mercury to identify and establish effects endpoints and toxicity benchmarks that can be linked to the measurement endpoints and the ECSM. A review was performed on available mercury ecotoxicological literature to develop effects thresholds or benchmarks (in terms of exposure concentrations in various media and dietary doses) that can be compared to the corresponding estimated exposures. Consistent with the measurement endpoints selected for the ERA, only survival, reproductive, and/or growth endpoints were considered that were specific to the receptor groups and/or focal receptors.

E.4 Exposure Analysis

Exposure Analysis established a relationship between the chemical stressor (mercury, present as either THg, MeHg, or IHg) and the focal receptors through: (1) spatial distribution of mercury concentrations across AOC 4, (2) calculation of exposure point concentrations (EPCs) for exposure medium/focal receptor pairs based on the most likely exposure scenario for each focal receptor, and (3) calculation of reasonable maximum daily mercury intake rates (DMIRs) via the food chain from abiotic and biotic sources by focal avian and mammalian receptors.

E.5 Risk Characterization

The Risk Characterization presents the evidence linking mercury exposure in AOC 4 to potential adverse effects. Deterministic or point estimates of risks were quantified based on the Hazard Quotient (HQ) approach and evaluation of available site-specific studies provided a weight-of-evidence (WOE) for the potential risks. The WOE framework applied in the current evaluation is based on predetermined weighting of the different measurement endpoints (1 to 5, in increasing order of importance to the assessment endpoint) and criteria for presence/absence and potential for adverse effects (low, medium, and high) in AOC 4. The following provides a summary of the findings on potential ecological risk estimates for receptors within AOC 4.

E.5.1 Benthic Invertebrates

A WOE evaluation of the available measurement endpoints indicated that exposure to mercury in AOC 4 is unlikely to result in adverse effects on benthic invertebrates within AOC 4. Four categories of measurement endpoints (abiotic bulk chemistry, sediment toxicity, benthic community analysis, and tissue residue) were considered in evaluating the survival, growth, and reproduction of benthic invertebrates in AOC 4.

Measurement endpoints indicating a high potential for effects generally also indicated an “undetermined” presence or absence of potential effects. Uncertainties in these measurement endpoints aside, the WOE evaluation of available measurement endpoints (all similarly weighted at a relative weight of 3 or 4) is not indicative of adverse effects to benthic invertebrates exposed to mercury in AOC 4.

E.5.2 Fish

A WOE evaluation of available measurement endpoints indicate that although exposures to mercury are generally elevated in bass species (based on tissue residue evaluations), fish species within AOC 4 are not likely experiencing population level adverse effects. Five categories of measurement endpoints (surface water chemistry, age/growth survey, condition survey, community structure survey, and tissue residue) were considered in evaluating the population-level survival, growth, and reproduction of fish species and their community structures in AOC 4.

All measurement endpoints had the same weight (at relative weight = 4), except for surface water chemistry (at relative weight = 3). While the direct contact exposures to surface water indicate negligible risks to fish, tissue concentrations indicate a medium to high potential for risk in several Assessment Reaches. Therefore, the potential for mercury-associated population- and community-level effects on fish species within AOC 4 are not expected.

E.5.3 Aquatic Vegetation

The evaluation of aquatic vegetation in AOC 4 indicates exposure to mercury in AOC 4 is not likely to result in adverse effects. Concentrations of THg and MeHg in abiotic exposure media (surface water and pore water) are below ecological benchmarks protective of survival and growth of aquatic vegetation.

E.5.4 Amphibians

The evaluations for amphibians indicate that exposures to mercury in AOC 4 are unlikely to results in adverse effects. THg and MeHg concentrations in surface water are below ecotoxicity benchmarks protective of various life stages of amphibians. Evaluation of tissue mercury (whole body) in three amphibian species indicates marginal risks, if any, of adverse population effects on amphibian species exposed to mercury in AOC 4.

E.5.5 Terrestrial Plants and Soil Invertebrates

Evaluations of direct contact exposures to soil mercury indicate that terrestrial plants and soil invertebrates are unlikely to experience population-level adverse effects in AOC 4 soils. Total mercury EPCs in surficial soil in within the floodplains are generally marginally greater than NOECs and comparable to LOECs.

E.5.6 Avian Receptors

Overall results indicate risk due to MeHg exposures in AOC 4 may exist for several avian receptors, including piscivores (such as belted kingfisher), carnivores (such as Eastern screech owl), and insectivores (such as tree swallow). Conservative deterministic modeling indicated that estimated dietary doses were generally ten times above the LOAEL doses for all avian receptors except mallard duck and American robin (with cumulative HQ_{LOAELs} of 1.8 and 1.7, respectively). The potential for risk based on evaluations of available blood mercury concentrations in kingfisher and the passerines (maximum HQ_{LOECs} of 2.9 and 2.1 for belted kingfisher and tree swallow, respectively) are lower than the risk based on the dietary exposure modeling (HQ_{LOAELs} of 19.6 and

17.2 for belted kingfisher and tree swallow, respectively). These results indicate that risks estimated by dietary dose modeling are likely overly conservative. Available site-specific studies generally support the conservative nature of the risks estimated in the ERA.

E.5.7 Mammalian Receptors

Overall evaluations of mammalian exposures to mercury in AOC 4 indicate a potential for risk to aerial insectivorous mammals (e.g., the big brown bat). Conservative deterministic modeling indicated that estimated dietary doses to all representative mammals, except the big brown bat, were comparable to or less than NOAEL doses and below LOAEL doses. Conservative nature of the risk estimates notwithstanding, a cumulative HQ_{NOAEL} = 9.7 and a cumulative HQ_{LOAEL} = 5.8 are estimated for the big brown bat, indicating the potential for population-level adverse effects. Both blood and fur THg EPCs for the bat species in a limited number of Assessment Reaches are above the corresponding conservative CBR_{NOEC}s, with uncertainty on the magnitude of the potential effects because CBR_{LOEC} are not available.

E.6 Uncertainty Analysis

The Uncertainty Analysis (Section 7) presents the uncertainties involved in quantifying risks and their potential influence on either over or underestimating the risks. Qualitative evaluations of the uncertainties in the ERA are generally biased towards overestimating the potential risks and hence, they are likely inconsequential.

E.7 Conclusions

Overall evaluations were performed for aquatic, semi-aquatic, and terrestrial receptors based on the WOE framework and available site-specific studies. The results of these evaluations are summarized in the following sections.

E.7.1 Aquatic Receptors

Mercury bioaccumulation by the invertebrates and fish species within AOC 4 may pose risks of adverse effects. However, the direct contact exposures (to sediment, pore water, and surface water mercury) and, more importantly, direct observations of various population and community metrics indicate no discernible adverse effects within AOC 4.

E.7.2 Semi-Aquatic Receptors

Risks of adverse effects are indicated for amphibians and piscivorous birds due to bioaccumulation and/or dietary exposures to mercury within AOC 4 Assessment Reaches beyond RRM 2.7. However, calculated potential risks for these groups of receptors incorporate significant uncertainties biased toward overestimation of risks, particularly for the amphibians. A field study on reproductive effects on kingfishers indicated limited potential risks in AOC 4, which also suggest that the estimated deterministic HQs for the kingfishers (representing piscivorous birds) are likely overly conservative, owing to either exposure estimates and/or effects estimates.

E.7.3 Terrestrial Receptors

Risks of adverse effects are indicated for carnivorous birds, invertivorous songbirds, and bats due to dietary exposures to mercury within AOC 4. However, calculated risks for these groups of receptors incorporate significant uncertainties biased toward overestimation of risks. Available field studies on tree swallow, Carolina wren, and bats in AOC 4 support these findings.

Field studies in AOC 4 have observed effects on biochemical parameters due to tree swallow exposures to mercury, but available data suggest that mercury has little impact on their reproduction and survival. The ERA also indicates that tree swallows are likely exposed to elevated levels of MeHg in AOC 4. However, the estimated risks to their populations are conservative and uncertain in the light of the available field studies in AOC 4.

Field studies of Carolina wrens in AOC 4 have indicated lower fledgling rates in AOC 4 than in study-specific reference sampling locations. However, further analysis of the data indicate that differences in reproductive parameters were generally not significant, or were greater between years in the reference sampling locations, suggesting that any observed effects of mercury were due to interannual variability. American robin, evaluated in the ERA, may be assumed to have similar MeHg exposures and sensitivities as Carolina wrens in AOC 4. Hence, the finding of limited likelihood of risk in this ERA for American robins is consistent with the results of the field study on Carolina wrens.

Various biochemical indicators of potential endocrine, immune, genetic effects on AOC 4 bats are available, although their implications are unclear with respect to individual fitness and, more importantly, population level effects. Overall, the studies on these biochemical indicators show that bats are affected in AOC 4 compared to study-specific reference sampling locations. However, these biochemical indicators do not demonstrate clear correlations to the measures of mercury exposures in bats from AOC 4 (e.g., mercury in blood and fur), indicating factors other than mercury exposures are at play for the observed differences. Consistent with these findings, the ERA also indicates limited risks due to mercury for the bat populations in AOC 4.

E.8 Recommendations

The results of the ERA indicate that potential adverse effects to the ecological receptors are due to trophic transfer of MeHg originating in the South River system—a finding that is consistent with the current understanding of the system on which the proposed remedial strategy is based. Owing to the size, linear nature, complexity, and spatial variability of the South River system, reduced exposure of ecological receptors (and humans), and subsequent overall risk reduction, will be best achieved in AOC 4 by conducting remedial measures in an adaptive management approach involving integration of various interim measures, monitoring, and community outreach and education. Such an approach is already being planned for the AOC 4, and the results of the ERA provide further justifications for such an approach in ecological risk management and remedial decision making.

1.0 Introduction

On behalf of E.I. du Pont de Nemours and Company (DuPont), URS Corporation (URS) has prepared this *Ecological Risk Assessment* (ERA) report to evaluate potential exposures and risks to ecological receptors in the South River and South Fork Shenandoah watershed that have been influenced by historical mercury releases from the former DuPont Waynesboro Plant, located in Waynesboro, Virginia (the site). The ERA incorporates guidance from the U.S. Environmental Protection Agency (EPA) *Ecological Risk Assessment Guidance for Superfund* (ERAGs; EPA, 1997). The assessment focuses on Area of Concern 4 (AOC 4), which includes the aquatic, riparian and floodplain systems of parts of the South River downstream of the former DuPont- Waynesboro facility and parts of the South Fork Shenandoah River (see Figure 1-1).

1.1 Objectives and Approach

The primary objectives of the ERA are (1) to evaluate potential risks to ecological receptors potentially exposed to constituents of potential ecological concern (COPECs) in prey items, soil, sediment and surface water; and, (2) to provide risk information sufficient for remedial decision-making. Consistent with guidance, the elements of the ERA include the following:

- Identify/refine site-related COPECs.
- Identify ecological receptors that may be exposed to COPECs in soil, sediment, and surface water in the AOC 4.
- Identify potentially complete exposure pathways between COPECs and the identified ecological receptors.
- Determine whether concentrations of COPECs exceed screening-level ecotoxicological reference values considered to be protective of ecological receptors.
- Define assessment endpoints.
- Identify uncertainties and/or potential data gaps that may impact remedial decision-making.

1.2 Report Organization

The document is organized as follows:

- Section 2.0 provides a brief description of the site history and environmental setting.
- Section 3.0 presents the problem formulation, screening evaluations, and the ecological conceptual site model (ECSM).
- Section 4.0 ecological effects analysis to develop ecotoxicity benchmarks for mercury in various biotic and abiotic media, including wildlife toxicity reference values (TRVs).

- Section 5.0 presents the exposure analysis to determine ecological exposures to mercury for various representative ecological receptors.
- Section 6.0 presents the risk characterization approach, and risk calculation results.
- Section 7.0 discusses the key factors and assumptions that contributed to uncertainty in the ERA.
- Section 8.0 summarizes the results of the ERA.
- Section 9.0 presents recommendations for additional investigations or remedial actions that may be warranted based on the findings of the ERA.
- Section 10.0 lists the references cited in the report.

2.0 Site Background

The following is a brief summary of the site operational history, regulatory history and environmental setting. Information contained in this section has been summarized from the *Comprehensive Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report* (URS, 2009a) and *Final Report: Ecological Study of the South River and a Segment of the South Fork Shenandoah River* (URS, 2012).

2.1 Site Location

The former DuPont Waynesboro Plant (site) is located on approximately 177 acres of relatively flat land along the South River in the southeastern corner of Waynesboro, Virginia, which lies in the Central Valley section of the Valley and Ridge Province and the Blue Ridge physiographic provinces (Gaithright et al., 1977). The site location is shown in Figure 1-1. The valley is bounded to the east by the Blue Ridge Mountains and to the west by the Massanutten Mountains. The site, located at Relative River Mile (RRM) zero, abuts the South River which flows approximately 25 river miles north to its confluence with North River at Port Republic, Virginia where the combined flow forms the South Fork Shenandoah River (SFSR).

2.2 Summary of AOC 4 Investigations and Studies

2.2.1 On-Site

EPA issued the Hazardous Waste Permit for Corrective Action (Permit) under the RCRA in September 1998. A revised Permit (No. VAD003114832) was approved by the Commonwealth of Virginia, Department of Environmental Quality (VDEQ) – Office of Waste Permitting and Compliance (OWPC) on September 24, 2009 (VDEQ, 2009).

In accordance with the Permit, a RFI was completed to investigate historical on-site sources. DuPont completed the RFI in three separate phases from 2000 to 2009 and submitted a Comprehensive RFI Report to VDEQ and EPA Region 3 on November 30, 2009 (URS, 2009a). At the request of EPA, additional activities were completed in the fall of 2011 to address data gaps in the northeast area of the site. A revised Comprehensive RFI Report was submitted to VDEQ and EPA Region 3 in August 2012 to include the findings of the supplemental investigation.

The report recommended that Solid Waste Management Unit (SWMU) 1, SWMU 4, and SWMU 7 move forward into a Corrective Measures Study (CMS). Seventeen other SWMUs and two AOCs were recommended for no further action (NFA). Other recommendations were made to continue groundwater and outfall monitoring and to complete a sewer investigation to complement the CMS. DuPont is awaiting official approval from EPA for the report. However, it is understood that EPA is in general agreement with the units recommended for the CMS.

2.2.2 Off-Site

In addition to the investigation of on-site sources, DuPont and others have performed extensive investigations of physical, chemical and biological components of off-site portions of the South River, SFSR, and associated floodplain areas. These studies suggest that from 1929 to 1950 mercury from the site entered into the surface waters, sediments, floodplain soils, and ultimately the biota of the South River and part of the Shenandoah River System [Lawler, Matusky, and Skelly Engineers (LMS), 1981; LMS, 1982; LMS, 1989].

However, between discovery of the legacy mercury issue at the plant in 1976 and 1999 (with the exception of a structured, long-term fish monitoring plan developed by VDEQ) these studies were conducted by diverse, independent organizations resulting in limited scientific oversight and implementation, or interaction with the public. So, in 2001, DuPont and various Virginia regulatory agencies established the South River Science Team (SRST) as a multi-stakeholder and collaborative program to address the legacy mercury contamination of the South River, Virginia. Specifically, the SRST applies a watershed-level risk-based assessment process to evaluate the potential impact of the site. Also, the SRST effort draws heavily on the concepts of problem formulation and planning (as described by EPA) to guide the overall risk-based approach. The initial activities of SRST (as described here) have been documented in a peer-reviewed publication (Stahl, et. al. 2014).

The initial goals of the SRST were to coordinate the multiple research efforts, better understand fate and transport mechanisms for mercury in the system, explore reasons for the continued presence of mercury in fish tissues, and ensure that findings are effectively communicated to stakeholders. The SRST now includes several state and federal regulatory agencies, an expert panel, academic research institutions, and environmental groups and is organized along issue-specific task teams (e.g., human exposure, remediation options, communications, and implementation).

Over 100 technical reports/publications (many in peer-review journals) have resulted from the studies performed by SRST so far. It should be noted that many of the off-site studies were being performed as part of a Consent Decree among DuPont, the Natural Resource Defense Council (NRDC), and the Sierra Club (Virginia Chapter). The results of these investigations have been compiled into a final report that was submitted to the NRDC and various state and federal regulatory agencies on September 28, 2012 (URS, 2012), and a remediation proposal (Anchor QEA et al., 2013) submitted October 22, 2014. In February 2014, VDEQ signed a modification to the existing on-site RCRA permit, including the off-site areas as AOC 4. DuPont is also conducting a cooperative Natural Resource Damage Assessment (NRDA) with VDEQ, and the U.S. Fish and Wildlife Service (USFWS). The NRDA has generated novel research evaluating the potential effects of mercury on wildlife in AOC 4. This report draws significantly on the information generated by these many investigations in evaluating potential risks ecological receptors in AOC 4. Specific studies that contributed to the dataset used in this ERA and further details of these studies and data usability assessments are provided in Retrospective Data Quality Assessment (Appendix A). A human health risk assessment for AOC 4 is being prepared and submitted in parallel with this ERA.

2.3 Environmental Setting

The following subsections summarize the environmental setting, hydrology and other South River watershed characteristics. The environmental setting is based on information compiled from regional and local literature, previous site environmental reports, and recent field activities conducted as part of the RFI and SRST investigations.

The environmental setting of the South River watershed, which surrounds the former DuPont Waynesboro Plant, acts as an important control on the geomorphological, chemical, and biological components of the South River, which in turn influence the fate, transport, and potential risk associated with legacy mercury in AOC 4.

Additional information regarding the environmental setting of the site and AOC 4 watershed can be found in the AOC 4 RFI Report (URS, 2014a) and the Ecological Study Report (URS, 2012).

2.3.1 Climate

Waynesboro features a humid temperate climate, with average January temperatures of 6.1 degrees centigrade (^{o}C), average July temperatures of 29.4^{o}C, and annual precipitation of 0.94 meters (m) as measured at the Staunton, Virginia, sewage plant [Southeast Regional Climate Center (SERCC), 2007]. Precipitation is highest from March to September and slightly lower from October to February (URS, 2012). The average annual total snowfall in Staunton, Virginia, is 0.51 m.

2.3.2 Surface Water Hydrology

The South River, which the site abuts, is a fourth order, high gradient, cool water river system, and is classified as a single-thread, sinuous (but non-meandering) gravel-bed bedrock river (Turowski et al., 2008). The South River joins with the North River at Port Republic to form the SFSR. The South River has drainage basin areas of approximately 329 square kilometers (km^2) at Waynesboro, Virginia, and 549 km^2 at Harriston, Virginia [United States Geological Survey (USGS), 2007]. 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. River substrate is primarily composed of cobbles and boulders, with frequent bedrock exposures along the channel perimeter. The bankfull width of the channel ranges between 20 to 30 m, and the bankfull depth is approximately 2 to 3 m.

2.3.3 Ecological Resources

The following sections give a brief overview of the difference communities that are present in AOC 4. Further, the ecological resources of the South River and the SFSR have been summarized in AOC 4 RFI Report (URS, 2014a) and described in the Ecological Study Report *(*URS, 2012).

Aquatic Communities

Aquatic Communities in the South River and the SFSR are primarily composed of fish and aquatic invertebrate populations. Aquatic invertebrates live and forage on highly varied surfaces that include coarse-grained substrates, fine-grained sediment, submerged aquatic vegetation (SAV), and large woody debris (LWD). These surfaces trap suspended sediment and provide habitat for algal and bacterial cells that are grazed on by a variety of organisms including both invertebrates and vertebrates. Submerged aquatic vegetation is also a potential aquatic ecological receptor.

Invertivorous forage fish occupy an important position in the aquatic food web by enabling the trophic transfer of biomass from aquatic invertebrates to higher trophic levels in both aquatic and terrestrial food webs of AOC 4. The invertivorous fishes in AOC 4 prey upon aquatic invertebrates from the orders Ephemeroptera (mayflies), Trichoptera (caddisflies), and Diptera (black fly) larvae, particularly Chironomidae and Simuliidae, in addition to a variety of other aquatic invertebrates (Jenkins and Burkhead, 1994).

The highest trophic level organisms in the AOC 4 aquatic food webs are piscivorous, i.e., fish eating, ecological receptors. The smallmouth bass is a commonly cited example of this type of receptor, but others exist, including receptors in both the semi-aquatic and the terrestrial communities that are intrinsically tied to the aquatic communities. These piscivores feed largely on forage fish like longnose dace (*Rhinichthys cataractae*) and some large invertebrates, e.g., crayfish (*Orconectes spp*.).

Semi-Aquatic Communities

Semi-aquatic communities represent the interface between aquatic and terrestrial food webs by allowing biomass to readily transfer between trophic levels in aquatic, semi-aquatic, and terrestrial communities. Riparian areas along the river system provide habitat and foraging areas for many semi-aquatic populations as well as a corridor between other habitats that may otherwise be inaccessible.

These areas include a system of wetlands and lowland forested areas in which sediment, nutrients, and other materials in surface runoff are intercepted. The product of this ongoing morphological process of deposition is a habitat that can support semi-aquatic resources including amphibians and reptiles, omnivorous birds, and piscivorous birds and mammals.

One important link between aquatic and terrestrial communities in these areas are emergent aquatic insects that provide a food source for invertivorous terrestrial organisms, including birds, bats, and spiders (Cristol et al., 2008).

Terrestrial Communities

Terrestrial resources of the flood plain are made up of a patchwork of habitats and land uses that support a variety of communities. These resources include developed land, row corps, pasture/hay, early successional habitat, and upland forests. The populations that use these resources include vegetation of a variety of cover types, soil invertebrates, birds and mammals.

As mentioned previously many of the populations found in the terrestrial communities use resources found in all three communities of AOC 4. One group of terrestrial organisms that have been extensively studied in AOC 4 is passerine birds [e.g., tree swallows (*Tachycineta bicolor*)]. Many of these bird species will use resources in terrestrial areas for nesting and feed on emergent aquatic insects found in the aquatic and semi-aquatic areas of the South River (Brasso and Cristol, 2008).

2.3.4 Special Status Species

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 or species of concern using habitat within the boundaries of AOC 4. The results of the query are provided in Table 2-1, along with habitat or life history information.

The query identified 24 species of special status in AOC 4. One invertebrate was identified as having a state status of "Listed Endangered," and two invertebrates were listed as having a state status of "Listed Threatened."

The three special status species were selected for evaluation in the risk assessment based on habitats satisfying their life history requirements occur within AOC 4. In accordance with ERA guidance (EPA, 1997; EPA, 1998), these species were evaluated for potential individual effects. The assessment of individual effects is described further in Section 3.7.1.

2.4 Current and Future Land Use

Currently, the on-site area is an active industrial facility and is expected to remain so. Current off-site land use consists of the South River, adjacent floodplains, ponds, and agricultural and residential properties. Vacant lands and the rivers are used for recreation and hunting.

The ecological risk assessment necessarily focuses on current conditions. The land use composition of the South River watershed is 33% agricultural, 56% forested, and 11% developed. Wetlands cover 0.01% of the watershed, which is less than the coverage of open water (0.6%) and barren lands (0.05%; Fry et al., 2009). The area immediately adjacent to the South River predominantly consists of agricultural pastures and fields with a narrow border of trees along the banks although riparian forests are present in some areas. Off-site land use is expected to vary consistent with watershed development.

Owing to the nature of mercury and its behavior in the environment, the recovery of AOC 4 after remediation is expected to take many years. As part of the long-term remedial strategy agreed upon by the NRDC and DuPont, a framework for a long-term monitoring and adaptive management plan has been designed. Under this framework, changing land uses can be monitored and incorporated into the long-term monitoring as necessary.

3.0 Problem Formulation

3.1 Scope of Problem Formulation

Problem formulation is a systematic planning process that identifies the factors to be addressed in an ERA (EPA, 1997). The problem formulation for the ERA in AOC 4 includes the following elements:

- Refine the preliminary list of contaminant of potential ecological concern (COPEC).
- Present the ecological conceptual site model(s).
- Describe the fate and transport of COPECs.
- Identify potentially complete exposure pathways.
- Identify ecological receptors potentially at risk.
- Select assessment and measurement endpoints.

3.2 COPEC Selection

Ecosystems such as the South River and the SFSR typically have a variety of potential stressors, including chemical (e.g., mercury) and others (temperature, suspended sediment). Some chemical stressors can be considered COPECs if certain conditions are met. The objective of the COPEC screening phase was to determine areas of AOC 4 where sediment, surface water, and soil may exceed applicable and relevant ecological screening values (ESVs) derived for the protection of relevant biota.

The chemical constituents initially screened in this ERA were previously selected primarily for site characterization. Presence of chemicals other than mercury species are not related to site releases, but may have implications for ecological and other impacts in AOC 4. Hence, available data on these constituents were evaluated in the initial screening.

The sample collection efforts for sediment, surface water, and soil evaluated as part of the AOC 4 ERA are described in detail in the Ecological Study Report (URS, 2012), and summarized below. Sediment, surface water, and soil data collected from 2000 to 2012 were included in the ERA analysis to represent current conditions in the river and floodplain, and to reflect the consistency in sampling methodologies implemented by the SRST since 2001. Sediment data were not collected using standardized protocols until 2002; previous sediment collection may have collected bank soils and reported the results as sediment due to the lack of fine-grained sediment deposits in many areas of AOC 4.

3.2.1 Surface Water and Sediment Data Collection

The initial (Phase I) sediment and surface water sample location selection process is described in detail in the Ecological Study Phase I Work Plan [DuPont Corporate Remediation Group (CRG), 2006] and is summarized here. For the Phase I system characterization, a targeted selection process was used to determine sampling locations. A review of available scientific information on AOC 4 was used to target AOC 4 sampling locations as well as reference sampling locations on the South River and North River. The following information was used to select these sampling locations (AOC 4 and reference):

- Proximity to the site (historical source);
- Location of previous sampling locations/density of historical data;
- Geomorphic assessments (DuPont CRG, 2005);
- Gradients of mercury concentrations in:
  - Prey items (Murphy, 2004);
  - Surface water (DuPont CRG, 2005); and
  - Sediment, surface water, and fish tissue (VDEQ ongoing monitoring); and
- Proximity to riverine wetland-type habitats (aerial photographic survey).

Other factors were that were considered in the selection of sampling locations included: the proximity to potential physical and chemical stressors (e.g., sewage outfall, mine waste, site impacts) and professional judgment for spatial coverage.

After a review of the existing information, 16 potential Phase I sampling locations were selected for further characterization:

- Thirteen (13) sampling locations from AOC 4 (between RRM 0.6 and 22.4 and one sampling location in SFSR beyond RRM 24); and
- Three reference sampling locations [one upstream of the Site (SR-01), and two on the North River (NR-01 and NR-02)].

Phase I reference sampling locations NR-01 and NR-02 were included for the estimation of potential ecological exposures to trace metals and PAHs for interstitial sediment samples collected in 2006 from March to September (see Section 3.2.4). Table 3-1summarizes the Phase I sample locations relative to the AOC 4 ERA Assessment Reaches. In September 2005, field biologists evaluated the Phase I sample locations using protocols outlined in the EPA Rapid Bioassessment Protocols (RBP) (Barbour, et al., 1999). Each of the 16 sample locations (13 AOC 4 and three reference locations) was physically characterized and scored 30 times along the wetted channel width. The Phase I sample location segment lengths ranged from approximately 0.4 to 1 mile. These data provide information regarding baseline habitat quality and a framework for determining the suitability of potential reference sampling locations. A principal components analysis (PCA) was then performed on the habitat data to select sampling locations and three reference locations that match the dominant characteristics of the study areas. The detailed results of the PCA are presented in Ecological Study Phase I Work Plan (DuPont CRG, 2006).

As part of the Phase I investigations, trace metals (cadmium, copper, chromium, lead, selenium, and zinc), organochlorine pesticides (OCPs), and polycyclic aromatic hydrocarbons (PAHs) were analyzed in surface water and sediment samples, collected monthly from March to October 2006 at five of 13 Phase I sampling locations in AOC 4 and at the three Phase I reference sampling locations. Mercury species [total mercury

(THg) and methylmercury (MeHg)] were analyzed monthly at these Phase I sampling locations between March 2006 and April 2007. Routine sediment sampling was suspended due to the relative stability of the data. However, surface water sampling continues to be conducted on a bimonthly basis at the Phase I sampling locations.

Beyond the Phase I investigations, numerous other SRST studies (including Phase II investigations) have collected sediment and surface water data that were used as part of the COPEC screening in AOC 4 ERA. The projects, sample locations, and other information regarding these data are described in the Retrospective Data Quality Assessment (RDQA - Appendix A).

3.2.2 Soil Data Collection

Either under the direction of, or in collaboration with EPA and VDEQ, soil samples have been collected for the analysis of THg and MeHg in many sampling locations throughout the South River floodplain and associated river banks. The studies and major findings are described in the Ecological Study Report (URS, 2012). The projects, sampling locations, and other information regarding these data are described in the RDQA (Appendix A).

3.2.3 Screening Methodology

Screening evaluations were performed for the constituents in sediment, surface water, and soil from 16 Assessment Reaches (see Table 3-1). These evaluations were consistent with the principles and procedures of the ERAGS (EPA, 1997). The following sections provide a description of the Assessment Reaches and the screening approach.

Assessment Reaches

Data from a variety of studies form the basis for the AOC 4 ERA. Consequently, study-specific terminologies have been used to describe exposure and/or sampling areas within AOC 4 and relevant reference areas. To the extent possible, the terminology in this ERA has generally been consolidated to include the following:

- Assessment Reach: Stream reaches designated specifically for the ERA, including “Upstream Reference Reach”, “Reference Reach”, “Buffer Reach”, and “Study Reach”; and
- Sampling Location: Discrete sampling location from specific studies (e.g., sampling locations within the Assessment Reaches).

The ERA Assessment Reaches were partitioned spatially based on the natural river reach breaks defined by intersecting the 2-foot USGS Light Detection and Ranging (LiDAR) contours with the channel centerline; LiDAR contours were used to calculate channel slopes for reach breaks that were used to develop a longitudinal profile of the river. This approach has the advantage of selecting reaches with similar slopes, which is a primary control on the substrate composition of the stream bed. Adjacent reach breaks were combined where data were not sufficient to provide representative mercury concentrations for each data type for each reach break. This process resulted in 16 ERA Assessment Reaches as shown in Table 3-1, including one upstream Reference Reach (RRM -2.7 to -0.7), one Buffer Reach (RRM -0.7 to 0.0) and 14 Study Reaches (between RRM 0.0 to 24 and a portion of the SFSR). Available abiotic data within these

Assessment Reaches are shown in Figures 3-1, 3-2, and 3-3 for surface water, sediment, and soil, respectively.

The Reference Reach is upstream (RRM -2.7 to -0.7) of the historical outfall at the former Waynesboro Plant (RRM 0). Abiotic media within this reach are out of the influence of the former plant. Therefore, this reach represents an upstream reference location without site-related impacts. The Buffer Reach (RRM -0.7 to 0) is a short reach on the South River located immediately upstream from the Site outfall with slightly elevated mercury concentrations in the abiotic media relative to the Upstream Reference Reach (RRM -2.7 to -0.7). Site-related effects within this reach are uncertain and, hence, it is considered a “buffer” between the Upstream Reference Reach and the downstream Assessment Reaches. Additional Reference Reaches on the Middle River, North River, South River (upstream), and beyond the South River 62-year floodplain are included, where applicable, to evaluate mercury residues in the tissues of various ecological receptors. These additional Reference Reaches are not included as part of Table 3-1, but are discussed further in the Exposure Analysis section of this ERA report (see Section 5.0). Multiple Reference Reaches (or areas) are used in the ERA because the ERA relied on data from various studies, which did not always use the same reference area(s).

Screening Approach

Descriptive statistics were calculated for each sediment, surface water, and soil sample type and the data were evaluated relative to respective ESVs. Descriptive statistics calculated for each Assessment Reach included sample size (*n*), minimum concentration, maximum concentration, and arithmetic mean concentration. The EPA software program ProUCL (Ver. 5.0) was used to calculate descriptive statistics. Media-specific ESVs are further described in the following sections on the media-specific data evaluations.

3.2.4 Sediment Data Evaluation

The South River is a high-gradient stream with predominately coarse-grained substrates. Fine-grained sediment deposits that can be sampled using traditional methods are generally found on the channel margins and behind obstructions, such as downed trees. In response, the SRST developed a sampling method using a bilge pump to entrain fine-grained sediment from the interstices of coarse-grained materials (Jensen et al., 2006). The composition from interstitial sediment is generally similar to the composition of bulk sediment, but the collection method removes much of the sand. The average ($\pm$ standard error) of grain-size analysis of 23 sediment samples collected by this method from one location was 12 $\pm$ 0.3 % clay (<2 µm), 65 $\pm$ 1.4 % silt (2 to 63 µm), and 23 $\pm$ 1.6 % sand (>63 µm). The percent silt is generally higher than in fine-grained channel margin deposits, which are 23% clay, 23% silt, and 54% sand (URS, 2012). Because mercury tends to adsorb to silt, interstitial sediment concentrations may be slightly higher than sediment from depositional features.

Sediment datasets were evaluated separately based on collection methodologies. Bulk sediment data included surficial sediment (0 to 0.5 feet) sampled using direct grabs or sediment cores. Interstitial sediment data included fine-grained sediments (0 to 0.5 feet) sampled using bilge pump from the interstices of larger diameter sediment particles (e.g., gravel, cobble, and boulder). Sediment data were screened for mercury species, total metals, and PAHs.

Mercury Species

ESVs for sediment were based on published screening values and site-specific sediment toxicity testing. A literature-based conservative sediment THg criterion of 0.18 milligrams per kilogram (mg/kg) and site-specific sediment THg and MeHg criteria of 18.9 mg/kg and 0.102 mg/kg, respectively, were used in screening sediment THg and MeHg.

The conservative sediment THg criterion of 0.18 mg/kg was obtained from the EPA Region 3 *Freshwater Sediment Screening Benchmarks*. This value was originally published as a threshold effect concentration (TEC) by MacDonald et al. (2000). Available sediment criteria for MeHg are not relevant to ecological exposure because they are lower than concentrations found in sediment from non-mercury impacted sites in the region. For example, the available Region 3 sediment screening benchmark for MeHg of 0.00001 mg/kg [0.01 nanogram per gram (ng/g)] is two orders of magnitude lower than the 95% upper prediction limit concentration (UPL_{95}) of 0.0042 mg/kg (4.2 ng/g) measured in sediment samples collected from Reference Reaches in the South River, Middle River, and North River (URS, 2012).

To differentiate the AOC 4 Assessment Reaches from Reference Reaches in terms of exceedances of a screening value, an alternative criterion equivalent to the maximum no-effect concentration from site-specific sediment toxicity testing of 0.102 mg/kg was used as a sediment screening criterion for MeHg. An additional screening value for THg in sediment of 18.9 mg/kg represented the maximum concentration that did not result in adverse effects to benthic invertebrate test organisms in site-specific sediment toxicity testing (URS, 2012).

As part of the Ecological Study, sediment quality triad (SQT) testing was conducted on interstitial sediment composite samples from three AOC 4 sampling locations (RRM 3.5, 11.8, and 23.5) and two reference sampling locations (SR-01, located at RRM -2.7, and MR-01, from the Middle River). Toxicity tests were conducted in accordance with applicable EPA methods (EPA, 2000). The sediment toxicity tests included the following:

- *Hyalella azteca* 10-day Survival and Growth Test for Sediments (EPA Method 100.1; EPA, 2000)
- *Chironomus dilutus* (formerly *Chironomus tentans*) 10-day Survival and Growth Test for Sediments (EPA Method 100.2; EPA, 2000)

Test endpoints for each *H. azteca* included 10-day survival and mean dry weight per surviving organism; endpoints for *C. dilutus* included 10-day survival and mean ash-free dry weight per surviving organism. Acute tests are appropriate for the SQT framework and have been used in the development of sediment quality benchmarks (e.g., Field, et al., 2002). Laboratory performance criteria were satisfied for the endpoints in each test and the test results complied with National Laboratory Accreditation Conference (NELAC) standards.

Comparisons of the toxicity testing results to sediment mercury concentrations indicate that the performance of test organisms in the 10-day exposures was not affected by the gradient of THg or MeHg concentrations in sediment from AOC 4 sampling locations. Survival and growth endpoints were not statistically lower in AOC 4 sampling location treatments with sediment THg concentrations ranging from 0.943 mg/kg dw (RRM 0.1) to 18.9 mg/kg dw (RRM 3.5) or sediment MeHg concentrations ranging from 0.00183 mg/kg dw (1.83 ng/g dw) (RRM 0.1) to 0.102 mg/kg dw (RRM 3.5). The results of the screening evaluation of bulk sediment and interstitial sediment data are presented in Table 3-2.

Bulk Sediment

Concentrations of THg in bulk sediment samples were greater than the conservative criterion of 0.18 mg/kg in nearly all samples collected within each Assessment Reach, with the exception of RRM -2.7 to RRM -0.7 (see Table 3-2). However, a substantially lower number of Assessment Reaches contained bulk sediment samples with THg concentrations that exceeded the 18.9 mg/kg benchmark derived from site-specific THg sediment toxicity testing. Maximum THg concentrations were less than 18.9 mg/kg at seven of the 16 Assessment Reaches, primarily in the upstream Assessment Reaches, RRM -2.7 to RRM 1.7, and in Assessment Reaches further downstream, RRM 13.5 to RRM 20.9, and the SFSR. In the remaining Assessment Reaches, maximum THg concentrations in bulk sediment samples exceeding the site-specific criterion ranged from 24.2 mg/kg (RRM 20.9 to 24.0) to 884 mg/kg (RRM 4.4 to 5.2) (see Table 3-2 and Figure 3-1). With the exception of Assessment Reaches with zero exceedances, the number of samples exceeding the site-specific benchmark ranged from a low of two out of 36 samples collected (RRM 11.3 to 12.5) to a high of 35 out of 61 samples collected (RRM 4.4 to 5.2) (see Table 3-2 and Figure 3-1).

A total of 159 bulk sediment samples were collected for MeHg analysis among all Assessment Reaches. Only eleven (*n*=11) of these samples exceeded the site-specific benchmark for MeHg, 0.102 mg/kg. These exceedances occurred at seven of the 16 Assessment Reaches with maximum MeHg concentrations ranging from 0.103 mg/kg (RRM 7.9 to 9.2) to 0.389 mg/kg (RRM 11.3 to 12.5) (see Table 3-2 and Figure 3-1). With the exception of Assessment Reaches with zero exceedances, the number of exceedances per Assessment Reach ranged from a low of 1 out of 24 samples collected (RRM 9.2 to 11.3) to a high of 4 out of 11 samples collected (RRM 1.7 to 2.7) (see Table 3-2 and Figure 3-1).

Interstitial Sediment

The screening evaluations for mercury concentrations (THg and MeHg) in interstitial sediment are presented in Table 3-2. Concentrations of THg in bulk sediment samples were greater than the conservative criterion of 0.18 mg/kg in nearly all samples collected within each Assessment Reach, with the exception of RRM -2.7 to RRM -0.7 (see Table 3-2). Additionally, 11 of the 16 Assessment Reaches had maximum THg concentrations above the 18.9 mg/kg site-specific ESV. The only Assessment Reaches with maximum THg concentrations below the site-specific ESV were RRM -2.7 to -0.7, RRM -0.7 to 0.0, RRM 13.5 to 16.7, RRM 16.7 to 20.9, and the SFSR. In the remaining Assessment Reaches, maximum THg concentrations in interstitial sediment samples exceeding the site-specific ESV ranged from 24.6 mg/kg (RRM 9.2 to 11.3) to 211 mg/kg (RRM 2.7 to 4.4) (see Table 3-2 and Figure 3-1). With the exception of Assessment Reaches with zero exceedances, the number of samples exceeding the site-specific benchmark ranged from a low of 1 out of 59 samples collected (RRM 20.9 to 24) to a high of 42 out of 108 samples collected (RRM 2.7 to 4.4) (see Table 3-2 and Figure 3-1).

Concentrations of MeHg in interstitial sediments were below the site-specific criterion of 0.102 mg/kg in samples collected from Assessment Reaches from RRM -2.7 to RRM 2.7, as well as the South Fork Shenandoah River. Among the remaining Assessment Reaches, maximum MeHg concentrations ranged from 0.141 mg/kg (RRM 9.2 to 11.3) to 0.775 mg/kg (RRM 7.9 to 9.2) (see Table 3-2 and Figure 3-1). The Assessment Reach with highest number of interstitial sediment MeHg ESV exceedances was RRM 11.3 to 12.5 (20 exceedances out of 64 samples) (see Table 3-2).

Trace Metals, PAHs

Potential ecological exposures to trace metals and PAHs were estimated for interstitial sediment samples collected at eight Phase I sampling locations in South River in 2006 from March to September.

Concentrations for metals (mean and maximum) were compared to available benchmarks for freshwater sediment to evaluate the potential impacts to benthic invertebrate communities. Sediment thresholds used for metals included a no-effect screening value TEC and an effects-based threshold [Probable Effect Concentration (PEC)] from MacDonald et al. (2000).

Concentrations of total PAHs (tPAHs) in sediment were evaluated according to EPA guidance on the evaluation of PAH mixtures based on Equilibrium Partitioning (EPA, 2003). The toxicity of 13 individual PAH compounds is expressed as the sum of equilibrium sediment benchmark toxic units ($\Sigma ESBTU_{FCV}$), which represents the sum of the organic-carbon normalized sediment concentration divided by the organic-carbon normalized final chronic value (FCV) developed for each compound (EPA, 2003). For the purposes of $ESBTU_{FCV}$ calculations, 50 percent of the detection limit was used to estimate the concentration of PAH compounds below the detection limit. To account for other PAH compounds that were not measured in the sample, the sum of the toxic units for the 13 PAH compounds is multiplied by an uncertainty factor of 6.78, which estimates the toxic units of “total PAHs” with 80 percent confidence. If the $ESBTU_{FCV}$ calculated for a sample is greater than 1.0, PAH mixtures may exceed levels that are protective of benthic organisms (EPA, 2003).

The results of the exposure estimate for benthic invertebrates exposed to trace metals and tPAHs in South River are summarized as follows:

- Mean trace metal concentrations in interstitial sediment in AOC 4 generally increase downstream of Waynesboro and again at the confluence with Mine Creek (RRM 8.7). While the maximum detected concentrations exceed TEC values for several trace metals in several Assessment Reaches, they do not exceed the corresponding PEC values, with the exception of cadmium, for which only the maximum detected concentrations (i.e., one of eight samples) exceed the PEC..

Mean concentrations for most trace metals were between TEC and PEC levels (see Table 3-3).

- tPAH concentrations in sediment in AOC 4 also increase downstream of Waynesboro (RRM 0.6 and 3.0) and then appear to rapidly decline. ESBTUs for PAH mixtures were less than 1.0 for all sampling locations evaluated in South River (see Table 3-4).

3.2.5 Surface Water Data Evaluation

Surface water data were screened for mercury species, total metals, and PAHs. Sample collection and analysis was described in URS (2008), included as Appendix B.

Mercury Species

Surface water datasets were evaluated separately based on flow conditions and the fraction analyzed. Baseline flow surface water data represented conditions when subsurface flows contribute the majority of stream flow. Storm flow data were defined by samples collected at flow conditions greater than baseline flow. Baseline flow and storm flow surface water datasets were further partitioned into filtered and unfiltered samples (see Tables 3-5 and 3-6 and Figure 3-2).

ESVs for THg [(770 nanograms per liter (ng/L) in filtered sample and 908 ng/L in unfiltered sample] and MeHg (4 ng/L) in surface water were based on Virginia Water Quality Criteria (VAWQC), EPA water quality criteria documents, and/or EPA Region3 *Freshwater Screening Benchmarks*. THg concentrations in filtered samples were evaluated relative to the chronic VAWQC of 770 nanogram per liter (ng/L), which is consistent with the EPA National Recommended Water Quality Criteria (NRWQC) for the chronic protection of aquatic life. In unfiltered samples, THg concentrations were evaluated relative to the criteria continuous concentration (CCC) of 908 ng/L derived in EPA (1995). The CCC provided the basis for the dissolved (filtered) criterion used by VAWQC and NRWQC. Concentrations of MeHg in filtered and unfiltered samples were evaluated relative to the EPA Region 3 freshwater screening benchmark of 4 ng/L, which was originally published by the Canadian Council of Ministers of the Environment (CCME) in the *Canadian Environmental Quality Guidelines*: *Summary Table* (December 2003). The results of the screening evaluation of surface water under baseline flow and storm flow conditions are presented in Tables 3-5 and 3-6, respectively.

Baseline flow

During baseline flow conditions, concentrations of THg in unfiltered samples were below the VDEQ criterion (908 ng/L) in all but one sample, collected in Assessment Reach RRM 7.9 to RRM 9.2 (2,727 ng/L). A total of 1,250 unfiltered baseline flow surface water samples was collected for MeHg analysis among all Assessment Reaches. Only twenty-four (n=24) of these samples exceeded the ESV for MeHg, 4 ng/L. These exceedances occurred at eight of the 16 Assessment Reaches with maximum MeHg concentrations ranging from 4.2 ng/L (RRM 1.7 to 2.7) to 7.5 ng/L (RRM 4.4 to 5.2) (see Table 3-5 and Figure 3-2).

Similar to unfiltered, during baseline flow conditions, concentrations of THg in filtered samples were below the VDEQ criterion (770 ng/L) for all data. A total of 1,721 filtered baseline flow surface water samples was collected for MeHg analysis among all Assessment Reaches. Only 16 (*n*=16) of these samples exceeded the ESV for MeHg, 4 ng/L. These exceedances occurred at four of the 16 Assessment Reaches with maximum MeHg concentrations ranging from 5.3 ng/L (RRM 20.9 to 24) to 62 ng/L (RRM 1.7 to 2.7) (see Table 3-5 and Figure 3-2).

Stormflow

During stormflow conditions, maximum concentrations of THg in unfiltered surface water exceeded the ESV (908 ng/L) in six of the 13 Assessment Reaches sampled, with maximum THg concentrations ranging from 1,501 ng/L (RRM 1.7 to 2.7) to 4,656 ng/L (RRM 20.9 to 24). With the exception of Assessment Reaches with zero exceedances, the number of unfiltered samples exceeding THg criterion ranged from 1 in 36 samples collected (RRM 1.7 to 2.7) to 10 in 53 samples collected (RRM 13.5 to 16.7) (see Table 3-6 and Figure 3-2). Similar to THg, maximum concentrations of MeHg in unfiltered surface water exceeded the ESV (4 ng/L) in six of the 10 Assessment Reaches sampled, with maximum MeHg concentrations ranging from 4.3 ng/L (RRM 1.7 to 2.7) to 28 ng/L (RRM 20.9 to 24). With the exception of Assessment Reaches with zero exceedances, the number of unfiltered samples exceeding MeHg criterion ranged from one out of 33 samples collected (RRM 1.7 to RRM 2.7) to six out of 28 samples collected (RRM 20.9 to RRM 24) (see Table 3-6 and Figure 3-2).

During stormflow conditions, THg and MeHg concentrations in filtered surface water were below surface water criteria (770 ng/L and 4 ng/L, respectively) for all data collected (see Table 3-6). However, filtered and unfiltered stormflow samples were not collected for THg and MeHg analysis at Assessment Reaches RRM 2.7 to RRM 4.4, RRM 7.9 to RRM 9.2, and RRM 12.5 to 13.5. Additionally, filtered and unfiltered samples were not collected for MeHg analysis at Assessment Reaches RRM 0.8 to RRM 1.7, RRM 11.3 to RRM 12.5, as well as in the South Fork Shenandoah River.

Trace Metals, PAHs, OCPs

Surface water samples were collected at eight Phase II sampling locations and were analyzed for filtered trace metals, PAHs, and OCPs. Samples were collected during baseline flow conditions. The maximum detected results were compared with ESVs based on chronic VAWQC or other relevant benchmarks (e.g., Suter and Tsao, 1996) if no VAWQC were available. The complete screening results are described in URS (2008), included as Appendix B.

Trace metals were consistently detected at concentrations below the hardness-adjusted chronic VAWQC for freshwater at the South River sampling locations and at reference sampling locations. No PAHs were detected.

Four OCPs were detected: delta benzene hexachloride (BHC), endosulfan I, gamma-lindane, and heptachlor. With the exception of heptachlor, maximum detections for OCPs were below the relevant benchmark (VAWQC value of 3.8 ng/L). Heptachlor was detected in four of 35 samples, with maximum detections slightly above the benchmark at two sampling locations (6 ng/L at RRM 3.0, and 4.7 ng/L at RRM 8.7).

3.2.6 Soil Data Evaluation

Screening evaluations for soil was performed only for mercury because historically mercury was the focus of the investigations and only mercury was analyzed in soils. Soil datasets (collections up to December 31, 2013 inclusive) were evaluated separately based on floodplain by Assessment Reach and by sample depth. Where data were available, floodplain extents included 0.3-year, 2-year, 5-year, and 62-year flood intervals (see Figure 3-3). Samples taken within 0 to 0.5 feet from the surface were designated as surficial while samples taken from 0.5 to 2.0 feet from the surface were designated as sub-surface.

Samples collected from the 0 to 2.0 foot depth interval were included in the screening evaluation. This sampling depth is conservative because the 0-1 feet is the soil interval with the greatest exposure to soil invertebrates and plants. Suter (2007) indicates that that earthworms are most abundant in near-surface soils, defined approximately as 2 – 30 centimeters (cm) below ground surface (bgs) or approximately 0.1 to 1.0 foot bgs. This depth interval is consistent with the common default sampling depth for plants; therefore, Suter (2007) indicates that the top 30 cm sampling interval is appropriate for evaluating exposure to plants and soil invertebrates. Soil chemistry data from the 0 to 1-foot sampling depth provides representative exposure point concentrations (EPCs) for evaluating direct contact exposure pathways to plants and soil invertebrates, as well as EPCs that may be used to estimate bioaccumulation into plants and soil invertebrates that may be consumed by upper trophic terrestrial wildlife. Deeper sample intervals are not warranted, as the 2008 soil sampling event (URS, 2012) found that soil concentrations were higher in the 0 to 0.5-foot interval than the 0.5- to 2.5-foot interval in 440 of 548 samples (80%). This result also supports the decision to screen the 0 to 0.5-foot interval separately, as this interval is indicative of the maximal THg exposure in soil.

The ESV for THg in soil was based on the maximum concentration observed in the uncontaminated Upstream Reference Reach, RRM -2.7 to RRM -0.7, 0.18 mg/kg. This concentration is assumed to be local background and is in agreement with the range of background mercury concentrations reported for VA by the USGS (Shacklette and Boerngen, 1984). The results of the screening evaluation of soil are presented in Table 3-7.

Generally, the highest THg concentrations were observed in soils collected from the 0.3-year, 2-year, and 5-year floodplains from RRM 0.0 to RRM 24. In the 0.3-year floodplain, the portion of samples exceeding the ESV (# exceedances/ sample size) in the sub-surface soils was generally similar to or greater than the portion of samples exceeding the ESV in the surface soils, per Assessment Reach (see Table 3-7 and Figure 3-3). Conversely, in the 2-year, 5-year, and 62-year floodplains, the portion of samples exceeding the ESV was generally greater in the surface soils than the sub-surface soils per Assessment Reach (see Table 3-7 and Figure 3-3).

3.2.7 Summary

Screening evaluations indicate that trace metals, OCPs, and PAHs in surface water and sediment are present in AOC 4 at concentrations that are unlikely to cause adverse ecological effects. Screening evaluation for soil focused on mercury. Based on screening evaluations for mercury, the following conclusions can be drawn regarding the distribution of THg and MeHg in sediment, surface water, and soil from AOC 4:

- THg concentrations exceeded the conservative ESV in nearly all interstitial and bulk sediment samples; however, a substantially lower number of samples contained THg concentrations exceeding the site-specific no-effect benchmark derived from sediment toxicity testing.
- MeHg concentrations exceeded the site-specific no-effect benchmark in a limited number of interstitial and bulk sediment samples.
- THg and MeHg concentrations in surface water samples collected during baseline flow conditions were below ESVs in nearly all samples.
- THg concentrations in surface and sub-surface soil samples exceeded the ESV in a majority of 0.3-year, 2-year, and 5-year floodplain samples from RRM 0.0 to RRM 24; Maximum concentrations of THg in surface soil exceeded the ESV in all AOC 4 Assessment Reaches and floodplains, with the exception of South Fork Shenandoah River; Maximum concentrations of THg in sub-surface soil exceeded the ESV in all Assessment Reaches and floodplains, with the exception of RRM 4.4 to 5.2 (62-year floodplain) and RRM 12.5 to 13.5 (62-year floodplain).

Based on the results of the COPEC selection phase, mercury has been retained as the primary COPEC in the AOC 4 for further evaluation, which is focus of the rest of this report.

3.3 Ecotoxicity of Mercury

This section provides a general introduction of mercury speciation in AOC 4 and toxicity to ecological receptors. A detailed effects analysis for representative ecological receptors is provided in Section 4.

The analysis of potential effects of mercury on AOC 4 ecological receptors focuses on inorganic complexes of divalent mercury [Hg(II); IHg] and MeHg. Although elemental mercury [Hg(0)] was used at the site, mercury speciation in off-site areas is likely restricted to IHg and MeHg. This is based on the history of mercury use at the former DuPont Waynesboro Plant, modes of transport from the plant to the watershed, and dominant biogeochemical reactions in surface water, sediment and floodplain soil.

During the period when mercury was used at the site, Hg(0) was transported to the site and converted to mercuric [Hg(II)] sulfate for use as catalyst. Retorting the spent catalyst and spills likely introduced Hg(0) to site subsurface (e.g. sewers). As such, on-site investigations have identified Hg(0) in portions of the Pumphouse Sewer and Chemical Sewer in the area of the former Chemical Building and former Mercury Recovery Area.

Hg(0) in dark anaerobic environments is persistent – Hg(0) droplets in these environments form surface coatings of oxidized Hg(II) species that limit the volatilization and promote persistence of Hg(0) (Amyot et al. 2004) and solubility and transport of Hg(II). As a result, mercury has been detected in plant outfalls as Hg(II) and Hg(0) [detectable as dissolved gaseous mercury (DGM)] (Turner and Jensen, 2005). However, since the extensive remediation of the plant sewers, the loads from the plant are likely to decrease substantially.

Upon mixing with the South River, DGM concentrations decrease as the Hg(0) in solution rapidly volatilizes to the atmosphere (Turner and Jensen, 2005). Local increases in DGM may result from inputs of Hg(II) from bank erosion or other sources. DGM is generated from Hg(II) via photochemical reactions (e.g., Zhang and Lindberg, 2001). As it is produced, DGM rapidly volatilizes to the atmosphere. The dominant species of mercury transported by surface water are particulate associated IHg (log K_d = 6-7), small complexes or adsorbed to colloids [detectable as reactive mercury ($Hg(II)_R$)] and MeHg (Flanders et al., 2010). Inorganic mercury can be converted to MeHg by a diverse array of anaerobic microbial organisms through the process of methylation (Compeau and Bartha, 1985; Fleming et al., 2006). Although MeHg has been discharged directly to the environment in some cases (e.g., Minamata Bay, Japan; Ekino et al., 2007), there are currently few direct anthropogenic sources of MeHg to the environment (Boening, 1999).

In soil, chemical analysis has confirmed that mercury is present as IHg and MeHg. Selective sequential extractions (SSE) and extended X-Ray Absorption Fine Structure (EXAFS) have demonstrated that 65-89% of THg in soil is present as metacinnabar or Hg-thiol, the most stable of the Hg complexes (Ptacek et al., 2013). Metacinnabar is also less bioavailable than other Hg complexes. Previous SSE results observed low mercury concentrations in the water soluble (F1) fraction (7 ng/L; Flanders et al., 2010), indicating that Hg(0) does not account for the species of mercury seen in the F4 fraction (the fraction where Hg(0), if present, would be found); other forms of mercury found in the F4 fraction include Hg(I) compounds, and Hg(II)-humic complexes (Bloom et al., 2003). MeHg is present at low concentrations in soil (<0.1% of total; Cianchetti et al., 2008).

Similar to Hg (II) in surface water, it is possible that Hg(II) can be reduced to Hg(0) in soil by both biotic and abiotic pathways. However, the vast majority of Hg(II) in soil is not available for reduction and release to the atmosphere (Obrist et al., 2010). Abiotic pathways include reduction of Hg(II) by humic substances (Alberts et al., 1974) and ultraviolet (UV) radiation (particularly UV-B; Choi and Holsen, 2009). Hg(II) can be reduced by both aerobic and anaerobic bacteria; rates are higher under anaerobic, reducing conditions (Obrist et al., 2010). The reduction of Hg(II) to Hg(0) does not result in formulation of Hg(0) droplets (Hussein et al., 2007).The adverse effects of mercury depend on its speciation and route of exposure. Inorganic mercury is primarily nephrotoxic in wildlife, but in some laboratory exposures, other effects, including enzyme inactivation and genotoxicity have been observed (Wolfe et al., 1998). Exposure to IHg is primarily via ingestion or direct contact (Wolfe et al., 1998).

MeHg is the mercury species of greatest concern for wildlife health. MeHg is absorbed 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 exposure via ingestion of food items is the primary exposure route for MeHg. The toxicokinetics and biotransformation of MeHg differs from IHg; MeHg is slower to depurate than other mercury species (Scheuhammer et al., 2007) and 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; EPA, 1997; Basu et al., 2005). In contrast, IHg partitions evenly in blood between protein and plasma, is poorly transported across the blood-brain barrier, and is stored primarily in the kidney and liver. Exposure to MeHg has been hypothesized 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).

3.4 Preliminary Risk Management Goals

An important component of the risk assessment process is the definition of a risk management goal [*Presidential/Congressional Commission on Risk Assessment and Risk Management* (PCCRARM), 1997). Risk management goals are a key step in the problem definition stage, and help guide the risk analysis process. They may be refined based on remedial feasibility (PCCRARM, 1997) or as new information becomes available. The preliminary risk management goals are defined as follows:

- Substantively reduce THg and MeHg concentrations in surface water and fish tissue and MeHg production in sediments in the South River and SFSR.
- Relax fish consumption advisories in the South River and SFSR through the reduction in fish mercury body burden.
- Reduce MeHg exposure to ecological receptors in the South River and SFSR.
- Improve habitat conditions to enhance ecological functions in the South River channel within AOC 4.

3.5 Ecological Conceptual Site Model (ECSM)

The ECSM is a representational understanding of mercury movement in AOC 4 from primary sources to ecological receptors. The ECSM synthesizes and summarizes extensive site-specific information from the Ecological Study and data collected on AOC 4 and data analysis by SRST scientists to identify potentially complete exposure pathways. The ECSM:

- Describes the fate and transport of mercury, focusing on the key linkages between mercury sources and potential receptors.
- Incorporates fate and transport of mercury in AOC 4 through identification of potentially complete pathways.
- Identifies ecological receptors that may be exposed to mercury.

The ECSM for ecological exposure in AOC 4 is presented in Figure 3-4.

3.5.1 Contaminant Fate and Transport

The exposure of ecological receptors to mercury is dependent on the fate and transport, which links the sources of contamination to exposure media via release and transport mechanisms, which are described in detail below.

Sources of Mercury

The fate and transport of mercury is more complex than for other metals because of mercury methylation, which is a biological process where IHg is converted to MeHg by bacteria in anoxic sediment. The IHg that is converted to MeHg in sediment is a mixture of IHg released in the past and ongoing sources that are active today. The Ecological Study (URS, 2012) provided a detailed ranking of the sources of IHg to the South River based on a mass balance approach, and contains detailed information regarding the annual loads from each source. The sources of IHg to the South River are ranked in the following order:

- Bank erosion
- Invista plant (site) outfall
- Fluxes from deep to shallow sediment
- Tributaries/floodplain runoff
- Groundwater
- Bank leaching
- Atmospheric deposition

The largest source is estimated to be erosion of soil from river banks with IHg derived from that previously released from the facility and deposited on river banks. River bank erosion is not a source of MeHg to AOC 4. There are two primary bank substrate types contributing to IHg loads. The first type is associated with the existing river banks where suspended sediment was deposited during storm events. The other type of is associated with historical release-age deposits (HRADs), which are areas where sediment (silt and clay) has been deposited in large amounts on the channel margins due to historical flow patterns in the river. These formed around the time when mercury was in use at the site (1929-1950) and as such tend to have higher mercury concentrations than other banks. HRADs are found throughout the South River, but the majority (39 of 46) is found between RRM 1.5 and RRM 11.6.

Mercury loading from the site is the second largest IHg source to the South River. There is little MeHg loading from the site due to low concentrations of MeHg in outfall water. Since the beginning of routine monitoring as part of the RCRA corrective action in 1998 the average IHg mercury load has been approximately ~1 g/d. Several interim remedial measures have been conducted at the site to remove mercury from the storm water system. In response, the loads were temporarily higher than 1g/d but are declining to pre-remediation levels. It is currently not known how long the site will continue to act as a mercury source, but interim remedial measures are being designed with the goal of eliminating IHg loads under baseline flow conditions.

The two largest sources of IHg are located in the upstream segments of the South River, and few if any discrete sources are located in downstream of approximately RRM 12. This is supported by the findings of loading studies (URS, 2012; Hydroqual, 2009) which found that under baseline flow conditions there was no net positive loading of IHg below approximately RRM 12. However, there are other diffuse sources of mercury that are likely important in both the South River and SFSR.

Diffusive fluxes of IHg from sediment stored in the gravel matrix of the river bed are estimated to be the third highest IHg source to the South River. Flux from sediment is the single most important source of MeHg to the water column. Given the importance of aqueous exposure for MeHg uptake by clams and other invertebrates (URS, 2012), sediment flux is an important component in MeHg fate and transport in the South River.

Several other sources contribute relatively small IHg and MeHg loads to the South River. Bank leaching, the process by which soil particles dissolve in the presence of water and mercury, is transported through soil pore spaces via advection, is estimated to be a minor source of IHg and MeHg to the South River (URS, 2012); however, interactions between surface water and bank soils are an ongoing area of study. Likewise, while groundwater may account for ~30% of river discharge in some reaches (Grosso, 2006), relatively low mercury concentrations have been observed in alluvial groundwater from the South River. The average 0.45 µm filtered groundwater THg and MeHg concentrations <10 ng/L and <1 ng/L, respectively (URS, 2012). Despite their role in draining areas of the floodplain with high mercury concentrations in soil, tributaries and floodplain drainage channels represent small sources to the river (URS, 2012). This is largely due to the fact that most tributaries are intermittent, and only flow during storm events, and have relatively low mercury concentrations.

AOC 4, like most aquatic systems in the northeastern United States, receives mercury from atmospheric deposition. Smallmouth bass from background (reference) areas (e.g., North River), which receive mercury from atmospheric deposition alone, contained THg concentrations ranging from 0.1 to 0.3 mg/kg THg (VDEQ, 2007), nearly 100% of which is present as MeHg (Bloom, 1992). Although this concentration is lower than what is found in AOC 4, it is only slightly below the EPA-recommended tissue-based water quality criterion of 0.3 mg/kg MeHg (EPA, 2010).

Release and Transport Mechanisms

Although the site was the original source of mercury and continues to discharge mercury today, the primary release and transport mechanisms resulting in ecological exposures are floodplain-river interactions and mercury methylation and bioaccumulation.

Floodplain-River Interactions

The present day and historical hydrologic dynamics between the South River and its floodplain are the primary drivers of IHg transport in the South River. Historically, IHg from the site adsorbed to solids, settled out, and was deposited and stored in the floodplain or as sediment in the stream channel. Sediment is stored in the gravel matrix of the stream bed and in deposits along the channel margins, often behind obstructions such as large woody debris, rocks, boulders, or storm-related debris piles. Some areas of sediment storage in the channel remained and became a more permanent part of the floodplain. Over time, eroded floodplain soils or resuspended sediments have served as an ongoing source of suspended mercury-impacted sediment.

Mercury Methylation and Bioaccumulation

An important component of the ECSM is mercury methylation and bioaccumulation. Mercury methylation is the primary mechanism that links the presence of mercury in media to biological receptors in the South River system. Mercury methylation is a biochemical reaction in which IHg is taken up by bacteria and converted to MeHg, which has different chemical, physical, and toxicological properties than IHg. A key difference between the two species is that MeHg is much more efficiently bioaccumulated than IHg.

Mercury methylation is performed by anaerobic bacteria, including sulfate- and iron-reducing bacteria in anoxic or suboxic aquatic habitats. In the South River, areas of mercury methylation are diffuse throughout the system, and likely include limited areas of wetlands and remnant channels on the floodplain, fine-grained sediment deposits located in the channel, or the hyporheic zone, the area below the streambed where significant interactions occur between surface water and groundwater (Flanders et al., 2010; Yu et al., 2012). While wetlands are not prominent features along the South River Floodplain, they are generally considered to provide favorable geochemical conditions for methylation (i.e., organic carbon, anoxic or suboxic sediment, and electron acceptors), and as such may be important sources of MeHg to ecological receptors foraging in wetlands, such as wading birds, invertebrates, and mammals. Fine-grained sediment deposits provide favorable conditions for methylation and sequester high concentrations of IHg. Much of the channel margin area, particularly in the first few miles of the South River, consists largely of fine-grained sediment. The hyporheic zone may be an important source of MeHg in aquatic systems due to a high surface area and the presence of fine-grained sediment within the gravel matrix of the hyporheic zone.

The link between areas of methylation and mercury exposure is important. MeHg, once produced, can adsorb to particles or flux from sediment to pore water or overlying water via advection and diffusion. These particles can then serve as food items for detritus-feeding and filter-feeding aquatic invertebrates, which form the basis of the aquatic food web.

Exposure Media

Mercury is present in environmental media in AOC 4 due to the fate and transport pathways described above. As shown in the ECSM (see Figure 3-4), exposure media relevant to ecological exposure in the AOC 4 are as follows:

- Soil
- Sediment
- Pore water
- Surface water
- Biological tissue

Ecological receptors may encounter these media through their use of certain habitats, through their feeding habits or indirectly via their feeding behavior. These exposure routes are discussed below.

Exposure Routes

Ecological receptors in AOC 4 can be exposed to mercury via several routes. These exposure routes are as follows:

- Direct contact exposure to abiotic media (surface water, sediment, pore water, and soil)

- Ingestion of aquatic and terrestrial biota
- Incidental ingestion of sediment or soil particles during feeding

The South River has a relatively complex and robust aquatic food web that has substantially improved since the advent of the Clean Water Act (URS, 2012); some areas have degraded benthic macroinvertebrate communities due to sedimentation and high nutrient concentrations (VDEQ, 2009). The aquatic community however, is able to efficiently biomagnify MeHg. Understanding the structure of this food web is the key to determining potential risk to ecological receptors in the aquatic habitats of AOC 4. The Ecological Study Final Report (URS, 2012) provides detailed descriptions of the biological communities of the South River.

The benthic macroinvertebrate communities are key components of the aquatic food web. Benthic macroinvertebrates feed on surfaces that trap suspended sediment with high concentrations of IHg and MeHg. As such, they are the base of the food web, serving as dietary items for the large variety of forage fish. In addition to being key components in the aquatic food web, aquatic invertebrates are also an important food item for terrestrial ecological receptors. Benthic macroinvertebrates are in direct contact with secondary sources (sediment, pore water, and surface water).

Invertivorous forage fish and piscivorous (i.e., fish eating) fish are also potential aquatic ecological receptors. Large fish [e.g., smallmouth bass (*Micropterus salmoides*)] are important sport fish and provide food items for semi-aquatic ecological receptors. They are potentially exposed to mercury through dietary pathways and through contact with surface water.

Semi-aquatic receptors include organisms that roost or nest in a terrestrial environment but forage in the aquatic habitats of AOC 4. This group may include amphibians, reptiles, omnivorous birds, and piscivorous birds and mammals. Some semi-aquatic receptors (e.g., some amphibians and reptiles) may also feed on terrestrial dietary items.

Terrestrial ecological receptors include vegetation, invertebrates, birds and mammals. Some may be exposed to mercury from both terrestrial and aquatic sources of mercury.

Exposure Pathways

The ECSM (see Figure 3-4) provides a graphical depiction of the potentially complete exposure pathways present in the South River. The following sections describe the more significant aspects of this exposure in the AOC 4.

There are several categories of exposure pathways:

- Potentially complete and significant
- Secondary exposure pathway
- Complete but insignificant

Potentially complete and significant pathways will be evaluated quantitatively using the food, water, and sediment/soil ingestion rates. The quantitative evaluation is described further in the selection of candidate measurement endpoints (see Section 3.6). Secondary exposure pathways include those that are complete but for which sufficient information does not exist to warrant a separate quantitative evaluation. These pathways will be accounted for through an alternative approach, such evaluation of whole body mercury concentrations.

Some pathways are considered complete but insignificant. These pathways have been included for completeness. For example, direct contact exposure to wildlife receptors is not considered to be a significant pathway relative to dietary pathways due to low frequency and/or duration of exposure and limited contribution to overall exposure (EPA, 2003). Dermal exposure to terrestrial wildlife is reduced by the feathers of birds, fur on mammals, and scales on reptiles, which limit the contact of the skin surface with constituents in soil. Relative to ingestion pathways, the dermal exposure pathway to wildlife is particularly limited for metals because most metals bind to soils and are unlikely to dissociate from soil to cross the skin even if contact occurs (EPA, 2003). Table 3-7 lists the potentially complete exposure pathways for each ecological receptor category.

Direct Contact with Surface Water

Direct contact with surface water is potentially complete for benthic macroinvertebrates, fish, SAV, and amphibians. Exposure may be through contact with membranes (e.g., skin) or through uptake via gills. Reptilian, avian and mammalian ecological receptors have protective biological membranes or other biological features that prohibit the uptake of mercury (EPA, 2003). For this reason, this pathway has been classified as complete but insignificant and will not be evaluated.

Ingestion of Surface Water

Semi-aquatic and terrestrial avian and mammalian ecological receptors ingest surface water as drinking water. This pathway will be evaluated quantitatively for these receptors. Incidental ingestion is a complete secondary pathway for benthic macroinvertebrates, fish, amphibians, and reptiles but will not be evaluated quantitatively. However, by evaluating the whole body mercury concentrations of benthic invertebrates, fish, amphibians and reptiles, the evaluation will account for mercury exposure by incidental ingestion.

Ingestion of Aquatic Biota

The direct ingestion of aquatic biota is a complete pathway for many aquatic and semi-aquatic organisms, and an important mercury exposure route for ecological receptors. Organisms may be exposed through consumption of benthic macroinvertebrates and fish from the aquatic habitats of the AOC 4 study area. In addition, some terrestrial insectivorous avian and mammalian receptors (i.e., bats) feed heavily on emergent aquatic insects or other dietary items (e.g., crayfish) directly from the river.

Direct Contact with Sediment and Pore Water

Aquatic and semi-aquatic ecological receptors that dwell or forage in sediment may be exposed via direct contact with sediment and/or sediment pore water. These include benthic macroinvertebrate communities, SAV, and reptiles and amphibians, which may inhabit or feed in areas of fine-grained sediment deposition. Reptilian, avian and mammalian ecological receptors have protective biological membranes or other biological features that prevent the uptake of mercury by dermal exposure (EPA, 2003). For this reason, this pathway has been classified as complete but insignificant and will not be evaluated.

Ingestion of Sediment

Sediment may be ingested incidentally by several aquatic and semi-aquatic ecological receptors during feeding. For piscivorous birds and mammals and omnivorous birds, incidental sediment ingestion will be quantitatively evaluated through the use of food web models, using published or generally accepted sediment ingestion rates. Incidental sediment ingestion is a complete secondary pathway for benthic macroinvertebrate communities, reptiles and amphibians but will not be evaluated quantitatively. However, by evaluating the whole body mercury concentrations of benthic invertebrates, fish, amphibians and reptiles, the evaluation will account for mercury exposure by incidental ingestion.

Direct Contact with Floodplain Soils

Semi-aquatic and terrestrial receptors that derive some portion of their diet or spend part of their life history in the floodplain of AOC 4 are potentially exposed to soil-associated mercury. Soil dwelling receptors including the terrestrial vegetation and soil invertebrates may be exposed through direct contact with soil. Some avian, mammalian, and reptilian receptors contact soil through feeding or burrowing but have biological membranes or materials that prevent uptake of mercury by dermal exposure (EPA, 2003). Amphibians may come into contact with soil for some portion of their life history, such as reproduction or feeding, so this pathway has been classified as a secondary pathway, which will not be quantified. However, by evaluating the whole body mercury concentrations of amphibians, the evaluation will account for mercury exposure by incidental ingestion.

Ingestion of Floodplain Soils

Several semi-aquatic and terrestrial ecological receptors may ingest floodplain soil during feeding for some portion of their diet. Invertivorous and herbivorous mammals may be exposed to soils through indirect ingestion associated with the consumption of primary food items. Incidental ingestion will be quantitatively evaluated through the use of food web models, using published or generally accepted soil ingestion rates. Amphibians and reptiles may ingest some soil incidentally, so this pathway has been classified as a secondary pathway, which will not be quantified. However, by evaluating the whole body mercury concentrations of amphibians and reptiles, the evaluation will account for mercury exposure by incidental ingestion.

Ingestion of Terrestrial Biota

Terrestrial and some semi-aquatic predatory organisms may prey on organisms that are exposed to mercury from terrestrial soils. Although mercury methylation is limited in infrequently inundated soils relative to more frequently inundated soils (e.g., Skyllberg et al., 2003), food web analysis of the South River suggests that biomagnification of soil-associated MeHg is possible (Newman et al., 2011).

3.6 Assessment Endpoints, Risk Questions and Candidate Measurement Endpoints

Appropriate assessment endpoints focus the risk assessment on particular components of the ecosystem that could be adversely affected by COPECs (EPA, 1997). Assessment endpoints were selected based on the following:

- The selection of mercury as the primary COPEC and its mechanism of toxicity;
- The potential ecological receptor groups present in the AOC 4 watershed; and
- The potentially complete exposure pathways.

Assessment endpoints were selected to assess risks at a population- or community-level of organization. Population-level effects generally depend on extrapolating effects from individual organisms (e.g., individual growth rate) to attributes of populations (population growth rate; Barnthouse, 2008). Community-level effects are evaluated when possible to determine potential impairment of the structure and function of ecological communities (e.g., benthic invertebrates and fish,). The assessment endpoints, level of organization, and a representative focal species are provided in Table 3-9.

The assessment endpoints were selected to define the ecological value in such a way that specific hypotheses or risk questions can be postulated and specific measurement endpoints (MEs) can be selected. Risk questions identify potential specific responses of the assessment endpoints when exposed to mercury. The risk questions set up the potential lines of evidence that can be used to provide and answer and measure of effect.

The MEs are specific characteristics of the environment that is a numerical expression of the valued ecological characteristic, and may be a measure of effect or exposure (EPA, 1997). The MEs contain information as to which mercury species (i.e., THg, IHg or MeHg) will be evaluated. The assessment endpoint, risk questions, and MEs for the receptor groups are included in the following sections and tables:

- Section 3.7.1: Aquatic Receptors (see Table 3-10)
- Section 3.7.2: Semi-Aquatic Receptors (see Table 3-11)
- Section 3.7.3: Terrestrial Receptors (see Table 3-12)

3.6.1 Aquatic Receptors

Benthic Invertebrates

- Population Level: Survival, Growth and Reproduction of Benthic Invertebrates
  - Risk Question: Is mercury in abiotic (sediment, sediment pore water, and surface water) and biotic (tissue residues in invertebrates) media from AOC 4 present at concentrations that may result in adverse effects on the survival, growth or reproduction of benthic invertebrates?
  - Measurement endpoints (MEs):
    - ME #1: Comparison of exposure point concentrations [EPCs, the lower of the 95% upper confidence limit of the mean (95% UCL) or

the maximum detected concentrations] for THg and MeHg in surface water, pore water, and sediment to corresponding ecotoxicity benchmarks protective of the survival, growth, or reproduction of benthic invertebrates.

    - ME #2: Statistical comparison ($p<0.05$) of the survival and growth of test organisms exposed to sediment from AOC 4 with that of organisms exposed to sediment from Reference Reaches.
    - ME #3: Comparison EPCs for THg tissue residues (in whole body invertebrate tissue) to critical body residue (CBR) thresholds associated with effects on survival, growth, or reproduction of benthic invertebrates.

- Community Level: Structure of the Benthic Community
  - Risk Question: Are the structures of benthic invertebrate communities at sampling locations within AOC 4 compared to Reference Reaches indicative of impairment that is consistent with mercury concentrations measured in environmental media (e.g., sediment, pore water, and/or surface water)?
  - Measurement Endpoints (MEs):
    - ME #1: Statistical comparisons of benthic community metrics ($p<0.05$) including, richness, composition, and tolerance/intolerance metrics from sampling locations in AOC 4 to sampling locations in Reference Reaches.
    - ME #2: Multivariate statistical comparisons ($p<0.05$) of benthic community structure based on species-abundance data from sampling locations in AOC 4 to sampling locations in Reference Reaches.

Fish

- Population Level: Survival, Growth, and Reproduction of Fish Populations
  - Risk Question 1: Is mercury in surface water from AOC 4 present at concentrations that may result in adverse effects on survival, growth, or reproduction of fish?
  - ME #1: Comparison of the EPCs for THg and MeHg in surface water to water-quality criteria for the survival, growth or reproduction of fish.
  - Risk Question 2: Is mercury in fish tissue from AOC 4 present at concentrations that may result in adverse effects on survival, growth, or reproduction of fish?
  - ME #2: Comparison of the EPCs for THg in whole body fish tissue to CBR thresholds associated with effects on survival, growth, or reproduction.

- Risk Question 3: Is the age and growth in fish from AOC 4 different or lower compared to the same metrics in Reference Reaches?
- Measurement Endpoint 3: Statistical comparison ($p<0.05$) of the age and growth of fish from AOC 4 to rivers in the region or state.
- Risk Question 4: Is the body condition of fish from AOC 4 different or lower compared to the same metrics in Reference Reaches?
- Measurement Endpoint 4: Statistical comparison ($p<0.05$) of the condition of fish from AOC 4 to rivers in the region or state.

- Community Level: Structure of the Fish Community
  - Risk Question 1: Are the structures of the fish communities at sampling locations within AOC 4 and Reference Reaches indicative of impairment that is consistent with mercury concentrations measured in environmental media (e.g., surface water)?
  - Measurement Endpoint 1: Qualitative comparisons of fish community structures, including total abundance, taxa richness, family-level and feeding guild distribution from sampling locations in AOC 4 to Reference Reaches.

Submerged Aquatic Vegetation (SAV)

- Population Level: Survival and Growth of SAV
  - Risk Question: Is mercury in sediment, pore water, or surface water from AOC 4 present at concentrations expected to cause adverse effects to aquatic plants?
  - ME #1: Comparison of the EPCs for THg in pore water and surface water against benchmarks for the survival and growth of aquatic plants.

3.6.2 Semi-Aquatic Receptors

Amphibians: Survival, Growth, and Reproduction

- Risk Question: Are the concentrations of mercury in sediment, surface water, pore water or soil from AOC 4 greater than benchmarks that are protective of survival, growth, or reproduction of amphibians?
- ME #1: Comparison of the EPCs for THg and MeHg in pore water and surface water from AOC 4 to benchmarks for the survival, growth, or reproduction of amphibians.

Piscivorous Birds: Survival, Growth, and Reproduction

- Risk Question: Is mercury present in dietary items at levels where effects on survival, growth or reproduction of piscivorous birds may be expected?

- ME #1: Comparison of the estimated daily mercury intake rate (DMIR) based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).
- ME #2: Comparison of the EPCs for tissue THg and/or MeHg (e.g., in blood) for piscivorous birds from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.

Omnivorous Birds: Survival, Growth, and Reproduction

- Risk Question: Is mercury present at levels in the dietary items or incidentally-ingested sediment where effects on survival, growth, or reproduction of omnivorous birds may be expected?

  ME #1: Comparison of the estimated DMIR based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).

Piscivorous Mammals: Survival, Growth, and Reproduction

- Risk Question: Is mercury present in dietary items at levels where effects on survival, growth, or reproduction of piscivorous mammals may be expected?
- ME #1: Comparison of the estimated DMIR based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).

3.6.3 Terrestrial Receptors

Terrestrial Vegetation: Survival and Growth

- Risk Question: Are the mercury concentrations in soil from AOC 4 present at levels that may result in adverse effects on the survival or growth of terrestrial plants?
- ME #1: Comparison of the EPCs for soil THg to the corresponding benchmarks for the survival and growth of plants.

Soil Invertebrates: Survival and Growth

- Risk Question: Are the concentrations of mercury in soil from the South River present at levels that may result in adverse effects on the survival or growth of soil invertebrates?
- ME #1: Comparison of the EPCs for soil THg to benchmarks for the survival and growth of soil invertebrates.

Invertivorous Birds: Survival, Growth, and Reproduction

- Risk Question: Is mercury present in dietary items at levels where effects on survival, growth, or reproduction of invertivorous birds may be expected?
- ME #1: Comparison of the estimated DMIR based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).

- ME #2: Comparison of the EPCs for tissue THg and/or MeHg (e.g., in blood) for birds from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.

Carnivorous Birds: Survival, Growth, and Reproduction

- Risk Question: Is mercury present in dietary items at levels where effects on survival, growth, or reproduction of carnivorous birds may be expected?
- ME #1: Comparison of the estimated DMIR based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).

Aerial Insectivorous Mammals: Survival, Growth, and Reproduction

- Risk Question: Is mercury present in dietary items at levels where effects on survival, growth, or reproduction of aerial insectivorous mammals may be expected?
- ME #1: Comparison of the estimated DMIR based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).
- ME #2: Comparison of the EPCs for tissue THg and/or MeHg (e.g., in blood) for bats from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.

Terrestrial Invertivorous Mammals: Survival, Growth, and Reproduction

- Risk Question 1: Is mercury present in dietary items and incidentally-ingested soil at levels where effects on survival, growth, or reproduction of terrestrial invertivorous mammals may be expected?
- ME #1: Comparison of the estimated DMIR based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).

Herbivorous Mammals: Survival, Growth, and Reproduction

- Risk Question 1: Is mercury present in dietary items and incidentally-ingested soil at levels where effects on survival, growth, or reproduction of herbivorous mammals may be expected?
- ME #1: Comparison of the estimated DMIR based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).

3.7 Focal Species for Ecological Risk Assessment

The focal species for the assessment are selected based on their prevalence in AOC 4 and available exposure data. Because the South River (within AOC 4) has undergone extensive study, there are multiple candidate species within each receptor category that could be evaluated (e.g., for insectivorous birds). The selected focal species are listed in Table 3-8.

3.7.1 Special Status Species

As noted within Section 2.3.4 of this document, three Threatened or Endangered species may inhabit portions of the AOC 4. Based on the habitat requirements, all of the species in Table 2-1 have been included in the assessment. Several categories of special status species are identified as potentially occurring in AOC 4. These species occur in six groups: birds (one sp.), fish (one sp.), terrestrial invertebrates (two spp.), aquatic invertebrates (eight spp.), terrestrial vegetation (ten spp.) and wetland vegetation (two spp.).

The assessment endpoints for special status species are selected from the same receptor group (e.g., piscivorous birds). In accordance with ERA guidance, the risk characterization is performed on the individual level following conservative exposure estimates. Potential effects to individuals are assessed using the highest no-observed-adverse-effect-level (NOAEL) identified during the effects analysis (see Section 4).

4.0 Ecological Effects Analysis

The purpose of the effects analysis is to identify threshold concentrations of THg, IHg, and MeHg in exposure media that may result in adverse effects to representative ecological receptors identified in the ECSM (See Table 3-8). This section reviews the site-specific and literature-derived ecological effects information for mercury and identifies, where possible, the threshold concentrations for the effects representing the assessment endpoints and associated measurement endpoints (See Table 3-9 to 3-11). This section summarizes the approaches and recommended threshold concentrations of THg and MeHg in exposure media; detailed description of the methodology and findings is provided in Appendix C of this report.

The effects analysis also describes the derivation of Critical Body Residues (CBRs) to estimate ecological risk in AOC 4. The use of CBRs has several advantages over exposure (e.g., concentrations in water or dietary items) based approaches (McCarty and Mackay, 1993). Advantages include the consideration of bioavailability and accumulation kinetics and the integration of several exposure routes, including dietary uptake, direct contact and ingestion of water or sediment. In general terms, literature-based whole body CBRs were selected, which relate to endpoints associated with survival, reproductive success, and development. Endpoints such as physiological, biochemical, or genetic biomarkers are generally not considered as evidence of an effect level, because while they may be useful as measures of exposure, these biomarkers are not always correlated with effects on an organismal, population, community or ecological scale (Forbes et al., 2006).

4.1 Benthic Macroinvertebrates

Potential effects to benthic invertebrates exposed to mercury in AOC 4 were evaluated based on the Sediment Quality Triad (SQT) investigations and CBR approaches. The SQT approach includes the evaluation of co-located sediment samples for chemical analysis, benthic community sampling, and sediment toxicity testing. In addition to chemical analysis of bulk sediment, pore water concentrations were evaluated as an additional measurement of potential exposure.

4.1.1 Sediment Quality Triad (SQT) Evaluation

As indicated in Section 3.2.4, as a part of the Ecological Study, a SQT investigation was conducted to evaluate potential mercury-associated toxicity to benthic macroinvertebrates in AOC 4 across a gradient of sediment THg concentrations. A summary of the key elements of the SQT investigation that are pertinent to evaluating potential site-specific effects on benthic macroinvertebrates associated with mercury exposure is presented below.

Sediment Chemistry Evaluation

The results of sediment mercury analyses were compared to generic sediment quality benchmarks (SQBs) to evaluate the potential for mercury-associated effects based on bulk sediment chemistry. Generic SQBs are typically derived from large co-occurrence databases of sediment chemistry and toxicity data from a wide range of freshwater environments. The resulting SQBs have limited relevance to site-specific exposures and may not reflect a reliable cause/effect relation between exposure to an individual constituent, particularly mercury, and an ecological effect observed in test organisms exposed to a mixture of chemical and non-chemical stressors that may be acting together in a sediment toxicity test. Because contaminant concentrations tend to co-vary in sediments (Long et al., 1998, Smith and Jones, 2006), concentrations of multiple constituents are likely to be correlated with observed toxicity, even when the concentration of the constituent in question is not sufficiently high enough to contribute significantly to toxicity (Fuchsman et al., 2006). Recognizing the limitations of co-occurrence SQBs, THg concentrations were compared to the severe effects level (SEL) of 2.0 mg THg/kg developed by Persaud et al. (1992).

A SQB was not identified from the available literature sources of ecological screening values to evaluate potential exposure to MeHg in sediments.

Pore Water and Surface-Water Chemistry Evaluation

Invertebrate exposure to mercury in aqueous media within the benthic environment may be associated with pore water or surface water. Aqueous exposure of infaunal benthic invertebrates is primarily associated with exposure to pore water; epifaunal benthic invertebrates are exposed primarily to surface water at the sediment-surface water interface, but may also be exposed to pore water in shallow sediment.

Aqueous toxicity studies were evaluated to identify potential effects associated with exposure to mercury in pore water and surface water. Studies presenting concentration-response relationships for survival and growth endpoints for benthic invertebrate test organisms were prioritized in the effects analysis. In studies establishing concentration-response relationships for relevant benthic test organisms exposed to aqueous mercury, statistically significant reductions in growth were observed at lower aqueous mercury concentrations than reductions in survival (Chibunda, 2009; Azevedo-Pereira and Soares, 2010; Valenti et al., 2005). Data from these studies on median lethal concentrations (LC_{50}) for benthic test organisms exposed to THg in filtered and unfiltered aqueous media over various durations indicate that effects are associated with aqueous exposures exceeding 10,000 ng THg/L (Appendix C; Figure C-1).

Potential sublethal effects associated with benthic invertebrate exposure to THg in aqueous media were evaluated using studies reporting concentration-response relationships for growth endpoints (Chibunda, 2009; Azevedo-Pereira and Soares, 2010; Valenti et al., 2005). Growth endpoints from these studies were expressed on a relative basis given the varied, but biologically sensitive metrics used to measure growth in each study (e.g., total body length, dry weight).

The relative growth of benthic invertebrate test organisms decreased with exposure to increasing concentrations of THg (Appendix C; Figure C-2). The minimum bounded NOEC of 4,000 ng THg/L was identified for the 21-day exposure of juvenile *Villosa iris* (Valenti et al., 2005); the LOEC of 8,000 ng THg/L was identified as the lowest concentration at which a statistically significant reduction in growth was reported. A query of growth endpoints for freshwater benthic invertebrate test organisms in the EPA

ECOTOXicology database did not indicate a more sensitive growth endpoint for inorganic forms of mercury. Therefore, these NOEC and LOEC values are adequately sensitive to evaluate adverse growth effects in AOC 4. Based on this analysis, 4,000 ng THg/L was selected as a NOEC and 8,000 ng THg/L was selected as a LOEC to evaluate potential sublethal growth effects to benthic macroinvertebrates exposed to pore water and surface water at the sediment-surface water interface.

Aqueous Methylmercury Exposure

Toxicological data on the effects of aqueous exposures of MeHg on benthic invertebrate test organisms are limited. However, water quality screening benchmarks have been derived for MeHg for the general protection of aquatic life as shown below.

Methylmercury Water Quality Screening Benchmark	NOEC (ng/L)	LOEC (ng/L)	Source
Canadian Water Quality Guideline (WQG)	4	40	CCME (2003)
Effect Concentration (EC20) Daphnids	--	870	Suter and Tsao(1996)
EPA Tier II Secondary Chronic Value (SCV)	2.8	--	Suter and Tsao (1996)

The bounded NOEC and LOEC values presented in the Canadian Water Quality Guidelines (WQGs) were selected to evaluate potential benthic invertebrate exposure to MeHg in filtered pore water. These values represent conservative screening values derived for the broader protection of aquatic life. As such, these benchmark concentrations are not necessarily indicative of adverse effects to benthic invertebrate organisms, which may be substantially less sensitive to MeHg exposure than the aquatic test organisms (e.g., daphnids) used to derive the benchmarks.

Sediment Toxicity Testing

As discussed in Section 3.2.4, site-specific toxicity testing (10-day survival and growth of *H. azteca* and *C. dilutus*) was performed as part of a SQT investigation conducted in the South River in 2010 to evaluate benthic macroinvertebrate exposure in the sediment-limited, cobble/gravel, and bedrock benthic habitats that are predominant in the river. The use of interstitial sediment for the SQT evaluation represents a conservative estimate of exposure, because interstitial sediment collected using the Beckson pump have lower sand content than FGCM deposits (Flanders et al., 2010). The results of the sediment toxicity testing are described in detail in Appendix C. The results of site-specific SQT toxicity testing indicate that adverse effects on growth and survival of benthic macroinvertebrate test organisms do not occur at sediment THg and MeHg concentrations up to 18.9 mg/kg and 0.102 mg/kg, respectively (Appendix C, Figure C-3).

As an additional line of evidence to support the findings of the site-specific sediment toxicity test results, the Sediment Toxicity Database (SEDTOX) compiled by the National Oceanic and Atmospheric Administration (NOAA) was queried to identify relevant survival endpoints from toxicity studies conducted in sediment environments where mercury was the primary COPEC. Endpoints with sediment THg concentrations below the threshold effects concentration (TEC; MacDonald et al., 2000) of 0.18 mg/kg and those containing non-mercury constituents (e.g., polycyclic aromatic hydrocarbons, pesticides, non-mercury metals) at concentrations exceeding the probable effect concentrations (PEC; MacDonald et al. 2000) were not included in the analysis to remove toxicity not associated with mercury exposure. Control-adjusted survival was not statistically different than control survival in 85 percent of samples with THg concentrations ranging from 0.18 mg/kg to 949 mg/kg; control-adjusted survival in these samples was 80 percent or greater in 88 percent of samples (Appendix C; Figure C-4). At THg concentrations greater than 18.9 mg/kg, survival in 54 of 67 study endpoints (81 percent) was not significantly lower than control survival. The findings of the SEDTOX data evaluation further validate the findings of site-specific toxicity testing, which indicated negligible effects on *H. azteca* survival at the maximum THg exposure concentration of 18.9 mg/kg tested in the SQT investigation.

Summary of Effects Thresholds

Using the analyses presented in the preceding sections, NOECs were identified for sediment exposures for THg and MeHg, as summarized below. Corresponding LOECs were not estimated by simply applying an uncertainty factor of ten to the NOECs because the estimated NOECs are conservative, representing the highest tested site-specific sediment concentrations, and it is unclear whether an uncertainty factor of 10 is appropriate.

site-Specific SQT Sediment Benchmarks	NOEC	LOEC	Basis
Total mercury (mg/kg dw)	18.9	NA	NOECs based on SQT investigations; LOECs not identified.
Methylmercury (mg/kg dw)	0.102	NA	

4.1.2 Critical Body Residues (CBRs)

Literature studies were evaluated to identify critical body residues (CBRs) for mercury in invertebrate tissue residues. These CBRs were used to evaluate potential effects associated with larval insects and crayfish tissue samples collected in AOC 4.

Larval Insects

Nine studies were evaluated that reported mercury concentrations in tissue residues associated with survival, growth, or reproductive success endpoints for aquatic invertebrates (Appendix C; Table C-1). While most studies evaluated survival endpoints, growth and reproduction endpoints were the most sensitive endpoints. These studies are reviewed in greater detail in Appendix C; the findings of this review are summarized here.

Benthic invertebrate CBRs were selected based on the review of available studies associating invertebrate tissue residues with potential effects on growth and reproduction (see Appendix C; Table C-1). A CBR_{NOEC} of 0.037 mg MeHg/kg ww was selected for MeHg based on its effects on growth of hexagenid mayfly nymphs (Naimo et al., 2000). A corresponding CBR_{LOEC} was not identified. Nor was it estimated by simply applying an uncertainty factor of 10 on the CBR_{NOEC} because there is insufficient information to support this extrapolation. Bounded reproduction endpoints for daphnids reported by

Biesinger et al. (1982) of 1.53 and 2.33 mg THg/kg ww were selected as the minimum CBR_{NOEC} and CBR_{LOEC} for THg, respectively.

The selected CBRs are comparable to (for THg) or more conservative than (for MeHg) the results of a field study of population-level benthic invertebrate impacts and measured invertebrate tissue residues. In a long-term study conducted near a mine site at Clear Lake, California, Suchanek et al. (2008) reported a THg body burden of 1.44 mg THg/kg ww and a MeHg body burden of 0.335 mg MeHg/kg ww in larval Chironomidae (chironomids). Chironomids did not experience any significant population-level effects and the littoral invertebrate community did not exhibit any significant response to the mercury exposures from surface water and sediment. The findings of Suchanek et al. (2008) indicate that the selected CBRs are adequately conservative to evaluate potential benthic invertebrate impacts in AOC 4. CBRs were not identified for emergent adult invertebrates due to the lack of data available to evaluate adverse ecological effects based on tissue residue concentrations. However, it is assumed that CBRs protective of aquatic stages (i.e., larvae or nymphs) are protective of post-metamorphosis adult stages because organisms are generally more sensitive to adverse effects of contaminants during early life stages than during adulthood (UNEP, 2002).

Crayfish

Studies linking mercury concentrations in crayfish tissue at environmentally relevant exposures to adverse effects were not identified in the literature. Based on available information regarding the relative toxicity of crayfish to mercury exposure, CBRs in whole body crayfish are not likely to be lower than the CBRs derived for invertebrates in the previous section. Effects of mercury on the survival or reproduction of crayfish are generally observed at aqueous concentrations much higher than the NRWQC of 770 ng/L (filtered) for THg. The NRWQC of 770 ng THg/L represents the Criterion Continuous Concentration (CCC) that is derived using acute toxicity of IHg on 29 genera of freshwater animals and estimated acute to chronic ratios. The supporting NRWQC database included crayfish species demonstrating species mean acute IHg toxicity at 20,000 ng THg/L (EPA, 1985; EPA, 1995). In more recent studies not included in the NRWQC database supporting the derivation of the mercury NRWQC, *Astacus astacus* individuals exposed to $HgCl_2$ at 100,000 to 800,000 ng/L experienced cardiac arrhythmia and high levels of mortality (Styrishave et al., 1995; Styrishave and Depledge, 1996). As a result, potential effects associated with crayfish tissue mercury concentrations measured in AOC 4 were evaluated relative to the THg and MeHg CBRs derived in the preceding section.

4.1.3 Summary of Benthic Invertebrate Effects Benchmarks

Based on the rationale presented in the preceding sections, the following ecological effects benchmarks have been identified to evaluate benthic macroinvertebrate exposure in AOC 4.

Exposure Media	NOEC	LOEC	Basis
Sediment (mg/kg dw)			
Total mercury	18.9	NA	NOECs based on SQT investigations; LOECs not identified.
Methylmercury	0.102	NA	
Surface/Pore Water (ng/L)			
Total mercury	4,000	7,000	Bounded NOEC and LOEC derived based on the relative growth of benthic macroinvertebrates evaluated in Chibunda (2009); Azevedo-Pereira and Soares, (2010); Valenti et al. (2005).
Methylmercury	4	40	NOEC represents the CCME *Water Quality Guideline for the Protection of Aquatic Life* derived based on a LOEC of 40 ng/L for daphnid reproduction divided by a safety factor of 10 (CCME, 2003).
Critical Body Residue (mg/kg ww)			
Total mercury	1.53	2.33	Based on the lowest bounded endpoints for daphnid (Beisinger et al., 1982); See Table C-1 in Appendix C.
Methylmercury	0.037	NA	CBR_{NOEC} based on growth of hexagenid mayfly nymphs (Naimo et al.,2000); See Table C-1 in Appendix C; CBR_{LOEC} not identified.

Notes:
NA – Not Available; LOECs were not estimated based on extrapolation from corresponding NOECs because typical uncertainty factor (i.e., 10) may not be appropriate.

4.2 Aquatic Vegetation

Potential effects to submerged aquatic vegetation (SAV) in AOC 4 were evaluated based on direct contact exposure to sediment, and pore water/surface water concentrations. A community structure evaluation was also performed. The following subsections describe the selection of mercury benchmarks for SAV. Literature reviews did not identify toxicity data related to the exposure of aquatic plants to mercury in sediment. Therefore, SAV exposure to mercury was evaluated based on exposure to surface/pore water, as described below.

A summary of available literature on toxicity of mercury on aquatic plants is available in EPA (1985) and Boening (2000), and summarized in Appendix C. In developing the *Canadian Water Quality Guideline for the Protection of Aquatic Life*, the CCME (2003) identified IHg and MeHg effect concentrations of 1 ug/L (i.e., 1,000 ng/L) or greater for freshwater aquatic plants. Based on these data, 1,000 ng/L was selected as a LOEC (for both THg and MeHg) to evaluate potential sublethal growth effects to SAV exposed to mercury in pore water and surface water. Comparisons of the available toxicity data indicate that general surface water quality criteria are protective of the varied effects concentrations for different aquatic plants. The following criteria are selected as conservative NOECs for THg and MeHg for plant exposure in surface water and pore water:

- THg: 770 ng THg/L (filtered) based on the chronic National Recommended Ambient Water Quality Criteria [(NRWQC), EPA (2014)]/ Virginia State Water Quality Criteria (VASWQC) for the protection of aquatic life
- MeHg: 100 ng MeHg/L based on applying a safety factor of 10 to the lowest chronic effects concentrations (of 1000 ng/L) identified for plants by CCME (2003).

Exposure Media	NOEC	LOEC	Basis
Surface/Pore Water (ng/L)			
Total mercury	770	1000	NRWQC/VASWQC of 770 ng/L represents a conservative benchmark for SAV exposure.
Methylmercury	100	1000	NOEC represents the lowest chronic effects concentrations of 1000 ng/L identified (CCME, 2003) for aquatic plants divided by a safety factor of 10.

4.3 Terrestrial Vegetation

Potential effects to terrestrial vegetation in AOC 4 were evaluated based on direct contact exposure to soil mercury concentrations. Five mercury phytotoxicity studies involving seven species of terrestrial plants were identified for the derivation of soil mercury benchmark (Appendix C; Table C-2). Only soil studies were included; hydroponic studies (plants grown in solution) were not included because they are not relevant toward deriving soil benchmarks (in terms of mercury concentrations in bulk soil). Among soil studies, only those studies were included for which sufficient details could be obtained (such as test species, test soil properties, test duration, effect endpoints, and benchmarks). The selected studies generally measured effects on germination, emergence, root elongation, shoot growth, and biomass growth.

Studies in Table C-2 (Appendix C) indicate that NOECs are generally greater than 7 mg Hg/kg dw, whereas LOECs are generally greater than 10 mg Hg/kg dw. Selected studies represent a wide range of soil types, endpoints, and species. Therefore, a geometric mean of NOECs (13 mg THg/kg dw) and LOECs (29 mg THg/kg dw), except those estimated from figures in Sheppard et al. (1993), were selected as the soil benchmarks for evaluating terrestrial vegetation exposed to THg in AOC 4. However, it should be noted that in the studies, soluble mercury salts were freshly added to the soils and are readily bioavailable. Mercury bioavailability is likely to be lower due to it speciation and the effects of mercury ‘aging’ or strong complexation by organic ligands in soil. Therefore, benchmarks based on the laboratory studies of freshly spiked soils are likely to be conservative. A review of available literature on mercury bioavailability in soils indicates that mercury has very limited bioavailability compared to mercuric chloride freshly spiked on test soils in the laboratory. Site-specific investigations of mercury bioavailability and speciation in two soils from AOC 4, and plant and invertebrate toxicity studies, also indicate that mercury bioavailability is limited in AOC 4 soils. As discussed in Appendix C, the benchmarks identified based on laboratory studies were adjusted upward by a site-specific bioavailability factor of 3. This factor was based on consideration of the available literature and site-specific investigations, which indicate lack of uptake (Berti et al. 2013) and effects of mercury on terrestrial plants. This includes a study on seedling emergence and growth of three plant species [wheat (*Triticum aestivum*), soybean (*Glycine max*), and radish (*Raphanus sativus*)] grown on a soil collected from the AOC 4 floodplain (See Appendix C) which found no effect on seedling emergence and growth at THg concentrations of 57 mg/kg in soil.

Exposure Media	NOEC	LOEC	Basis
Soil (mg THg/kg dw)			
Total mercury	54	87	Based on the geometric mean of select NOECs and LOECs from soil studies in Table C-2 in Appendix C and a site-specific bioavailability factor of 3.

4.4 Soil Invertebrates

Potential effects on soil invertebrates in AOC 4 were evaluated based on direct contact exposure to soil mercury concentrations. Seven studies representing six invertebrate species were identified for the derivation of soil mercury benchmarks for soil invertebrates. These studies are described in detail in Appendix C, and are summarized here.

Studies of mercury effects on soil-burrowing oligochaetes were included in the assessment, as they best represent the direct contact exposure pathway for soil mercury. Studies in Table C-3 (in Appendix C) represent a wide range of soil properties (pH = 6.0 to 7.9 and soil organic matter ranging from 0 to 10%) and the measured effects endpoints represent assessment endpoints targeted for soil invertebrates (survival and reproduction). The geometric mean of NOECs (6 mg THg/kg dw) and LOECs (12 mg THg/kg dw), except those estimated from figures in Sheppard et al. (1993), were selected as the basis for evaluating the effects on the soil invertebrates in AOC 4. However, similar to soil benchmarks for terrestrial plants, the soil benchmarks for soil invertebrates are expected to be conservative because of the higher mercury bioavailability of freshly spiked soils used in toxicity testing and potential acclimation reported in Gudbrandsen et al. (2007).

Similar to the final benchmarks for plants, the laboratory-study based mercury benchmarks for soil invertebrates were also adjusted upward using the same site-specific bioavailability factor of 3. The resulting soil benchmarks to be used for the evaluation of soil invertebrates in AOC 4 are shown below.

Exposure Media	NOEC	LOEC	Basis
Soil (mg THg/kg dw)			
Total mercury	18	36	Based on the geometric mean of select NOECs and LOECs from soil studies in Table C-3 in Appendix C and a site-specific bioavailability factor of 3.

4.5 Fish

Potential effects on fish in AOC 4 were evaluated based on direct contact exposure to surface water and whole body CBRs. The following subsections describe the selection of corresponding benchmarks for fish.

4.5.1 Surface Water Benchmarks

A summary of aquatic toxicity of mercury on freshwater fish are provided in Appendix C. Based on this review of the available literature for aqueous toxicity of mercury to fish, the following surface-water mercury benchmarks were selected to evaluate fish exposed to mercury in AOC 4:

- THg: 770 ng THg/L (dissolved) for THg based on the current NRWQC (EPA, 2014) and VASWQC.
- MeHg: 290 ng MeHg/L (dissolved) for MeHg based on the lowest chronic toxicity value observed in a multi-generational exposure for brook trout (McKim et al., 1976).

4.5.2 Critical Body Residues (CBRs)

Several studies have attempted to establish mercury CBRs for the protection of fish (Niimi and Kissoon, 1994; Wiener and Spry, 1996; Beckvar et al., 2005; and Dillon et al., 2010). These studies are reviewed in Appendix C and are summarized here. For the purposes of the risk assessment, literature-based whole body CBRs were selected that relate to endpoints associated with mortality, such as survival, reproductive success and development. Literature-based whole-body CBRs indicate a conservative (i.e., no effect) screening benchmark of 0.21 mg THg/kg ww for juvenile and adult fish. Multiple sources support the derivation of a low-effect level of 0.44 mg THg/kg ww for juvenile and adult fish in AOC 4 (Beckvar et al., 2005; Dillon et al., 2010). This range of CBRs will used to evaluate potential effects associated with mercury concentrations measured in juvenile and adult fish tissue sampled in AOC 4.

4.5.3 Summary of Fish Effects Benchmarks

Based on the rationale presented in the preceding sections, the following ecological effects benchmarks have been identified to evaluate fish exposure to mercury in AOC 4.

Exposure Media	NOEC	LOEC	Basis
Surface/Pore Water (ng/L)			
Total mercury	770	NA	NRWQC/VASWQS of 770 ng/L (filtered) represents a conservative benchmark for fish exposure at various life stages.
Methylmercury	290	NA	Lowest chronic toxicity value observed in a multi-generational exposure for brook trout (McKim et al., 1976)
Critical Body Residue (mg/kg ww)			
Total mercury	0.21	0.44	CBR_{NOEC} based on Beckvar et al. (2005); CBR_{LOEC} derived from data compiled in Beckvar et al. (2005).
Methylmercury	0.21	0.44	CBRs for MeHg are equivalent to THg based on assumption that nearly all mercury in fish is methylated.

4.6 Amphibians

Amphibians may be exposed to mercury through dietary ingestion pathways and direct contact with sediments/soils and surface/pore water. Literature reviews did not identify toxicity data related to amphibian exposure to mercury in sediment and soil. Therefore, amphibian exposure to mercury was evaluated based on exposure to surface/pore water and critical body residues.

4.6.1 Surface Water Benchmarks

A summary of aqueous endpoints for various amphibians and life stages developed from literature reviews have been discussed in several studies (Schuytema and Nebeker, 1996; WHO, 1989; Boening, 2000; Linder and Grillitsch, 2000). Comparisons of compiled aqueous toxicity endpoints for amphibians indicate that general surface water quality criteria are more conservative than varied effects concentrations at the different life stages evaluated, including sensitive life stages. Adverse effects concentrations for lethality, malformations, and reproductive changes are generally greater than 1,000 ng /L for THg. Based on this comparison, ambient surface water quality criteria that are protective of a broad range of aquatic life are selected as conservative NOECs for amphibian and reptile exposures to THg and MeHg in surface water:

- THg: 770 ng THg/L (filtered) based on the chronic NRWQC/VASWQC for the protection of aquatic life
- MeHg: 4 ng MeHg/L based on the CCME WQG for the protection of aquatic life.

It is important to note that these concentrations do not represent effect concentrations, but rather conservative benchmarks below which adverse effects to sensitive life stages of amphibians are not likely.

4.6.2 Critical Body Residues (CBRs)

Mercury CBRs (in term of whole body tissue residues) for adverse effects on amphibians have not been established. Limited relevant studies are available and all of these studies are associated with the South River investigations (Todd et al., 2011a, 2011b, 2012; Bergeron et al., 2011; Bergeron et al., 2010), which will be evaluated as part of the risk characterization.

In the absence of amphibian CBR information for mercury, investigators have compared whole body concentrations to fish CBRs (Todd et al., 2011a; Hothem et al., 2010; Burke et al., 2010; Bergeron et al., 2010). In the few studies where amphibian effects have been compared to fish benchmarks, effects-based body burdens in amphibians were greater than benchmarks for fish (Burke et al., 2010; Todd et al., 2011a). As a result, the fish CBRs derived in Section 4.5.2 were used to evaluate whole body adult amphibian and reptile tissue concentrations.

4.6.3 Summary of Amphibian Effects Benchmarks

Based on the rationale presented in the preceding sections, the following ecological effects benchmarks have been identified to evaluate amphibian exposure to mercury in AOC 4.

Exposure Media	NOEC	LOEC	Basis
Surface Water (ng/L)			
Total mercury	770	NA	NRWQC/VASWQS of 770 ng/L (filtered) represents a conservative benchmark for fish exposure at various life stages.
Methylmercury	4	NA	NOEC represents the CCME *Water Quality Guideline for the Protection of Aquatic Life* derived based on a LOEC of 40 ng/L for daphnid reproduction divided by a safety factor of 10 (CCME, 2003).
Critical Body Residue (mg/kg ww)			
Total mercury	0.21	0.44	CBR_{NOEC} based on Beckvar et al. (2005) for fish; CBR_{LOEC} derived from data compiled in Beckvar et al. (2005) for fish.
Methylmercury	0.21	0.44	CBRs for MeHg are equivalent to THg based on assumption that nearly all mercury in amphibians is methylated (similar assumption as for fish).

4.7 Wildlife

To evaluate the focal avian and mammalian species (Table 3-8) exposed to mercury, toxicity reference values (TRVs) were derived that represent daily doses for each wildlife receptor that is equivalent to no observed adverse effects level (NOAEL) and lowest observed adverse effects level (LOAEL). To augment the wildlife risk characterizations, CBRs (based on blood, fur, and/or muscle) were also derived, where possible, to compare against the avian and mammalian tissue mercury levels measured in AOC 4. The following subsections provide a summary of the TRVs and the CBRs that were derived for the representative avian and mammalian receptors for the AOC 4. More detailed reviews are provided in Appendix C.

4.7.1 Toxicity Reference Values (TRVs)

TRVs were derived to evaluate the potential for adverse ecological effects associated with the dietary doses estimated using the approach described in Section 5. Reference doses to evaluate potential effects were derived from the following sources:

- Literature-derived TRVs: An evaluation of mercury toxicity to avian and mammalian wildlife was conducted to identify TRVs for comparisons with the daily doses calculated for IHg and MeHg. TRVs were derived from the review of toxicity studies from the literature as NOAELs or LOAELs. Selections of the appropriate TRVs to evaluate potential risks due to mercury in AOC 4 were based on their direct relevance to the assessment endpoints for the maintenance and sustainability of wildlife populations (survival, growth, and reproduction, see Section 3.6). Observations of physiological (e.g., immunotoxicity, endocrine effects), behavioral, or other sublethal endpoints were not included in the derivation of TRVs because their dose-dependence and population-level implications are unclear.
- Background doses: Daily doses estimated based on site-specific measurements of mercury in dietary items from the study-specific background (reference) areas were also considered in the evaluation of potential site-related ecological effects. Mercury is a global contaminant, with regional impacts within United States (Driscoll et al., 2007); the bioaccumulation of mercury in aquatic ecosystems has resulted in state-wide fish consumption advisory over a dozen states (USGS, 2000). Due to the regional impact of mercury on aquatic systems, it was necessary to quantify background doses to assess potential site-related exposures relative to exposure due to ambient conditions in Virginia.

In addition, for receptors with prey items having limited range, the background dose essentially represents a site-independent background dose. The site-independent background dose from the background (reference) areas may be useful in evaluating the relevance of literature-derived TRVs with high uncertainty (due to limited toxicological data, inter-species extrapolation, etc.) in characterizing potential site-related risks to wildlife populations.

The following subsections describe the derivation of TRVs for comparisons to doses calculated for avian and mammalian wildlife receptors.

4.7.2 Avian Toxicity Reference Values (TRVs)

Avian TRVs for mercury were selected using data from various controlled studies, as summarized in Appendix C. These derivations generally used the critical study approach (CSA), as used in other studies deriving TRVs for the evaluation of dietary dose models

[Canadian Council of Ministers of the Environment (CCME), 1998; EPA, 1995a; EPA, 1995b; Sample and Suter, 1993; USACHPPM, 2004)].

The CSA involves finding a technically defensible, definitive study (i.e., the critical study) in which a toxicity threshold is bracketed by experimental doses, expressed as a NOAEL or LOAEL (Blankenship et al., 2008; EPA, 2003). As appropriate, uncertainty factors (UFs) are then applied to the LOAEL or NOAEL from the critical study to derive generic or receptor-specific TRVs. The UFs may account for three potential sources of uncertainty: differences in species sensitivity between the test species and the species to be protected, sub-chronic to chronic extrapolations, and LOAEL-to-NOAEL extrapolations.

As shown below, separate avian TRVs were derived for MeHg and IHg. To account for the species sensitivity, MeHg TRVs were derived for each receptor group represented by the focal species. Due to the lack of data and relatively low toxicity of IHg (compared to MeHg), only one set of IHg TRVs were derived for all avian receptors.

Methylmercury (MeHg) TRVs

Avian sensitivity to MeHg differs between species (Heinz et al., 2009; Heinz et al., 2011). In a study evaluating the sensitivities of embryonic exposure to MeHg, Heinz et al. (2009) injected MeHg into the air cell of eggs of 26 species of birds. Embryo survival (median lethal concentration, LC_{50}) varied between species, indicating relative differences in the sensitivities of birds to MeHg exposure. Based on the relative sensitivities described by Heinz et al. (2009), existing literature studies for dietary exposures were evaluated to identify TRVs representative of the potential variation in MeHg sensitivities between receptors. In addition, literature studies on effects of dietary MeHg exposure on small-bodied avian species (e.g., passerines) were evaluated separately in the derivation of TRVs, given the higher mass-specific metabolic rates and higher food requirements per unit mass of passerines relative to larger bodied birds included in most toxicological studies. Dietary TRVs were developed for the following focal avian receptors and categories:

- Belted kingfisher (Piscivore): Specific data on belted kingfisher were not available. Therefore, belted kingfisher TRVs were estimated by identifying a high sensitivity piscivore as a surrogate. Although belted kingfisher were not included in the Heinz et al. (2009) study, because of their piscivory and relatively small size, they were conservatively included in the high sensitivity category, defined as receptors or related taxa with egg survival LC_{50} values lower than 0.25 mg/kg (Heinz et al., 2009).
- Mallard (Omnivore): Specific data on mallard are available. Additionally, Heinz et al. (2009) reported that of the 26 species with eggs dosed with MeHg, only double crested cormorant were less sensitive than mallard (LC_{50} values of 2.42 and 1.79 mg/kg, respectively). To derive TRVs for mallard, available data were reviewed on mallard and similarly moderate and low sensitivity piscivores/waterfowl, defined as receptors or related taxa with egg survival LC_{50} values greater than 0.25 and 1 mg/kg, respectively (Heinz et al., 2009).

- Eastern screech owl (Carnivore): Specific data on Eastern screen owl are not available. Information on the MeHg toxicity of carnivores relative to other birds is also not available. However, based on their similar dietary habits, the Eastern screech owl (a raptor) is unlikely to be more sensitive than the two raptors (American kestrel and osprey) found to be in the high sensitivity group of birds in the Heinz et al. (2009) study. In the absence of more relevant data, sensitivity of the Eastern screech owl is assumed to be similar to the high sensitivity piscivores, and TRVs were derived accordingly.
- Tree swallow and American robin (Passerines): These are small-bodied receptors in the avian order Passeriformes. Tree swallow with LC_{50} = 0.32 mg/kg in the Heinz et al (2009) study are of moderate sensitivity (defined as having LC_{50} between 0.25 and 1.0 mg/kg). However, TRVs were derived based on field studies on tree swallows as these studies were considered more appropriate and adequate for evaluating passerines exposed to mercury.

The following sections detail the selection of TRVs for MeHg for the above avian receptors.

Belted Kingfisher: High Sensitivity Piscivore/Waterfowl

Dietary studies evaluating survival, growth, and reproduction endpoints for species or related taxa with high sensitivity to MeHg, as classified by Heinz et al. (2009) were available for American kestrel (*Falco sparverius*) and great egret (*Ardea alba*). The results of these studies and the derivation of the high sensitivity Piscivore/Waterfowl TRV are described in detail in Appendix C (Table C-6). Based on the review of dietary studies evaluating survival, growth, and reproduction endpoints for avian species with high sensitivity to MeHg (see Table C-6 in Appendix C), the LOAEL of 0.055 mg MeHg/kg-day estimated based on the Albers et al. (2007) American kestrel study was used to evaluate effects of MeHg exposure on piscivores and waterfowl with high sensitivity to MeHg. Applying the LOAEL-to-NOAEL UF of 3.25, a NOAEL of 0.017 mg MeHg/kg-day was estimated as the basis for a no observed adverse effect exposure to high sensitivity piscivores and waterfowl. The LOAEL-to-NOAEL UF was estimated based on the mean ratio of LOAEL to NOAEL doses reported for avian studies with survival, growth, and reproduction endpoints (see Table C-6 in Appendix C; French et al., 2010; Heinz and Lock, 1976; Heinz et al., 2010; Scheuhammer, 1988). This UF is comparable to or more conservative than LOAEL-NOAEL UFs applied in the derivation of water quality criteria for the protection of wildlife, which ranged from 2 to 3 (EPA, 1995a; EPA, 1995b; EPA, 1997).

Mallard: Low-Moderate Sensitivity Omnivore/Waterfowl

Dietary studies evaluating survival, growth, and reproduction endpoints for species or related taxa with low-moderate sensitivity to MeHg, as classified by Heinz et al. (2009) were available for mallard, ring-necked pheasant (*Phasianus colchicus*), white leghorn chicken (*Gallus gallus*), common loon (*Gavia immer*), and Japanese quail (*Coturnix japonica*). Table C-6 in Appendix C presents a summary of the TRVs associated with dietary studies for birds with low-moderate sensitivity to MeHg. Based on the review of dietary studies evaluating survival, growth, and reproduction endpoints for avian species with low-moderate sensitivity to MeHg, the LOAEL of 0.078 mg MeHg/kg BW/day was estimated from studies by Heinz (1974, 1976a, 1976b, and 1979). The LOAEL is intended to be protective of avian receptor categories represented by mallard. Applying the LOAEL-to-NOAEL UF of 3.25, a NOAEL of 0.024 mg MeHg/kg-day was estimated as the basis for a no observed adverse effect exposure to low-moderate sensitivity piscivores and waterfowl.

Eastern Screech Owl: Carnivores

As indicated previously, in the absence of more relevant data, carnivores are conservatively assumed be as sensitive as the high sensitivity piscivores. Therefore, the TRVs derived based on Albers et al. (2007) study on American kestrel, is used to evaluate Eastern screech owl exposed to MeHg in AOC 4.

Tree Swallow and American Robin: Passerine Birds

Available toxicity literature evaluating passerine birds exposed to mercury was reviewed independent of toxicity literature for piscivores and waterfowl. Taxa studied to evaluate piscivores and waterfowl exposed to mercury are relatively large bodied (e.g., mallard and loon) with lower mass-specific metabolic rates and lower mass-specific food ingestion rates in comparison with passerine birds (Bennett and Harvey, 1987). As a result, TRVs based on larger birds (and of different feeding guild) may not be sufficiently conservative for the protection of passerine species. To address the uncertainty in identifying adequately protective dietary TRVs for comparison with modeled doses for tree swallow and American robin, studies specifically evaluating the toxicity to passerines were evaluated. These studies are described in detail in Appendix C.

Using the dietary no effect concentrations derived from the tree swallow field studies (Gerrard and St. Louis, 2001; Longcore et al., 2007; Custer et al., 2008) [1], NOAEL doses were estimated based on a mean BW of 0.0202 kg and FIRs of 0.0116 kg dw/day or 0.0352 kg ww/day derived by Nagy (2001) for passerine birds. As summarized in Table C-6, estimated NOAELs for tree swallow ranged from 0.009 to 0.078 mg/kg BW/day[2]. The NOAEL of 0.078 mg/kg BW/day is very similar to the NOAEL of 0.067 mg/kg BW/day estimated based on Gerrard and St. Louis (2001), which provides the most comprehensive evaluation of tree swallow exposure to mercury. Although the NOAEL derived from Gerrard and St. Louis (2001) has a robust basis and corresponds well with the NOAEL derived based on Longcore et al. (2007), a geometric mean of 0.036 mg/kg BW/day calculated from the three NOAELs (0.009, 0.067, and 0.078 mg/kg BW/day) was used as the basis to evaluate modeled exposure for passerines. The geometric mean of the three NOAELs from these studies was conservatively used to account for potential uncertainty in deriving TRVs from field studies. Although corresponding LOAELs were not derived based on these field studies, the maximum NOAEL from the field studies (0.078 mg/kg BW/day) was conservatively identified to represent a potential upper bound of the no effect dataset.

[1] A similar field study is available for the South River (Brasso and Cristol, 2008) that results in an estimated NOAEL of 0.008 mg/kg BW/day, similar to that based on Custer et al. (2008) study but likely overly conservative compared to 0.067 mg/kg BW/day based on Gerrard and St. Louis (2001).Only the three independent studies (Gerrard and St. Louis, 2001; Longcore et al., 2007; Custer et al., 2008) are included for the current derivation of NOAELs for tree swallows. However, Brasso and Cristol (2008) will be considered specifically in the risk characterizations.

Inorganic Mercury (IHg) TRVs

Relatively fewer studies were available to evaluate chronic avian toxicity of IHg (Appendix C, Table C-7). Avian TRVs for IHg were estimated based on endpoints presented in Hill and Schaffner (1976), based on the suppression of egg fertilization in Japanese quail at 4 mg THg/kg dw in diet, a LOAEL was estimated as 0.9 mg IHg/kg BW/day assuming a body weight of 0.15 kg and a food ingestion rate (FIR) of 0.0169 kg dw/day (Sample et al., 1996). A NOAEL for IHg was estimated based on the no effect treatment of 2 mg THg/kg dw from Hill and Schaffner (1976), which is equivalent to 0.45 mg IHg/kg BW/day based on the above assumptions for body weight and FIR. TRVs derived for IHg were used for comparisons to IHg doses calculated for each representative avian receptor.

4.7.3 Summary of Avian Toxicity Reference Values (TRVs)

A summary of the TRVs used to evaluate potential risks associated with modeled dietary doses of IHg and MeHg to avian receptors within AOC 4 is provided in the table below.

Receptors	NOAEL (mg/kg BW/day)	LOAEL (mg/kg BW/day)	Basis
Methylmercury			
Piscivores/Waterfowl High Sensitivity	0.017	0.055	Reproductive effects on American kestrel (Albers et al., 2007)
Piscivores/Waterfowl Low-Moderate Sensitivity	0.024	0.078	Reproductive effects on mallard duck (Heinz, 1974; 1975; 1976a; 1976b; and 1979)
Carnivores	0.017	0.055	Reproductive effects on American kestrel (Albers et al., 2007)
Passerines	0.036/0.078[a]	ND	Based on geometric mean of NOAELs derived from field studies (Gerrard and St. Louis, 2001; Longcore et al., 2007; Custer et al., 2008)
Inorganic Mercury *All Birds*	0.45	0.90	Reproductive effects on Japanese quail (Hill and Schaffner, 1976)

Notes:
a - Dose represents a potential upper bound of the NOAEL dataset.
ND - A dose was not derived due to limited dietary studies indicating adverse ecological effects.

4.7.4 Mammalian Toxicity Reference Values (TRVs)

Mammalian TRVs for MeHg and IHg were identified using a similar CSA process as described in the preceding section for birds. Similar to birds, different sets of MeHg TRVs were derived for different categories of mammals whereas only a single set of IHg TRVs were derived for all mammals. The following subsections describe the derivation of MeHg and IHg TRVs.

Methylmercury (MeHg) TRVs

EPA (1995b) derived MeHg TRVs for mammals based on a compilation of mammalian toxicity studies. These data were reviewed, and additional mammalian effects data from studies conducted since 1995 were also included in the review. Table C-8 in Appendix C summarizes mammalian studies and associated TRVs and the underlying assumptions regarding their derivation. Based on the available data summarized in Table C-8 in Appendix C and other considerations, mammalian TRVs were derived for four groups of the mammalian receptors: river otter (a piscivore), white-tailed deer (an herbivore), short-tailed shrew (a terrestrial insectivore) and big brown bat (an aerial insectivore).

River Otter: Piscivore

A mink study by Wobeser et al. (1976b) was used as the basis for the derivation of MeHg TRVs for piscivorous mammals. This study was selected as the critical study for deriving TRVs for piscivorous mammals because it was a controlled, 93-day study of MeHg exposure to a site-specific receptor that identifies no effect and effect endpoints that are relevant for population-level implications. Because the study was considered to be subchronic, UFs were applied to the estimated NOAEL and LOAEL doses to represent a chronic exposure. The subchronic NOAEL (0.16 mg/kg-day) and LOAEL (0.27 mg/kg-day) doses derived from Wobeser et al. (1976b) were divided by a UF of three based on EPA (1997) to estimate chronic TRVs. The resulting chronic NOAEL for mammalian piscivores was estimated as 0.053 mg/kg BW/day and the chronic LOAEL was estimated as 0.09 mg/kg BW/day. The estimated NOAEL corresponds well with:

1) a NOAEL of 0.050 mg/kg BW/day[2] estimated from the 145-day study in which ranch mink were exposed to mercury-contaminated fish diet(Wobeser et al.,1976a),

2) a LOAEL of 0.09 mg/kg BW/day estimated based on a study in which multiple generations of mink were exposed to mercury-contaminated fish as part of their diet , and

3) a LOAEL observed in a 6-month study on adult male river otters exposed to MeHg via their diet (O'Connor and Neilsen, 1981).

Because mink and river otter are in the same family (*Mustelidae*), the chronic NOAEL and LOAEL derived based on Wobeser et al. (1976b) were used to evaluate potential risks to river otters in AOC 4.

White-Tailed Deer: Herbivore

Due to lack of MeHg toxicity data, derivations of screening level MeHg TRVs for white-tailed deer have generally relied on the either the mink study by Wobeser et al. (1976a and b) or a rat study by Verschuuren et al. (1976) and application of scaling factors (e.g., Sample et al. 1996). In the absence of more relevant data for mercury toxicity on white-tailed deer, the MeHg TRVs derived from the rat study based on survival and reproductive endpoints by Verschuuren et al., (1976) is used to evaluate white-tailed deer exposed to MeHg in AOC 4 (NOAEL of 0.090 mg/kg BW/day and a LOAEL of 0.420 mg/kg BW/day). An additional uncertainty factor is deemed unnecessary based on the Ford (2004) evaluation. As a part of the *Risk Management Criteria for Metals at Bureau of Land Management Mining Sites*, Ford (2004) derived a TRV for ruminants, using the Maximum Mineral Tolerance Levels for mercury to cows [National Research Council

[2] Assuming a dietary concentration of 0.33 mg MeHg/kg ww, a mink body weight of 1.0 kg, and an FIR of 0.015 kg/day ww.

(NRC), 1980)] and an uncertainty factor of 6. This TRV of 0.090 mg/kg BW/day is the same as the NOAEL from the rat study by Verschuuren et al. (1976).

Short-Tailed Shrew: Terrestrial Insectivore

Similar to herbivores, insectivores also lack data on MeHg toxicity. Available chronic toxicity data on mink and rat corroborate that mink (the larger of the two mammals) is generally more sensitive than rats to MeHg and IHg (Appendix C, Tables C-7 and C-8). However, among other things, the mink and rat differ in their diet. Both the rat and short-tailed shrew are insectivores whereas the mink is a piscivore. It is also unclear whether body weight scaling factors are applicable for MeHg toxicity toward mammals. Therefore, a NOAEL of 0.090 mg/kg BW/day and a LOAEL of 0.420 mg/kg BW/day for rats based on survival and reproductive endpoints from Verschuuren et al. (1976) were selected, without further extrapolation, to evaluate short-tailed shrew exposed to MeHg in AOC 4. A more detailed discussion of the available data and the selection of the TRVs for short-tailed shrew is provided in Appendix C.

Big Brown Bat: Aerial Insectivore

Available data are limited to evaluate the effects of mercury exposure to aerial insectivorous mammals (e.g., bats). No dietary dosing studies or field studies (similar to those used for passerines) were identified in the available literature that could be used to derive a receptor-specific NOAEL or LOAEL to evaluate potential risks associated with dietary exposure to bats. Therefore, a chronic NOAEL and LOAEL for aerial insectivores was estimated as 0.027 mg/kg BW/day and 0.045 mg/kg BW/day by applying a UF of 2 to the TRVs derived for mammalian piscivores. A UF of 2 was applied to account for potential differences in species sensitivity and/or potential uncertainty in the estimates.

As previously stated, the evaluation of mammalian aerial insectivores exposed to mercury within AOC 4 will also be performed based on comparisons of modeled doses to both the literature-derived TRVs and background doses. The dietary doses estimated for bats foraging in Reference Reaches will represent a site-independent dose that may be used to assess the relative exposure for bats in AOC 4, as well as to evaluate the uncertainty associated with the literature-derived TRVs described above.

Inorganic Mercury (IHg) TRVs

TRVs for mammalian exposure to IHg were selected based on a compilation of dietary exposure studies (Appendix C, Table C-7). A NOAEL TRV for IHg was selected based on a chronic no effect dietary concentration for reproductive effects of mercuric chloride on mink (Aulerich et al., 1974). In this study, the adult mink were fed diets at 10 mg/kg dw mercuric chloride (at 73.9% purity) for five months. No effects were observed on growth, mortality, and reproductive success relative to controls. Based on a dietary IHg concentration of 10 mg/kg dw, a BW of 1.0 kg and FIR of 0.137 kg dw/day, Sample et al. (1996b) derived a NOAEL of 1.01 mg/kg BW/day for IHg. This NOAEL is selected to evaluate IHg risks associated with dietary exposure to IHg in AOC 4. No LOAEL-based TRV was derived for mammalian exposure to IHg; however, Table C-7 (Appendix C) provides a summary of LOAEL values reported in various studies.

4.7.5 Summary of Mammalian Toxicity Reference Values (TRVs)

A summary of the TRVs used to evaluate potential risks associated with modeled dietary doses of IHg and MeHg to mammalian receptors within AOC 4 is provided in the table below.

Receptors	NOAEL (mg/kg BW/day)	LOAEL (mg/kg BW/day)	Basis
Methylmercury			
Mammalian Piscivores	0.053	0.09	Based on intoxication and mortality in mink (Wobeser et al., 1976b) and subchronic to chronic extrapolation factor of 2.
Mammalian Herbivores	0.090	0.420	Based on effects on survival and reproduction in rat (Verschuuren et al., 1976) and maximum tolerance level for cows (NRC, 1980)[3].
Terrestrial Mammalian Insectivores	0.090	0.420	Based on effects on survival and reproduction in rat (Verschuuren et al., 1976).
Aerial Mammalian Insectivores	0.027	0.045	Based on an interspecies uncertainty factor of 2 applied to the TRVs for piscivores (above).
Inorganic mercury			
All Mammals	1.01	NA	NOAEL derived by Sample et al. 1996 using mink reproductive endpoints reported by Aulerich et al. (1974).

4.7.6 Critical Body Residues (CBRs)

Birds

CBRs were derived to evaluate potential mercury-associated effects on avian receptors based on THg and MeHg concentrations measured in blood samples. Two categories of avian blood CBRs were derived to represent the potential variation in mercury sensitivities observed between species (Heinz et al., 2009):

- Passerines: Smaller-bodied receptors included in the avian order Passeriformes with higher mass-specific metabolic rates and mass-specific food ingestion rates in comparison with larger-bodied piscivores and waterfowl.
- Piscivores: Larger-bodied receptors with lower mass-specific metabolic rates and food ingestion rates in comparison with smaller-bodied passerines.

[3] A TRV for ruminants (cows) that was derived by using the Maximum Mineral Tolerance Levels for mercury (NRC, 1980) and applying an uncertainty factor of 6 was equivalent to the NOAEL in the Verschuuren et al. (1976) study using the rat model.

CBRs for passerine birds were derived based on mercury-associated embryotoxicity and established relations between mercury concentrations in eggs and adult female blood samples. Potential adverse effects of mercury on the survivability of embryos may result in population-level effects through reduced reproductive success. In a study evaluating the sensitivities of embryonic exposure to MeHg, Heinz et al. (2009) injected MeHg into the air cell of eggs of 26 avian species, including the passerine species tree swallow (*Tachycineta bicolor*) and common grackle (*Quiscalus quiscula*). Injected concentrations of 0.1 mg MeHg/kg ww resulted in a greater than 20 percent decline in the survival of tree swallow and common grackle embryos when compared to control eggs; injected concentrations of 0.05 mg MeHg/kg ww resulted in a nominal reduction in embryo survival (less than 10 percent) relative to control eggs. Given that Heinz et al. (2009) indicates that injected MeHg may be two to four times as embryotoxic as maternally deposited MeHg, the no observed effect and lowest observed effect endpoints for passerine species in this study were multiplied by a conservative uncertainty factor of two to establish passerine embryotoxicity NOEC and LOEC concentrations in eggs of 0.1 mg MeHg/kg ww and 0.2 mg MeHg/kg ww, respectively.

NOEC and LOEC values for embryotoxicity in passerine eggs derived from Heinz et al. (2009) were expressed as adult female blood concentrations based on the relation between mercury concentrations in eggs and maternal blood established from paired tree swallow samples collected in the North Fork Holston River (NFHR), Virginia. Evers (2009) identified a strong correlation (R^2 =0.77) between egg and maternal blood mercury concentrations for 27 paired tree swallow samples collected from the NFHR, which is geographically relevant to the South River. Adult female blood mercury concentrations were estimated from egg mercury concentrations based on the following relationship (Evers, 2009):

$$log([female\ blood\ Hg]) = \frac{log([egg\ Hg]) + 0.8363}{0.8808}$$

Using the embryotoxicity NOEC and LOEC derived from egg MeHg concentrations reported in Heinz et al. (2009), an adult blood no observed effect CBR (CBR_{NOEC}) of 0.7 mg MeHg/kg ww and a lowest observed effect CBR (CBR_{LOEC}) of 1.4 mg MeHg/kg ww, respectively, were estimated to evaluate potential effects of mercury exposure in passerine birds.

The derived CBR_{NOEC} and CBR_{LOEC} values for passerine birds were supported by a field study of reproductive success in Carolina wren (*Thryothorus ludovicianus*). Jackson et al. (2011) developed a model of nest survival as a function of female blood mercury concentrations based on field studies conducted on the NFHR and in the South Fork Shenandoah River watershed, primarily on the South River. The model predicted a 10 percent reduction in nest success in adult female Carolina wren containing 0.7 mg THg/kg ww in blood and an approximately 25 percent reduction in nest success for adult females with blood concentrations of 1.5 mg THg/kg ww (Jackson et al., 2011). This model is considered to be a conservative estimate of nest success because it does not adequately address inter-annual variability in key reproductive success parameters or the probability of re-nesting of individuals in failed nests. While there are uncertainties associated with the conservatism of this model, reductions in nest success predicted by the model based on adult female blood concentrations were in good agreement with rates of embryotoxicity associated with the estimated CBR_{NOEC} and CBR_{LOEC} concentrations in adult female passerine blood.

CBRs to assess potential effects to piscivorous birds based on blood mercury concentrations were derived from studies evaluating mercury-associated effects on breeding common loons (*Gavia immer*). Evers (2008) identified a 41 percent reduction in number of fledged young in adult females with blood THg concentrations exceeding 3.0 µg THg/g ww when compared to adult loons with blood mercury concentrations lower than 1.0 µg THg/g ww. Burgess and Meyer (2008) documented a similar reduction (40 percent) in fledged young when adult concentrations exceeded 3.45 mg THg/kg ww. These endpoints for common loon were more sensitive than other endpoints for fish-eating birds. Weech et al. (2006) did not identify adverse effects on growth or reproduction in bald eagle (*Haliaeetus leucocephalus*) at an average adult blood concentration of 6.7 mg THg/kg ww. Based on the greater sensitivity of common loon, a CBR_{NOEC} of 1.0 mg THg/kg ww and CBR_{LOEC} of 3.0 mg THg/kg ww were estimated using the thresholds reported in Evers (2008).

Mammals

CBRs were derived to evaluate potential mercury-associated effects on mammalian receptors based on mercury concentrations measured in blood, fur, and/or muscle tissue samples. In general, there are few studies linking specific effects of mercury on survival, growth and reproduction to concentrations of mercury in tissues. Three categories of mammal CBRs were derived based on availability of toxicology literature, the ecological receptors being evaluated and the diversity of tissue types sampled in AOC 4:

- Blood
- Fur
- Muscle

CBRs for mercury in blood and fur in bats were derived from studies of mercury collected from various species of bats collected in AOC 4 and the northeastern United States. Wada et al. (2010) evaluated tissue (blood and fur) and adrenocortical responses in insectivorous big brown bats (*Eptesicus fuscus*) from the South River and reference or ambient (non-point source) populations. A NOEC of 0.042 mg THg/kg ww was reported for big brown bats at reference sampling locations of the South River. This value corresponds well with THg concentrations (0.047 mg/kg ww) in blood from various bat species collected from sites with non-point mercury sources in the northeastern United States reported by Yates et al. (2014). These values are part of a range in NOECs, and are not the upper bounded NOEC. Available data were insufficient to relate THg concentrations in blood with adverse effects to survival, growth, and reproduction; therefore, a mammalian LOEC was not derived for this matrix. However, it is important to note that Wada et al. (2010) did not observe any effect on adrenocortical response at an average concentration of 0.11 +/- 0.012 mg/kg ww, indicating that the threshold for adverse effects on survival, growth, and reproductive endpoints exceed 0.11 mg/kg ww. As noted previously, biomarkers such as biochemical endpoints may be useful as markers of exposure, but are not necessarily predictive of effects on an organismal, population, community or ecosystem scale (Forbes et al. 2006).

For fur, a NOEC was derived based on the reference or ambient (non-point source) concentrations reported for the South River by Wada et al. (2010) for big brown bats (10.9 mg/kg ww). This value is supported by an average ambient concentration of 6.7 mg/kg ww reported in fur for various northeastern United States bat species (Yates et al., 2014). In addition, no neurochemical changes in little brown bat were identified in bats with fur containing less than 10 mg THg/kg ww from another AOC 4 study (Nam et al., 2012). Similar to the findings for blood, Wada et al. (2010) found no effect in big brown bats from AOC 4 with an average fur THg concentration of 28 mg/kg ww. However, this concentration was not considered in the derivation of the NOEC because it is above or near concentrations from other studies that indicate effects in other mammals. These effects include apparent behavioral alterations in wild mice at >10.8 mg THg/kg ww (Burton et al., 1977), neurochemical alterations in little brown bats at 10 – 40 mg THg/kg ww (Nam et al., 2012), and suspected mink mortality at 34.9 mg THg/kg ww (Wobeser and Swift, 1976). Given the uncertainty in identifying the lowest concentration at which effects are likely to occur, a LOEC was not derived for fur.

4.7.7 Summary of Wildlife Critical Body Residues (CBRs)

Based on the rationale presented in the preceding sections, the following CBRs are identified to evaluate wildlife exposures to mercury in AOC 4.

Receptors	CBR_{NOEC} (mg/kg ww)	CBR_{LOEC} (mg/kg ww)	Tissue Type	Basis
Methylmercury				
Passerine Birds	0.7	1.4	Blood	Based on embryotoxicity of MeHg injected in tree swallow eggs (Heinz et al., 2009) and egg to blood extrapolation based on Evers (2009)
Total Mercury				
Piscivorous Birds	1.0	3.0	Blood	Based on common loons Evers (2008).
Bats	0.042	NA	Blood	Based on big brown bats from reference conditions in South River (Wada et al., 2010)
	10.9	NA	Fur	Based on big brown bats from reference conditions in the South River (Wada et al., 2010)

5.0 Exposure Analysis

In the exposure analysis, mercury concentrations in exposure media within AOC 4 are characterized for each receptor group identified in the ECSM (see Section 3.5). Site-specific data collected as a part of the Ecological Study and other SRST investigations provide the basis for evaluating ecological exposures in AOC 4. Temporal and spatial patterns in the mercury concentrations in abiotic media have been adequately characterized in the Ecological Study. The primary purpose of the exposure analysis is to determine Exposure Point Concentrations (EPCs) in abiotic and biotic media, and to estimate dietary exposures to wildlife. The details of the EPCs and dietary exposure calculations are provided in Appendices E and F, respectively. Therefore, this section provides an overview of the RDQA performed to evaluate the usability of existing data to estimate exposure concentrations, the EPCs and dietary exposure calculation approaches. The results provided in Appendices E and F are discussed in the context of risk characterizations in Section 6.

5.1 Retrospective Data Quality Assessment

The purpose of the RDQA was to document the quality and usability of existing data for use in ERA decision-making. Given the different purposes of the historical investigations, all analytical data may not be of equivalent quality and relevance. A consistent process was employed to assess the overall quality of these datasets and to assess their usability for ERA. This process consisted of reviewing all available documentation from the different investigation sources, assessing its quality (i.e., comparability, sample integrity, accompanying QA/QC, representativeness, and relevance). The RDQA performed to support the ERA is provided in Appendix A. The datasets deemed usable by the RDQA were used in the exposure analysis.

5.2 Exposure Point Concentrations

EPCs are calculated for each of the 16 Assessment Reaches (14 Study Reaches within RRM 0 to 24 and SFSR, the Upstream Reference Reach, and the Buffer Reach), as well as other Reference Reaches on the Middle River, North River, South River (upstream), and outside of the South River 62-year floodplain (Figure 5-2). As indicated in Section 3.2.3, these multiple Reference Reaches represent various reference areas specific to the studies underlying the dataset used in the ERA. More specifically, the other Reference Reaches included as part of the risk estimate calculations for tissue mercury concentrations per receptor group include:

- Benthic Invertebrates: Middle Middle River (MR Middle), and Upper North River (NR Upper);
- Crayfish: Lower Middle River (MR Lower), Middle Middle River (MR Middle), and Upper North River (NR Upper);
- Avian: Lower Middle River (MR Lower), Middle Middle River (MR Middle), Upper Middle River (MR Upper), Lower North River (NR Lower), Upper North River (NR Upper), Upstream Reference Reach(RRM -2.7 to -0.7), South River Floodplain Reference Reach Outside of 62-year floodplain (SR RRM 16.7 to

20.9), Lower South River Waynesboro Nursery Property (SR WNP Lower), and Upper South River Waynesboro Nursery Property (SR WNP Upper);

- Mammals: Lower Middle River (MR Lower), Middle Middle River (MR Middle), Upper North River (NR Upper), South River Floodplain Reference Reach Outside of 62-year floodplain (SR RRM 16.7 to 20.9), South River near Fisherville, Virginia (SR Fisherville), and North River near Moscow, Virginia (NR Moscow).

EPCs are calculated for two purposes: for direct comparisons to respective toxicity benchmarks selected in Section 4 and for dose rate modeling to estimate wildlife exposures to mercury. Figures 3-1 to 3-3 (see Section 3.2) provides sediment, surface water, and soil sampling locations in each of the 16 Assessment Reaches. Figure 5-1 provides pore water sampling locations, and Figure 5-2 provides biota sampling locations. Sample designations in Figure 5-2 corresponds with EPC calculations discussed in this section and in Appendix E. Table 5-1 shows the EPCs calculated for direct comparisons to the respective toxicity benchmarks and Table 5-2 shows the EPCs calculated for use in dose rate models for the representative wildlife receptors. Appendix E provides the details of the EPC calculations. A brief overview of the calculation approach is provided below.

5.2.1 Calculation Approach

Generally the 95% UCL is selected as the EPC for each exposure medium and Assessment Reach to represent a conservative estimate of the average or typical exposure that a receptor may experience while foraging randomly in AOC 4. However, when the calculated 95% UCL exceeds the corresponding maximum detected concentration, the maximum detected concentration is selected as the EPC. Maximum detected concentrations were also selected as the EPC when a dataset was insufficient to calculate the 95% UCL (as determined by ProUCL).

Additionally, the following are considered in calculating the EPCs:

- Unless specified otherwise, the datasets are limited to the sampling period from 2000-2013 and included in the Master Database [See RDQA (Appendix A)];
- All concentrations for biotic media are expressed in wet weight (ww) basis; when concentrations based on only dry weight (dw) were available, the dw-to-ww conversions are achieved using:
  - Species-specific mean moisture content [i.e., percent (%) solids] data collected at the site; or
  - Literature-based, species-specific % solids data, when site-specific % solids data are not available.
- When paired THg and MeHg data are not available and where necessary, THg-to-MeHg conversions are generally based on % MeHg (i.e., the percent of THg that is MeHg) as follows:
  - Reach-wide, species and size (or age) specific mean %MeHg values are used wherever possible;

- In cases where %MeHg is not expected to vary spatially, site-wide mean %MeHg values are used. This approach is conservative because Assessment Reach-specific data were limited for specific media (in terms of species and size represented in pooled analysis), site-wide %MeHg showed low variability (as indicated by the Site-wide standard deviations), and the Site-wide mean %MeHg values are high (e.g., > 80% in fish tissues). Appendix E provides the details of specific media and purpose (for dose rate modeling vs. direct comparison) for which site-wide %MeHg values were applied for THg to MeHg conversions, only when MeHg data was lacking.

- Sample-specific IHg concentrations required to calculate EPCs for dose rate modeling are estimated based on the differences between paired, measured or estimated THg and MeHg concentrations; in a few cases where the MeHg concentration is higher than the THg concentration, IHg concentrations are assumed to be zero.
- EPCs for direct comparisons to available effects benchmarks are calculated only for the Assessment Reaches with available data.
- EPCs to be used as inputs to dose rate modeling are either calculated for Assessment Reaches with data, or extrapolated for Assessment Reaches lacking data. Required extrapolations for a given Assessment Reach generally assume that the EPC is equal to the highest EPC calculated for the next nearest adjacent Assessment Reach. For the Reference and Buffer Reaches, extrapolations assume the EPCs are equal, when corresponding data for one or the other is lacking.

5.2.2 Abiotic Media

For each Assessment Reach, EPCs are calculated for surface water, pore water, sediments, and soils. Details of the calculations are discussed in Appendix E and the resulting EPCs are shown in Tables E-3 through E-6.

5.2.3 Biotic Media

For each Assessment Reach, two sets of EPCs are calculated depending whether they are used for direct comparisons to respective effects benchmarks or as inputs to the dose rate models (DRMs) (see Table 5-1 and 5-2 and Figure 5-2 for sampling locations). Details of the calculations are discussed in Appendix E and the resulting EPCs are shown in Tables E-7 through E-17.

5.3 Wildlife Dietary Exposure

This section provides a brief overview of the DRMs used to evaluate dietary exposures to mercury for the following nine focal wildlife species identified in the ECSM in Section 3.5. Additional details are provided in Appendix F.

Wildlife Receptor Category	Focal Wildlife Species
Semi-aquatic piscivorous birds	Belted kingfisher (*Megaceryle alcyon*)
Semi-aquatic invertivorous/omnivorous birds	Mallard (*Anas platyrhynchos*)
Terrestrial carnivorous birds	Eastern screech owl (*Megascops asio*)
Terrestrial aerial insectivorous birds	Tree swallow (*Tachycineta bicolor*)
Terrestrial invertivorous songbirds	American robin (*Turdus migratorius*)
Semi-aquatic piscivorous mammals	River otter (*Lontra canadensis*)
Terrestrial invertivorous mammals	Short-tailed shrew (*Blarina brevicauda*)
Terrestrial herbivorous mammals	White-tailed deer (*Odocoileus virginianus*)
Aerial insectivorous mammals	Big brown bat (*Eptesicus fuscus*)

The DRMs estimate the dietary doses obtained by the focal species through the direct ingestion of mercury in dietary items and drinking water, and for select receptors, through the incidental or indirect ingestion of soil or sediment. A deterministic approach is used where point estimates of daily mercury intake rates (DMIRs), in milligrams (mg) of mercury per kilogram body weight per day (mg Hg/kg BW/day), are calculated using average or typical exposure factors for the focal species, and reasonable maximum exposure point concentrations (EPCs) in the applicable biotic and abiotic media.

5.3.1 Dose Rate Model Structure

The basic algorithm for calculating DMIR for each receptor is based on the following food web model or DRM:

$$DMIR = \frac{1}{BW}\sum_{i=1}^{N}\left(FIR_{ww} \times \sum_{j=1}^{M}\left(f_j \times C_j\right) + SIR \times C_S + WIR \times C_{SW}\right)_i \times AUF_i$$

where:

i	=	Number of Assessment Reaches where N is the total number of areas, representing the 16 Assessment Reaches and other applicable Reference Reaches
j	=	Receptor-specific dietary items (where M is the total number of dietary items)
BW	=	Receptor-specific mean body weight
FIR_{ww}	=	Receptor-specific mean daily food ingestion rate (wet weight)
f	=	Proportion of dietary item *j* to total dietary composition
C_j	=	Exposure point concentrations (EPCs) of IHg or MeHg in dietary item *j*
SIR	=	Receptor-specific incidental sediment or soil ingestion rate
C_S	=	EPCs of IHg or MeHg in sediment or soil
WIR	=	Receptor-specific daily drinking water ingestion rate
C_{SW}	=	EPCs of IHg or MeHg in unfiltered surface water
AUF	=	Area use factor

As indicated above, the DRMs include parameters relating to receptor-specific exposure factors, EPCs, and AUFs described below:

- Exposure Factors: Exposure factors refer to receptor-specific variables (e.g., BW, FIRww, SIR, WIR, etc.), which are typically derived from literature sources. The

EPA *Wildlife Exposure Factors Handbook* ["the Handbook" (EPA, 1993)] is the primary source of exposure factors data. Additional receptor-specific literature sources are also used to supplement exposure data from the Handbook. Exposure factors that are representative of typical or average (e.g., mean parameter) receptors and exposure conditions are used (see Table D-1, Appendix D). Receptor profiles (Tables D-2a through 2i, Appendix D) provide the basis for exposure factors included in the evaluation.

- EPCs: EPCs refer to exposure point concentrations based on site-specific measurements, namely mercury concentrations measured in exposure media (unfiltered surface water, bulk sediment, surficial soil, and dietary items). EPCs calculations to be used as inputs to DRMs were discussed in the previous section.
- AUFs: AUF reflects the proportion of the dose that a receptor may obtain as a result of foraging activities in a specific Assessment Reach relative to foraging within a larger area typical of the receptors foraging or home range. The AUF is simply the ratio of the size of an Assessment Reach (if it is smaller) to the receptor home range or territory size. Species with relatively small home ranges (e.g., American robin and short-tailed shrew) may forage entirely within a reach. However, species with larger home ranges (e.g., river otter) may forage within multiple Assessment Reaches. For the focal receptors, AUFs are defined either in terms of the shoreline length (for the belted kingfisher) or the area within the 0.3-year floodplain (for the rest of the receptors) in each reach, since the dietary items and mercury exposure originate primarily from within this area, including the river channel. Incorporation of the AUF in the evaluations of the Assessment Reaches relative to the entire AOC 4 is described in the Section 6.7.1 in the context of risk characterization.

5.3.2 Assessment Reaches

Each of the 16 Assessment Reaches (see Table 3-1) is considered an independent, discrete Assessment Reach for DRMs. Wildlife receptors, particularly those with home ranges larger than each reach, are not necessarily limited to forage within that Assessment Reach. In all likelihood, the receptor home ranges will not coincide with the Assessment Reach boundaries and the receptors will move among the Assessment Reaches for foraging. Nonetheless, Assessment Reach boundaries allow for systematic evaluation of potential exposures. Additionally, by considering the relative exposures in the Assessment Reaches, spatial heterogeneity in the media mercury concentrations and their contributions to the total exposures are captured.

5.3.3 Estimated Exposure Doses

Estimated exposures in terms of DMIRs are provided in Appendix F (Tables F-1 through F-9 for IHg and Tables F-10 through F-18 for MeHg). Overall exposures within AOC 4 incorporating AUFs and relative exposures in the different Assessment Reaches, are discussed in Sections 6.7.1 and 6.8.1 in greater detail in the context of risk characterization.

6.0 Risk Characterization

The risk characterization quantifies potential risks for ecological receptors identified in the ECSM (see Section 3.5). Potential risks to ecological receptors are estimated based on the selected measurement endpoints identified to evaluate the assessment endpoints of survival, growth, and reproduction identified for each receptor category (see Tables 3-9 through 3-12 and Sections 3.7.1 through 3.7.3). Overall risks to ecological receptor categories are characterized in a Weight of Evidence (WOE) assessment of the individual measurement endpoints consistent with the proposed WOE approach for the ERA (Appendix G).

Risk estimates are developed for receptors inhabiting or foraging within the 16 Assessment Reaches identified in Table 3-1as well as other receptor-specific Reference Reaches. Risk estimates are developed by comparing the estimated EPCs or dietary doses (e.g., DMIR for birds and mammals) of mercury (see Section 5.0) to a corresponding ecological or benchmark or TRV (see Section 4.0). Potential risks associated with direct contact or dietary exposure pathways were expressed as hazard quotients (HQs), which represent the ratio of: 1) the EPC to the ecological effects benchmark concentration or CBR, or 2) the calculated daily mercury intake rate (DMIR) to the TRVs for wildlife ingestion pathways:

$$HQ = \frac{EPC}{Benchmark\ or\, CBR} \quad or \quad \frac{DMIR}{TRVs}$$

The following sections provide discussions of the potential risks to the receptor groups identified in the CSM.

6.1 Benthic Invertebrates

The potential for adverse effects to benthic invertebrates exposed to mercury in AOC 4 is evaluated based on direct contact exposures, the SQT, and tissue residue approaches. The following subsections integrate the effects benchmarks (established in Section 4.1) with the exposure estimates (calculated in Section 5) to estimate and characterize potential risks to benthic invertebrate communities exposed to mercury in AOC 4.

6.1.1 Direct Contact Exposure

A broad spatial evaluation of potential risks to benthic invertebrates indicate that direct contact exposures to mercury in surface water, sediment pore water, and sediments are not expected to result in any adverse impacts to benthic invertebrate communities within AOC 4. Direct contact exposures to mercury in abiotic media were based on the following ME:

- ME #1: Comparison of the THg and MeHg EPCs in surface water, pore water, and sediments to corresponding benchmarks for the survival, growth, or reproduction of benthic invertebrates.

The sediment benchmark (NOEC) was based on the site-specific SQT evaluations and conservatively taken to be the maximum concentrations of THg and MeHg in sediments from SQT sampling locations, where no adverse effects were observed (see Section 4.1.1). In addition, aqueous benchmarks developed for benthic invertebrates are used to evaluate exposure to pore water and surface water (see Section 4.1.1). All surface water, sediment pore water, and sediment data, including those from SQT sample locations, are used to estimate potential risks to benthic invertebrates in the entire AOC 4. The results are summarized below.

- Surface Water: Tables 6-1a & b show the risk estimates for benthic invertebrates exposed to surface water mercury under baseline flow and episodic storm flow conditions, respectively. Both HQ_{NOEC} and HQ_{LOEC} for THg and MeHg are less than one for all Assessment Reaches, except for RRM 9.2 to 11.3 (HQ_{NOEC} = 1.4 for MeHg under baseline flow conditions as shown in Table 6-1a).
- Sediment Pore Water: Table 6-2 shows the risk estimates for exposures to mercury in sediment pore water. For THg, all HQs are less than one. For MeHg, HQ_{NOEC} is greater than one (with a maximum of 5.5) in all Assessment Reaches except RRM 0.0 to 0.8, but the HQ_{LOEC} is less than one (< 1) in all cases.
- Sediments: Table 6-3 shows the risk estimates for exposures to mercury in bulk and interstitial sediments within AOC 4. In bulk sediments, HQ_{NOEC} > 1 for THg in the Assessment Reaches between RRM 1.7 and 11.3, with three Assessment Reaches showing HQ_{NOEC} > 2 (RRM 2.7-4.4, RRM 4.4 to 5.2, and RRM 7.9 to 9.2 showing HQ_{NOEC} of 2.2, 10.6, and 4.5, respectively). For MeHg, HQ_{NOEC} > 1 in only two Assessment Reaches (RRM 1.7 to 2.7 and RRM 11.3 to 12.5 showing HQ_{NOEC} of 3.3 and 3.2, respectively). In interstitial sediments, HQ_{NOEC} for THg > 1 in six of seven Assessment Reaches between RRM 0.8 and 11.3, but all HQ_{NOEC} < 2, except for RRM 0.8 to 1.7 (HQ_{NOEC} = 3.1). For MeHg, HQ_{NOEC} > 1 in four Assessment Reaches between RRM 7.9 and 20.9, but all HQ_{NOEC} < 2.

The above estimates of potential risks indicate that overall exposures to mercury due to direct contact pathways may result in limited effects to benthic invertebrates in AOC 4. However, this finding must be considered with the findings of the SQT investigations conducted in a limited but representative number of sampling locations within AOC 4, as summarized in the following sections.

6.1.2 Sediment Quality Triad (SQT) Investigation

The SQT investigation, conducted as a part of the Ecological Study Report (URS, 2012), provides a site-specific assessment of the potential for adverse effects on benthic invertebrates exposed to mercury in sediment and pore water within AOC 4. The results of the SQT investigations support an assessment of potential impacts on benthic invertebrates based on the following measurement endpoints (see Section 3.6.1 and Table 3-9):

- ME #2 (Population Level Assessment): Statistical comparison ($p<0.05$) of the survival and growth of test organisms exposed to sediment from AOC 4 with that of organisms exposed to sediment from Reference Reaches.

- ME #1 (Community Level Assessment): Statistical comparisons of benthic community metrics ($p<0.05$) including, richness, composition, and tolerance/intolerance metrics from sampling locations in AOC 4 to reference sampling locations.
- ME #2 (Community Level Assessment): Multivariate statistical comparisons ($p<0.05$) of benthic community structure based on species-abundance data from sampling locations in AOC 4 to reference sampling locations.

The integrated findings of the SQT investigations (shown in Table 6-4), corresponding to ME #1 (sediment toxicity tests) and ME #1 and #2 (benthic community evaluations), indicate that exposure to mercury in interstitial sediments does not result in any measureable impacts to benthic macroinvertebrate communities at the four SQT sampling locations within AOC 4 compared to data from pooled reference sampling locations that are not subject to mercury contamination. Benthic macroinvertebrate community attributes at SQT sampling locations established at RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5 are generally consistent with the attributes of benthic macroinvertebrate communities at reference sampling locations established on the South River (SR-01) and on the Middle River (MR-01). Statistical evaluation of the sediment toxicity tests also indicate that the survival and growth of *H. azteca* and *C. dilutus* in AOC 4 sampling location treatments are not significantly lower than survival and growth in pooled reference sampling location treatments (MR-01 and SR-01). Furthermore, comparisons of the toxicity testing results to sediment mercury concentrations indicate that the performance of test organisms in the 10-day exposures are not affected by the gradient of THg or MeHg concentrations in sediment from the four sampling locations within AOC 4.

6.1.3 Tissue Residue Approach

In addition to the measurement endpoints based on mercury concentrations in the abiotic media and the SQT investigation, a measurement endpoint was evaluated based on the potential for adverse effects associated with mercury bioaccumulation by benthic macroinvertebrates:

- ME #3 (Population Level Assessment): Comparisons of THg and MeHg EPCs (Maximum or 95% UCL concentrations) measured in larval and emergent (adult) aquatic invertebrates and crayfish tissue residues to CBR_{NOEC} and CBR_{LOEC} benchmarks for ecological effects.

Risk estimates based on tissue residues for larval and adult aquatic insects and crayfish are presented in the following subsections.

Larval and Emergent Aquatic Invertebrates

Available tissue mercury concentrations in aquatic invertebrates relative to corresponding conservative CBRs are indicative of potential risks due to MeHg. Table 6-5 shows that tissue mercury EPCs for larval aquatic insects are greater in samples collected in the Assessment Reaches (between RRM 0 and RRM 24) than in Reference Reaches (RRM -2.7 to -0.7 and the Middle River). Tissue THg EPCs are generally below both the CBR_{NOEC} and CBR_{LOEC}. Tissue MeHg EPCs generally exceed the corresponding

CBR_{NOEC} with HQ_{NOEC} generally < 10, except for RRM 11.3 to 12.5 and RRM 12.5 to 13.5 (with HQ_{NOEC} = 11.4 and 109, respectively). The HQ_{NOEC} = 109 in RRM 12.5 to 13.5 is anomalous, for which the EPC (i.e., 95% UCL) is likely driven by the maximum MeHg concentration of 8.88 mg/kg ww—the next highest MeHg concentration for the dataset is 0.33 mg/kg ww.

For emergent (adult) aquatic invertebrates, available tissue mercury data (Table 6-5) indicate that the tissue THg EPCs are generally at or below the corresponding CBRs (i.e. $HQ_{NOEC} \leq 1$), but tissue MeHg EPCs exceed the CBR_{NOEC} in six Assessment Reaches, with three showing $HQ_{NOEC} > 10$ (RRMs 2.7 to 4.4, 7.9 to 9.2, 11.3 to 12.5). In the absence of a "low effects" benchmark, $HQ_{NOEC} > 10$ based on a conservative "no effects" benchmark may not necessarily indicate the potential for adverse effects.

Crayfish

Crayfish tissue mercury concentrations are generally higher within the Assessment Reaches than in the Reference Reaches, but are not at THg levels expected to result in adverse effects. Table 6-6 shows that tissue THg and MeHg (whole body) EPCs are greater in the Assessment Reaches compared to Reference Reaches; however, all tissue THg EPCs are below CBR_{NOEC} (and CBR_{LOEC}), indicating that adverse effects of exposures to THg are unlikely on crayfish populations within AOC 4.

A review of the literature on THg concentrations in crayfish tissue also indicates that crayfish exposures to mercury within RRM 0 to 2.7 and SFSR are within the range reported for areas with no known point source of mercury, and slightly higher within RRM 2.7 to 24. Allard and Stokes (1989) determined THg concentrations ranging from 0.022 to 0.614 mg THg/kg ww in 13 lakes in South-Central Ontario (Canada) that receive mercury loading to their watersheds via atmospheric deposition. Pennuto et al., (2005) determined mean THg concentrations in tail muscles ranging from 0.023 to 0.550 mg/kg ww[4] in crayfish sampled from four major drainage basins in New England. The study reported that 14 of the 28 sites had THg levels at or above an expected background concentration of less than 0.100 mg THg/kg ww proposed by Parks and Hamilton (1987). Tissue THg in crayfish ranges from 0.010 to 0.543 mg/kg ww within RRM 0-2.7 and SFSR, and 0.010 to 1.129 mg/kg ww within RRM 2.7 to 24 (Table E-9 in Appendix E). Tissue THg EPCs for the Assessment Reaches (0.159-0.662 mg/kg ww, Table 6-6) are comparable to the upper ranges reported in the literature.

As for tissue MeHg, evaluations based on CBR_{NOEC} alone (i.e., without accompanying CBR_{LOEC}) present an uncertainty regarding the likelihood of adverse effects. Tissue MeHg EPCs exceed the conservative CBR_{NOEC} in all Assessment Reaches (Table 6-6), with the Assessment Reaches downstream from RRM 7.9 showing generally greater HQs ($10 < HQ_{NOEC} \leq 15$). Based on tissue MeHg EPCs above a conservative "no effects" threshold (i.e., CBR_{NOEC}), potential risks cannot be ruled out for crayfish exposed to MeHg within AOC 4, but it cannot be determined whether these EPCs exceed "low effects" threshold (i.e., CBR_{LOEC}) to provide a more detailed interpretation.

[4] THg concentration in tail muscle was not significantly different from the remaining body THg concentration (Pennuto et al., 2005).

6.1.4 Benthic Invertebrate Risk Description

A WOE evaluation of all the measurement endpoints discussed in the preceding sections indicates that exposure to mercury in AOC 4 is unlikely to result in adverse effects on benthic invertebrates. Table 6-7 provides the WOE evaluation for the benthic invertebrates according to the proposed WOE approach (Appendix G). Four categories of MEs are considered in evaluating the survival, growth, and reproduction of benthic invertebrates in AOC 4. The pre-determined relative weights of these measurement endpoints, presence/absence of effects, and the magnitude of potential effects (discussed individually in the preceding sections) are shown for each Assessment Reach (Table 6-7).

Measurement endpoints indicating potentially high magnitude of effects generally also indicate an “undetermined” presence or absence of potential effects. The uncertainty regarding the presence or absence of potential effects stems from the lack of “low effects” benchmarks corresponding to the conservative “no effects” benchmarks on which the evaluations are based (e.g., for sediment and tissue MeHg concentrations). Despite uncertainties in these measurement endpoints, the WOE evaluation of available measurement endpoints (all similarly weighted at a relative weight of 3 or 4) does not indicate the potential for adverse effects to benthic invertebrates exposed to mercury in AOC 4.

6.2 Fish

Potential risks to fish exposed to mercury in AOC 4 are assessed based on the following MEs for population- and community-level evaluations, as indicated in Section 3.6.1:

- Population-Level MEs:
  - ME #1: Comparison of the EPCs for THg and MeHg in surface water to water quality criteria for the survival, growth or reproduction of fish.
  - ME #2: Comparison of the EPCs for THg in whole body fish tissue to CBR thresholds associated with effects on survival, growth, or reproduction.
  - ME# 3: Statistical comparison ($p<0.05$) of the age and growth of fish from AOC 4 to reference sampling locations.
  - ME# 4: Statistical comparison ($p<0.05$) of the condition of fish from AOC 4 to reference sampling locations.
- Community-Level MEs
  - ME# 1: Qualitative comparisons of fish community structures, including composition, total abundance, taxa richness, family-level and feeding guild distribution from sampling locations in AOC 4 to reference sampling locations.

The following subsections present risk estimates for fish exposed to mercury in AOC 4.

6.2.1 Direct Contact Exposure

The evaluation of direct contact exposure to surface water mercury (Population-level ME #1) indicates negligible risks to fish in the Assessment Reaches within AOC 4. As summarized in Tables 6-8a and b, for baseline flow and episodic storm conditions, EPCs for dissolved THg and MeHg are higher in surface water samples from the Assessment Reaches than Reference Reach, but all EPCs are orders of magnitude below NOEC criteria protective of general aquatic life (for THg) and specific to fish (for MeHg).

6.2.2 Tissue Residue Approach

The evaluation of available tissue mercury concentrations in fish (Population-level ME #2) from several Assessment Reaches, indicates that THg and MeHg concentrations in bass species from AOC 4 are at levels indicative of potential adverse effects. Comparisons of tissue mercury residues (whole body THg and MeHg) were evaluated for bass species, consistent with the derivation of CBRs for fish tissue in Section 4.5.2. Additionally, sampled bass species were categorized into two size classes based on total length (TL): TL < 130 mm (representing the young of the year [YOY] bass) and TL > 130 mm (representing the adult fish).

Available tissue residue data for YOY and adult bass are shown in Table 6-9. For the YOY bass, HQ_{NOECs} range from 5.3 to 7.3 and HQ_{LOECs} range from 2.5 to 3.5 in four Assessment Reaches within the South River. Tissue mercury concentrations for both THg and MeHg in YOY bass in SFSR within AOC 4 and RRM 0 to 0.8 are at or below the NOECs.

For the adult bass, EPCs are expectedly higher than those for the YOY from the same Assessment Reaches. Given that the same CBRs are also used for adult bass, the HQs are generally higher for the adult bass (Table 6-9). HQ_{NOECs} range from 2.6 to 12 and HQ_{LOECs} range from 1.3 to 6.1 in Assessment Reaches within AOC 4.

6.2.3 Age and Growth and Condition Factor Evaluations

Population-level ME #3 and #4 (i.e., statistical comparisons of available data on age, growth and condition for smallmouth bass, redbreast sunfish, and white sucker) do not show that the Assessment Reaches and reference sampling locations (in North River and/or South River) are significantly different. A description of the analyses and the results follows. To maximize statistical power, available fish age, growth, and condition data collected from South River sampling locations were pooled to create two assessment river segments: Upper South River and Lower South River (USR and LSR, respectively, see Table 6-10). This sampling area terminology (i.e., “assessment river segment”) is specific to the fish age, growth, and condition factor evaluations.

Age and Growth Evaluation

Age and length datasets for the North River, and South River were compiled from Murphy (2004) for the smallmouth bass and redbreast sunfish. Differences in back-calculated total lengths (from fish age) were assessed between sampling locations within the assessment river segments and the North River reference sampling location. A two-way analysis of variance (ANOVA), using age and assessment river segment as the main effects, was conducted to evaluate differences in total lengths; Tukey post hoc pairwise comparisons were used to evaluate significant differences between interactions. The adequacy of the ANOVA model was checked using normal probability and histogram plotting of the model residuals. Significant differences between assessment river segments and reference sampling locations were reported based on an alpha (α) < 0.05.

Statistical evaluations of fish age and length data for representative species indicated a decrease in growth only in South River sunfish relative to reference sampling locations. Back-calculated total lengths for smallmouth bass (age classes 1 to 8) were not statistically different in the South River relative to reference data from the North River (Table 6-11; Figures 6-1 and 6-2). Back-calculated total lengths for redbreast sunfish were significantly lower in age classes two through five in the USR assessment river segment (sampling locations SR1, SR2, and SR3) relative to reference data in the North River. In the LSR assessment river segment (sampling locations SR4 and SR5), total lengths of redbreast sunfish were significantly lower in age class two; no significant differences in total length were observed in other age classes in the LSR assessment river segment (Table 6-11).

Fish Condition Factor Evaluation

Fish condition is a measure of fish health where fish weights are compared to typical weights of the same type and size of fish. Fish condition metrics are statistically evaluated to identify differences in the condition of fish with body burdens exceeding the effects threshold (CBR_{LOEC}, see Section 4.5.2) of 0.44 mg/kg ww relative to fish from reference sampling locations with body burdens below the threshold concentration. Length and weight data from the VDEQ fillet database (1981-2007) and SRST database were used to calculate relative weights of smallmouth bass and white sucker. Relative weights were calculated for smallmouth bass based on standard weight relationships provided by Kolander et al. (1993); relative weights for white sucker were calculated based on standard weights provided by Bister et al. (2000). Fish in the database that were smaller than the minimum length requirements for each standard weight relationship were not included in the evaluation. Standard weight relationships were unavailable for redbreast sunfish; therefore, condition factors were calculated for redbreast sunfish based on the weight-length relationship presented in Anderson and Neumann (1996). Differences in condition metrics between fish exceeding the 0.44 µg/g threshold and fish from reference sampling locations were evaluated using a one-way analysis of covariance (ANCOVA) with total length as a covariate. Bonferroni pairwise comparisons were used to identify differences in condition metrics between river sections. The adequacy of the ANCOVA model was checked using normal probability and histogram plotting of the model residuals. Significant differences between assessment river segments and reference sampling locations were reported based on an alpha (α) < 0.05.

In the South River assessment river segments, the condition of representative bass, sunfish, and sucker species with whole body mercury concentrations exceeding the CBR_{LOEC} (0.44 mg/kg ww) was not decreased relative to the condition of those species from the South River reference sampling location (Table 6-11 and Figure 6-3). Relative weights of smallmouth bass from the areas assessment river segments with body burdens greater than the lower-bound effects threshold were not statistically lower than relative weights of smallmouth bass from the reference sampling location (Table 6-11). Similarly, condition factors for redbreast sunfish with body burdens exceeding the lower-bound effects threshold, were not significantly different from redbreast sunfish condition factors from the South River reference sampling location, although statistical differences were observed compared to the North River reference sampling location. Relative weights of white sucker were significantly greater in the South River assessment river segments relative to the South River reference sampling location. These findings indicate no decrease in condition factors for fish exceeding a body burden of 0.44 mg/kg ww.

6.2.4 Fish Community Structure

Available fish community structure data indicate that fish community composition and population metrics are not dissimilar between the evaluated South River Assessment Reaches within AOC 4 and the reference sampling locations. Details of the fish community structure evaluations are provided in the Ecological Study Report (URS, 2012). Summaries are provided below to address the community-level ME #1 for the current ERA.

Fish Community Composition

The resident fish community of the South River within AOC 4 has been evaluated during several field investigations dating back to 1890. Jordan (1890) documented 16 species of fish, 11 of which are still present today. Ross (1959), Cairns and Dickson (1972) and URS (2008) (included as Appendix B) conducted further assessment of the South River fish community, documenting 26, 24, and 34 species, respectively. A complete record of species documented in each study is presented in the Ecological Study Report (URS, 2012). As a part of the Ecological Study, fish populations were sampled in the spring and late summer of 2010 at four AOC 4 sampling locations (RRM 0.1, RRM 3.5, RRM 11.8, and RRM 23.5) and reference sampling locations [South River (SR-01) and Middle River (MR-01)].

The taxonomic composition of the fish community in AOC 4 was generally comparable throughout the four AOC 4 and reference sampling locations, as well as between seasons. AOC 4 locations had taxa richness (number of species) equal to or greater than that of both reference sampling locations for each sampling event. A total of 40 species of fish were documented during sampling events in 2010; 36 species of fish in the spring sampling event, and 35 species in the summer sampling event. Taxonomic richness during the spring event was the greatest for both the AOC 4 sampling locations at RRM 0.1 and RRM 11.8 (27 and 26 species, respectively). Reference sampling location MR-01 had the lowest taxa richness, with 18 species documented (Table 6-12a). Summer taxonomic richness was greatest at AOC 4 sampling location RRM 0.1, with 32 species present (an increase of five taxa at that location compared with spring). This represents the highest taxonomic richness documented for any sampling location in the South River. The remaining AOC 4 and reference sampling locations generally had similar taxa richness relative to data collected during the spring event (Table 6-12b).

Fish community composition differed spatially between the upper portion of the South River (sampling locations RRM -2.7 to RRM 3.5) and lower portion of the South River (sampling locations RRM 11.8 and RRM 23.5) and reference sampling location MR-01, but the differences are likely attributable to differences in aquatic habitat, rather than to differences in mercury exposures. Fish communities within the upper portion of the

South River within AOC 4 were dominated by individuals of the families *Catostomidae*, *Cottidae* and *Cyprinidae*, particularly longnose dace, mottled sculpin, and white sucker [See Figure 5-14 in URS (2012)]. AOC 4 sampling locations downstream from RRM 3.5 and the reference sampling location MR-01 were dominated by individuals of the families *Catostomidae*, *Centrarchidae* and *Cyprinidae*, particularly common shiner, fallfish, and redbreast sunfish. This shift in taxonomic composition is likely attributable to the changes in aquatic habitat (e.g., water temperature, stream size, and gradient) and certain species (e.g., mottled sculpin) that typically prefer cool, clear, moderate-to-high gradient streams (Jenkins and Burkhead, 1994).

Fish community compositions in AOC 4 and reference sampling locations were similar. Fish were grouped into one of three trophic feeding groups in order to assess trophic structure of the fish community. Fish were classified as omnivores, insectivores, or piscivores based upon adult feeding habits for each species. Both AOC 4 and reference sampling locations showed similar community structure, with insectivorous fishes accounting for the largest percentage of fish, followed by omnivorous and piscivorous fishes [see Figure 5-15 in URS (2012)].

Fish Population Metrics

Fish population estimates are also calculated for the four AOC 4 and the two reference sampling locations in Micro Fish 3.0 using the Burnham maximum likelihood theory (Van Deventer, 1989). Population estimates are normalized by acreage sampled and are presented as fish/hectare (f/ha).

Overall fish abundance and smallmouth bass abundance showed no consistent differences between the AOC 4 and reference sampling locations. During the spring sampling event, all AOC 4 sampling locations with the exception of RRM 23.5 had greater population densities than the Middle River reference sampling location (MR-01). However, overall fish abundance appeared to decrease with distance downstream from reference sampling location SR-01 (Table 6-13a). On the other hand, population densities of smallmouth bass generally increased with the distance down river. The greatest population density documented for AOC 4 sampling locations sampled during the spring sampling event was 122 f/ha at RRM 11.8; density was 132 f/ha at the Middle River reference sampling location MR-01 (Table 6-13b). The increase in smallmouth bass density measured at AOC 4 sampling locations RRM 11.8 and RRM 23.5 is likely due to habitat availability and preference for more lotic conditions at these areas (Edwards, et al., 1983). The lowest population density of smallmouth bass for the spring event was zero at the reference sampling location SR-01, followed by 24 f/ha at AOC 4 sampling location RRM 3.5.

Similar to population densities, smallmouth bass biomass was highest in the summer sampling event. Spring biomass was the highest at AOC 4 sampling locations RRM 23.5 (9.0 kg/ha), RRM 0.1 (7.9 kg/ha), and RRM 11.8 (6.9 kg/ha) (Table 6-13b). The lowest spring biomass of smallmouth bass was from the Reference sampling location SR-01, where no smallmouth bass were collected, followed by 2.0 kg/ha at RRM 3.5. Summer biomass was the highest at the AOC 4 sampling locations RRM 23.5 (19.9 kg/ha), RRM 11.8 (19.7 kg/ha,) and RRM 0.1 (11.0 kg/ha). Reference sampling location SR-01 and AOC 4 sampling location RRM 3.5 had the lowest summer biomass of 2.5 kg/ha and 6.9 kg/ha, respectively (Table 6-13b).

6.2.5 Fish Species Risk Description

A WOE evaluation of all available measurement endpoints indicate that although exposures to mercury are generally elevated in bass species based on tissue residue evaluations, fish species within AOC 4 are likely not experiencing population level adverse effects. Table 6-14 provides the WOE evaluation for the fish species conducted according to the proposed WOE approach (URS, 2014a). Five categories of MEs are considered in evaluating the population-level survival, growth, and reproduction of fish species and their community structures in AOC 4. The pre-determined relative weights of these measurement endpoints, presence/absence of effects, and the magnitude of potential effects (discussed individually in the above subsections) are shown for each Assessment Reach.

All measurement endpoints are weighted the same (relative weight = 4), except for surface water chemistry (relative weight = 3). While the direct contact exposures to surface water indicate negligible risks to fish, tissue concentrations—which account for dietary assimilation—indicate potentially medium to high potential for effects in several Assessment Reaches. However, as stated in Section 4.5.2, the CBRs for fish are based on conservative tissue residue benchmarks that are developed for the protection of juvenile and adult fish. Additionally, the available age, growth, condition and community structures comparisons indicate no appreciable differences between fish from AOC 4 and reference sampling locations. Therefore, the potential for mercury-associated population- and community-level effects on fish species within AOC 4 are not expected. However, implications of elevated mercury tissue residues in YOY and adult fish need to be addressed.

6.3 Aquatic Vegetation

The assessments of potential risks to aquatic vegetation exposed to mercury in AOC 4 were based on measurement endpoints evaluating direct contact exposure to surface water and pore water at concentrations associated with adverse effects and a comparison of SAV communities between AOC 4 and local or regional benchmarks:

- ME #1: Comparison of the EPCs for THg in pore water and surface water against benchmarks for the survival and growth of aquatic plants.

The evaluation of direct contact exposure to aquatic vegetation (ME #1) indicates that exposures to THg and MeHg in surface water and pore water are unlikely to result in adverse effects on aquatic vegetation. Direct contact risk estimates for aquatic vegetation are based on comparisons of EPCs for surface water and pore water THg and MeHg to the corresponding NOEC and LOEC.

Tables 6-15a and 6-15b provide the comparisons of dissolved THg and MeHg EPCs in surface water under baseline and storm flow conditions, respectively. Table 6-16 provides the comparisons of available dissolved THg and MeHg EPCs in pore water. For both THg and MeHg, and under both baseline and storm flow conditions, the EPCs are orders of magnitude below the toxicity benchmarks that are protective of aquatic vegetation. Similar results are obtained for pore water as well. Hence, no adverse effects are expected for aquatic vegetation exposed to surface and pore water mercury in AOC 4.

The evaluation of aquatic vegetation in AOC 4 indicates that concentrations of THg and MeHg in abiotic exposure media (surface water and pore water) are below benchmark concentrations protective of survival and growth of aquatic vegetation. These findings indicate that exposure to mercury in AOC 4 is not likely to result in adverse effects to aquatic vegetation.

6.4 Amphibians

The assessments of risks to amphibians exposed to mercury in AOC 4 are based on measurement endpoints evaluating direct contact exposure to surface water and pore water, and mercury bioaccumulation in tissues at concentrations associated with adverse effects:

- ME #1: Comparison of the THg and MeHg EPCs for sediment, pore water, surface water, and soil from AOC 4 to benchmarks for the survival, growth, or reproduction of amphibians.
- ME #2: Comparison of THg and MeHg EPCs for amphibian tissue residues to CBR_{NOEC} and CBR_{LOEC} benchmarks for ecological effects.

The following subsections present risk estimates for direct contact and tissue residue evaluations of mercury exposure to amphibians in AOC 4.

6.4.1 Direct Contact Exposure

Direct contact exposure to mercury in surface water (ME #1) is unlikely to result in adverse effects on amphibian populations in AOC 4. For all Assessment Reaches except RRM 9.2 to 11.3, EPCs for dissolved THg and MeHg in filtered surface water under baseline flow conditions (Table 6-17a) are below the corresponding NOECs that are protective of various life stages of amphibians. For RRM 9.2 to 11.3, the EPC for dissolved MeHg in surface water marginally exceeds the NOEC (i.e., a $HQ_{NOEC} = 1.4$). The EPCs for dissolved THg and MeHg under episodic storm conditions are all below toxicity benchmarks for all the Assessment Reaches for which data are available (Table 6-17b).

6.4.2 Tissue Residue Approach

Evaluation of tissue mercury in amphibian species (ME #2) indicates that potential risks to amphibians within AOC 4 cannot be ruled out due to uncertainties involved in the CBRs. Table 6-18 shows EPCs calculated based on available data on amphibian tissue residues. For American toad (*B. americanus*) and red-back salamander (*P. cinereus*), EPCs for THg are marginally greater than CBR_{NOEC} (i.e., $HQ_{NOECs} \leq 2.3$) and CBR_{LOEC} (i.e., $HQ_{LOECs} \leq 1.1$). MeHg EPCs are available for only American toad, and all are less than the corresponding CBR_{NOEC}. For the northern two-lined salamander (*E. bislineata*), $HQ_{NOECs} > 1$ (based on THg) for all the Assessment Reaches for which data are available; HQ_{NOECs} range as high as 6.9 (Table 6-18), but HQ_{LOECs} are ≤ 3.3. As discussed in Section 4.6.2, CBR_{NOEC} and CBR_{LOEC} are based on conservative benchmarks for fish tissue. The CBR_{LOEC} for THg of 0.44 mg/kg ww for fish may be conservative for the evaluation of mercury tissue residues in amphibians in AOC 4, as discussed below.

Several recent investigations associated with AOC 4 have evaluated the effects of maternal transfer of mercury on the survival and growth of amphibian offspring (Todd et al., 2011a, 2011b, 2012; Bergeron et al., 2011; Bergeron et al., 2010). Todd et al. (2011a) reported reduced growth of American toad (*Bufo americanus*) offspring with mothers containing the equivalent of adult whole body THg and MeHg concentrations of 0.66 mg THg/kg ww and 0.35 mg MeHg/kg ww, respectively. A site-specific $CBR_{LOEC} = 0.66$ mg THg/kg ww is slightly higher than the $CBR_{LOEC} = 0.44$ mg THg/kg ww based on fish. Uncertainties with respect to both quantitation and relevance to population-level impacts suggest that its utility in quantitative assessment is limited.

This CBR assumes that maternal tissue concentration has a direct adverse effect on offspring growth. Extrapolating a relationship between maternal exposure and effects in offspring is highly uncertain, as many factors can affect offspring growth. Additionally, the long term population-level impacts of reduced offspring growth are uncertain (Todd et al., 2012). Therefore, these CBRs are used only for qualitative comparisons. Using a $CBR_{LOEC} = 0.66$ mg THg/kg results in $HQ_{LOECs} < 2.2$ for the northern two-lined salamander, with only two Assessment Reaches exceeding a value of 2.0. However, this indication of limited potential risk is uncertain due to the inherent uncertainties in the CBR_{LOEC}, potential species-specific differences in tissue mercury concentrations and tolerance toward mercury. Hence, adverse effects are likely limited, but cannot be ruled out for the amphibian populations in AOC 4.

6.4.3 Amphibian Risk Description

The evaluation of amphibian exposures to mercury in AOC 4 indicates that THg and MeHg concentrations in surface water are below benchmark concentrations protective of various life stages of amphibians. Evaluation of whole body tissue mercury in three amphibian species indicates that population- level risks are unlikely toward amphibian species exposed to mercury in AOC 4, but they cannot be completely ruled out owing to the uncertainties in available benchmarks and potential species differences in bioaccumulation of and tolerance toward mercury.

6.5 Terrestrial Vegetation

The assessments of risks to terrestrial vegetation exposed to mercury in AOC 4 are based on measurement endpoints evaluating direct contact exposure to surficial soil (0-1 ft bgs) at concentrations associated with adverse effects:

- ME #1: Comparison of EPCs for surficial soil THg to corresponding benchmarks for the survival and growth of plants.

Evaluation of direct contact exposure to surficial soil mercury (ME #1) indicates that terrestrial vegetation is unlikely to experience population-level adverse effects. Except in in RRM 0.8 to 1.7 within the 2-year floodplain, the EPCs for surficial soil THg are below the NOEC that is protective of growth and survival of terrestrial plants (i.e., $HQ_{NOEC} < 1$) for each Assessment Reach within the four floodplains (0.3-, 2-, 5-, and 62-year) that were evaluated (see Table 6-19). The THg EPC in the 2-year floodplain in RRM 0.8 to 1.7 marginally exceeds the NOEC ($HQ_{NOEC} = 1.1$); however, the corresponding HQ_{LOEC}

< 1 (Table 6-19). These findings indicate that exposures to surficial soil mercury in AOC 4 are not likely to result in adverse effects on terrestrial vegetation.

6.6 Soil Invertebrates

The measurement endpoint for soil invertebrates exposed to mercury in AOC 4 was the evaluation of direct contact exposure to surficial soil at concentrations associated with adverse effects:

- ME #1: Comparison of the EPCs for surficial soil THg to corresponding benchmarks for the survival and growth of soil invertebrates.

Evaluations of direct contact exposures to surficial soil mercury indicate that soil invertebrates are unlikely to experience population-level adverse effects due to exposure to AOC 4 soils. EPCs for surficial soil THg marginally exceed the NOEC in several Assessment Reaches within the 0.3-, 2-, and 5-year floodplains (i.e., $HQ_{NOECs} \leq 3.4$) (Table 6-20). A majority of the NOEC exceedances were generally observed in the 0.3-year floodplain from Assessment Reaches RRM 0 to 0.8 (HQ_{NOEC} = 2.0) to RRM 4.4 to5.2 (HQ_{NOEC} = 2.3), in the 2-year floodplain from Assessment Reaches RRM 0 to 0.8 (HQ_{NOEC} = 1.8) to RRM 11.3 to 12.5 (HQ_{NOEC} = 2.3), and in the 5-year floodplain from Assessment Reaches RRM 0.8 to 1.7 (HQ_{NOEC} = 2.0) to RRM 4.4 to 5.2 (HQ_{NOEC} = 1.7) (Table 6-20). Relative to the LOEC, EPCs are marginally elevated in only three Assessment Reaches, each within the 0.3-year floodplain [RRM 0.8 to 1.7 (HQ_{LOEC} = 1.3) and RRM 4.4 to 5.2 (HQ_{LOEC} = 1.2)] and the 2-year floodplain [RRM 0.8 to 1.7 (HQ_{LOEC} = 1.7) and RRM 11.3 to 12.5 (HQ_{LOEC} = 1.2)] (Table 6-20). These findings indicate that exposures to surficial soil mercury in AOC 4 may result in limited localized risk, but overall no adverse effects on soil invertebrate populations are expected within AOC 4.

6.7 Avian Wildlife

As discussed in Sections 3.6 and 5.6, exposure and risk estimates for avian wildlife were based on dietary exposure estimated by food web modeling using site-specific MeHg and IHg in their diet items and mercury bioaccumulation in tissues at concentrations associated with adverse effects. One or both of the following MEs apply to the focal species (see Section 3.6):

- ME #1: Comparison of the estimated DMIR for IHg and MeHg based on dose rate modeling to the corresponding TRVs.
- ME #2: Comparisons of the EPCs for tissue THg and/or MeHg in birds from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction:
  - Comparison of blood THg EPC for piscivorous birds to corresponding CBRs; and
  - Comparisons of blood MeHg EPC for passerines to corresponding CBRs.

The following subsections discuss the evaluation of mercury exposure and associated risks for avian receptors in AOC 4.

6.7.1 Food Web Modeling

The results of deterministic dietary exposure modeling based on conservative exposure assumptions indicate very low potential for adverse effects on all representative birds resulting from exposure to IHg and potential adverse effects on all representative birds due to exposure to MeHg. Potential risks (based on HQs) are calculated separately under the following assumptions:

1. An avian receptor forages exclusively within the boundaries of the individual Assessment Reach (i.e., AUF = 1 for each Reach). The "HQ" represents a conservative maximum risk for each Assessment Reach.
2. An avian receptor forages within the boundaries of the individual Assessment Reach in proportion to the potential habitat that the Assessment Reach represents relative to its home range (i.e., AUF = Home Range within the Assessment Reach/Total Home Range). This "AUF-Adjusted HQ" represents the hypothetical contribution by each Assessment Reach (as far as spatial AUF is concerned) to the total risk if the receptor forages in background conditions (i.e., mercury exposures at background levels) while not foraging within the Assessment Reach. Note that when AUF for an Assessment Reach is 1, the HQ and AUF-Adjusted HQ are the same.
3. An avian receptor forages exclusively throughout the 14 Assessment Study Reaches within AOC 4 (including SFSR), but in proportion to AUF for each Study Reach. This "Cumulative HQ" is calculated as the weighted sum of HQs for each Study Reach, where weights are the AUFs and the sum of AUFs = 1 (i.e., one home range).

The HQ and AUF-Adjusted HQ provide measures of risks within each Assessment Reach relative to other Assessment Reaches. The Cumulative HQ provides the maximum possible risks due to overall exposures to mercury in all 14 Study Reaches (i.e., AOC 4 as a whole). Hence, the HQ and AUF-Adjusted HQ will be discussed in identifying reach-specific risks in the overall WOE evaluations for different environmental compartments (e.g., for aquatic, semi-aquatic, and terrestrial receptors). In addition, overall risks to individual receptors exposed to AOC 4 as a whole will be reflected in the Cumulative HQ.

The details of the risk calculations for each of the Assessment Reaches, including the Upstream Reference Reach (RRM -2.7 to -0.7) and SFSR are provided in Appendix F. Table 6-21 provides an overall summary for avian receptors, which is discussed below.

Inorganic Mercury

For exposures to IHg, the Cumulative HQ_{NOAELs} are higher in the Study Reaches than in the Upstream Reference Reach, but ≤ 2 for all birds except American robin, with $HQ_{NOAELs} \leq 3.4$ in all Assessment Reaches. The Cumulative HQ_{LOAELs} are also higher in the Study Reaches than in the Upstream Reference Reach, but ≤ 1 for all avian receptors except American robin, with $HQ_{LOAELs} \leq 1.7$ in all Assessment Reaches (i.e., the estimated DMIRs are comparable to the LOAEL dose). These results indicate that avian exposures to IHg via the dietary route in the Assessment Reaches within AOC 4 are elevated relative to the Upstream Reference Reach, but have very low potential, if any, to result in adverse population-level effects.

Methylmercury

Risk estimates for avian exposures to MeHg indicate that risk cannot be ruled out for the avian receptors. For avian receptors at potential risk, dietary items such as invertebrates and fish that tend to bioaccumulate MeHg, are the primary risk drivers. A summary of the risk estimates for the avian receptors is presented in Table 6-20 and discussed below, followed by a discussion on risk driving dietary items.

- Belted kingfisher: A cumulative HQ_{NOAEL} = 63 and a cumulative HQ_{LOAEL} = 20 for the Study Reaches are 17-fold higher than the HQ_{NOAEL} = 3.6 and HQ_{LOAEL} = 1.1 for the Upstream Reference Reach (RRM -2.7 to -0.7), and indicative of potential risks to the belted kingfisher population in AOC 4.
- Mallard duck: A cumulative HQ_{NOAEL} = 5.9 and a cumulative HQ_{LOAEL} = 1.8 for the Study Reaches are elevated relative to the HQ_{NOAEL} = 0.1 and HQ_{LOAEL} = 0.0 (i.e., < 0.05) for the Upstream Reference Reach, and are indicative of a low potential for risks to the mallard duck population in AOC 4.
- Eastern screech owl: A cumulative HQ_{NOAEL} = 38 and a cumulative HQ_{LOAEL} = 12 for the Study Reaches are approximately 11-folds higher than the HQ_{NOAEL} = 3.6 and HQ_{LOAEL} = 1.1 for the Upstream Reference Reach, and are indicative of potential risks of adverse effects on the Eastern screech owl population in AOC 4.
- Tree swallow: A cumulative HQ_{NOAEL} = 37and a cumulative HQ_{LOAEL} = 17 for the Study Reaches are elevated relative to HQ_{NOAEL} = 0.2 and HQ_{LOAEL} = 0.1 for the Upstream Reference Reach, and indicate risks to the tree swallow population in AOC 4.
- American robin: A cumulative HQ_{NOAEL} = 3.7 and a cumulative HQ_{LOAEL} = 1.7 for the Study Reaches are elevated relative to the HQ_{NOAEL} = 0.0 and HQ_{LOAEL} = 0.0 for the Upstream Reference Reach, and are indicative of a low potential for risks to the American robin population in AOC 4.

The above results indicate potential risk of adverse effects to belted kingfisher, mallard duck, Eastern screech owl, tree swallow, and American robin due to dietary exposures to MeHg in the AOC 4 Study Reaches. However, the risk calculations are based on conservative approaches for both effects evaluations (TRV derivations) and exposure evaluations (EPCs and doses based on food web modeling) that are likely to have resulted in over-estimation of actual risks. These will be discussed in more detail in Section 7.

Identification of dietary items that contribute the most to the total estimated MeHg doses for the avian receptors indicate that MeHg accumulation in certain dietary items drive the risks. The importance of these dietary items with respect to their contribution to total MeHg doses is summarized below.

- Belted kingfisher: Small fish (TL < 130 mm) contribute 95 to 98% of the total MeHg dose in the Assessment Reaches. The rest of the dietary items contribute to total doses at levels below the NOAEL dose of 0.017 mg/kg/day. Thus, MeHg accumulation in the small fish in AOC 4 is responsible for 100% of the risk to the belted kingfisher.

- Mallard duck: Aquatic invertebrates (including larval invertebrates and crayfish) contribute 75 to 96% of the total MeHg dose in the Assessment Reaches and the small fish (TL < 130 mm) contribute 3 to 25% of the total MeHg dose in the Assessment Reaches. Hence, MeHg accumulation in the aquatic invertebrates in AOC 4 is the primary risk driver for the mallard duck.
- Eastern screech owl: Small birds contribute 69 to 91% of the total MeHg dose in the Assessment Reaches. Small mammals also contribute as much as 17% of the total dose in some Assessment Reaches. Crayfish and wolf spiders contribute to total doses exceeding the NOAEL dose. Thus, MeHg accumulation in the small birds in AOC 4 is the primary risk driver for the Eastern screech owl, with other dietary items also contributing to the dose.
- Tree swallow: Emergent aquatic invertebrates contribute 63 to 98% of the total MeHg dose in the Assessment Reaches, with the remainder attributable to wolf spiders, exceeding the NOAEL dose in some Assessment Reaches. Thus, MeHg accumulation in emergent aquatic invertebrates in AOC 4 is the primary risk driver for tree swallow.
- American robin: On average, wolf spiders contribute 59% of the total MeHg dose in the Assessment Reaches, while earthworms (representing dietary invertebrates other than the wolf spiders) contribute 39% of total MeHg dose. Thus, MeHg accumulation in predatory terrestrial insects along the Assessment Reaches (such as wolf spiders) is the primary risk driver for American robin.

The above results show that the dietary items that contribute the most to the total estimated MeHg doses for the avian receptors include: small fish (TL < 130 mm) for the belted kingfisher, aquatic invertebrates and small fish for mallard ducks, small birds for Eastern screech owl, emergent aquatic invertebrates for the tree swallow, and wolf spiders for the American robin. Appendix F provides the calculation of total MeHg doses due to each dietary and non-dietary item. The aquatic to terrestrial transfer of MeHg occurs primarily via the consumption of small fish, emergent aquatic insects, and predatory terrestrial insects and small birds. Small birds in turn feed on emergent aquatic insects and predatory terrestrial insects.

6.7.2 Tissue Residue Approach

Available data indicates that mercury concentrations in the blood of representative avian receptors are generally higher in birds collected from the Assessment Study Reaches compared with Reference Reaches, and are also elevated relative to conservative CBRs. Table 6-22 compares the available mercury concentrations in the blood of representative avian receptors from the Study Reaches and Reference Reaches and corresponding CBRs (developed in Section 4.7.5) and the following provides a discussion of the results for the avian receptors.

- Belted kingfisher: Blood THg EPCs for belted kingfisher are elevated relative to the CBR_{NOEC} in several Study Reaches, i.e., HQ_{NOEC} > 2 in several Study Reaches are as high as 8.8 for RRM 13.5 to 16.7. Relative to the CBR_{LOEC}, blood THg

EPCs are elevated in only two Study Reaches (RRM 11.3 to 12.5 and RRM 13.5 to 16.7), with HQ_{LOECs} of 2.5 and 2.9, respectively. Both blood THg and MeHg EPCs are elevated in the Study Reaches relative to the Reference Reaches (upper MR, middle MR and upper NR). Blood THg and MeHg EPCs in the lower MR and lower NR are elevated compared to the rest of the Reference Reaches, perhaps due to proximity to AOC 4. This observation suggests that in some areas belted kingfisher habitats may overlap between the AOC 4 and nearby rivers.

- Mallard duck: Blood THg and MeHg EPCs for mallard ducks are elevated in the Study Reaches relative to the Reference Reaches (upper MR and upper NR), indicating higher mercury exposures in AOC 4, but appropriate CBRs are not available to quantify risk estimates.
- Eastern screech owl: Blood THg and MeHg EPCs for Eastern screech owl are elevated in the Study Reaches compared to the Reference Reaches (at RRM -2.7 to -0.7, middle MR, and upper NR). EPCs for the owls in the lower NR are higher than in the rest of the Reference Reaches. Appropriate CBRs are not available to quantify risk estimates.
- Tree swallow: Blood MeHg EPCs for Tree swallows from the Study Reaches are generally elevated compared to several Reference Reaches (including the Upstream Reference Reach RRM -2.7 to -0.7). Available data indicate that $HQ_{NOECs} > 1$, but generally < 4 in the Study Reaches. However, HQ_{LOECs} are generally less than two, with only two Study Reaches (RRM 13.5 to 16.7 and RRM 16.7 to 20.9) with HQ_{LOEC} at 2.1. Relative to the Reference Reaches, blood THg EPCs show the same trend as the blood MeHg EPCs in the Study Reaches.
- American robin: Available data indicate that blood MeHg EPCs in the four Study Reaches are elevated relative to Reference Reaches, but the EPCs exceed the CBRs only in RRM 1.7 to 2.7, with $HQ_{NOEC} = 4.3$ and $HQ_{LOEC} = 2.1$. Relative to the Reference Reaches, the blood THg EPCs are also elevated in the four Study Reaches, particularly in RRM 1.7 to 2.7, although there are no benchmarks with which to quantify potential risks.

The above results indicate that blood mercury concentrations in avian receptors are higher within AOC 4 than in Reference Reaches reflecting elevated exposures to mercury in AOC 4. For the mallard and the screech owl, appropriate CBRs are not available to calculate HQs. Blood mercury EPC comparisons to available conservative CBRs for belted kingfisher and the passerines (tree swallow and American robin) result in elevated HQ_{NOECs} (a maximum 8.8 and 4.3 for kingfisher and passerines, respectively) and marginally elevated HQ_{LOEC} (a maximum of 2.9 and 2.1 for belted kingfisher and passerines, respectively). These HQs may be interpreted to indicate that the individual birds may be at risk because the EPCs exceed the "no effects" thresholds, above which adverse effects cannot be ruled out. But the tissue residue EPCs are generally below or slightly above the "low effects" threshold and do not support the likely presence of population-level adverse effects.

6.7.3 Avian Risk Description

The results of the deterministic dietary exposure modeling indicate a potential for risk to avian receptors exposed to MeHg in AOC 4. Conservative deterministic modeling indicated that estimated dietary doses were generally ten times above the LOAEL TRVs for all avian receptors except mallard duck and American robin (with cumulative HQ_{LOAELs} of 1.8 and 1.7, respectively). The potential for risk based on evaluations of available blood mercury concentrations in kingfisher and the passerines (maximum HQ_{LOECs} of 2.9 and 2.1 for belted kingfisher and tree swallow, respectively) is lower than the potential based on the dietary exposure modeling (HQ_{LOAELs} of 19.6 and 17.2 for belted kingfisher and tree swallow, respectively). These results indicate that potential risks estimated by dietary dose modeling are likely overly conservative. Nonetheless, the overall results indicate that risk due to MeHg exposures in AOC 4 cannot be ruled out for several avian receptors, particularly piscivores (such as belted kingfisher), carnivores (such as Eastern screech owl), and insectivores (such as tree swallow).

6.8 Mammalian Wildlife

Similar to avian wildlife, exposure and risk estimates for mammalian wildlife were based on dietary exposure or food web modeling using site-specific MeHg and IHg in their diet items and mercury bioaccumulation in tissues at concentrations associated with adverse effects:

- ME #1: Comparison of the estimated DMIR for IHg and MeHg based on dose rate modeling to the respective TRVs.
- ME #2: Comparisons of the mercury tissue residue EPCs for mammals from AOC 4 to CBRs associated with effects on growth, survival, and reproduction:
  - Comparison of blood THg EPCs to corresponding CBRs; and
  - Comparisons of fur THg EPCs to corresponding CBRs.

The following subsections discuss the evaluation of mercury exposure and associated risks for mammalian receptors in AOC 4.

6.8.1 Food Web Modelling

Deterministic dietary exposure modeling is based on conservative exposure assumptions and TRVs. For exposures to IHg, the results indicate negligible risk to all representative mammals for exposures to MeHg; the results indicate a potential for adverse effects only on the big brown bat. Similar to the risk estimates for the avian receptors, three sets of HQs (HQ, AUF-Adjusted HQs, and Cumulative HQs) are calculated for mammals. Risk calculation details are provided in Appendix F. Table 6-23 provides overall summaries, which are discussed below.

Inorganic Mercury

Estimated IHg doses in mammals within AOC 4 are not expected to result in adverse effects. Although higher than in the Reference Reach, the cumulative $HQ_{NOAELs} \leq 1.2$ for mammalian exposures to IHg in the Study Reaches (Table 6-23). These results indicate that the mammals are exposed to mercury at higher doses in the AOC 4 Assessment

Study Reaches than in the Reference Reach, but their exposures are at levels that are unlikely to result in adverse population-level effects.

Methylmercury

With the exception of the big brown bat, the mammalian receptors are not expected to be at risk due to dietary exposures to MeHg within AOC 4. Estimated MeHg doses in big brown bats are elevated relative to conservative TRVs and are thus indicative of the potential risks for adverse effects. Dietary exposures to MeHg (summarized in Table 6-23) are discussed below for the mammalian receptors.

- River otter: A cumulative HQ_{NOAEL} = 1.0 and a cumulative HQ_{LOAEL} = 0.6 for the Study Reaches are elevated relative to the Reference Reach (HQ_{NOAEL} = 0.1 and HQ_{LOAEL} = 0.1), but are not indicative of risks to the river otter population in AOC 4.
- Short-tailed shrew: A cumulative HQ_{NOAEL} = 1.7 and a cumulative HQ_{LOAEL} = 0.4 are elevated for the Study Reaches relative to the Reference Reach, but are not indicative of risks to the short-tailed shrew population in AOC 4.
- White-tailed deer: Estimated MeHg doses for the white-tailed deer within AOC 4 are orders of magnitude lower than the NOAEL dose. Hence, the white-tailed deer population within AOC 4 is not at risk due to mercury exposure.
- Big brown bat: A cumulative HQ_{NOAEL} = 9.7 and a cumulative HQ_{LOAEL} = 5.8 are elevated for the Study Reaches relative to the Reference Reach (HQ_{NOAEL} = 0.2 and HQ_{LOAEL} = 0.1), and are indicative of risks to the big brown bat population within AOC 4.

The above results on estimated dietary exposures to MeHg indicate risk to the big brown bat population in the AOC 4 Assessment Study Reaches. However, similar to that for the avian receptors, the risk calculations for mammalian receptors are based on conservative approaches for both effects evaluations (TRV derivations) and exposure evaluations (EPCs and doses based on food web modeling) that are likely to have resulted in over-estimation of actual risks. The conservative nature of the risk estimations, as well as associated uncertainties, will be discussed in more detail in Section 7.

6.8.2 Tissue Residue Approach

Available data on blood and fur mercury concentrations in mammals are indicative of higher mammalian exposures to mercury in Study Reaches than in the Reference Reaches. Blood and fur mercury EPCs available for limited Study Reaches exceed the conservative CBRs derived in Section 4.7.5, indicating potential adverse effects on mammals in AOC 4. Blood and fur THg EPCs for two representative mammals (big brown bat and short-tailed shrew) and the little brown bat, are compared to the corresponding blood and fur CBRs. While the little brown bat is not a representative mammalian receptor selected for the current ERA, mercury tissue residues for this organism are evaluated due to its similarity to the big brown bat and data availability. Tables 6-24 and 6-25 provide the results of the evaluations for the blood and fur mercury concentrations, respectively, which are discussed below.

- Blood THg Concentrations: Available blood THg concentrations are limited to two Study Reaches (RRM 1.7 to 2.7 and RRM 11.3 to 12.5) for the big brown bat and one Study Reach (RRM 16.7 to 20.9) for the little brown bat, Reference Reaches (MR or NR) for both species, as discussed below.
    - Big brown bat: The blood THg EPC for the big brown bat in the two Study Reaches are elevated relative to both the Reference Reach EPCs and CBR_{NOEC} (HQ_{NOEC} = 3.1 and 10.1 in RRM 1.7 to 2.7 and RRM 11.3 to 12.5, respectively).
    - Little brown bat: The blood THg EPC for the little brown bat in RRM 16.7 to 20.9 is elevated relative to both the Reference Reach EPCs and CBR_{NOEC} (HQ_{NOEC} = 37.5). The EPCs in two Reference Reaches (middle MR and lower MR) also exceed the CBR_{NOEC} (HQ_{NOECs} = 2.2 and 4.1, respectively).
- Fur THg Concentrations: Available fur THg concentrations are limited to two Study Reaches and Reference Reaches for the big brown bat, little brown bat, and short-tailed shrew, as discussed below.
    - Big brown bat: Fur THg EPCs for the big brown bat in the two Study Reaches are marginally elevated relative to CBR_{NOEC} (HQ_{NOEC} = 1.9 and 2.3 in RRM 1.7 to 2.7 and RRM 11.3 to 12.5, respectively).
    - Little brown bat: Fur THg EPCs for the little brown bat in two Study Reaches are elevated relative to both the Reference Reach EPCs and CBR_{NOEC} (HQ_{NOEC} = 8.9 and 23.6 in RRM 1.7 to 2.7 and RRM 16.7 to 20.9, respectively).
    - Short-tailed shrew: Fur THg EPCs for the short-tailed shrew in two Study Reaches are marginally elevated relative to CBR_{NOEC} (HQ_{NOEC} = 2.2 and 3.7 in RRM 13.5 to 16.7 and RRM 16.7 to 20.9, respectively).

The above results indicate that exposures to mercury in select representative mammals are at levels higher than the corresponding CBR_{NOEC}, which is a conservative "no effects" criterion. The CBR_{NOEC} used in the above evaluations for both blood and fur THg are mostly based on concentrations in big brown bats from Reference Reaches associated with AOC 4 (see Section 4.7.5), and as such are likely not representative of an upper threshold for no effects. While exposures below these CBR_{NOECs} indicate no adverse risks, exposures above them do not necessarily indicate potential risks. Therefore, while mercury exposures (based on blood and fur mercury concentrations) in the select mammals are higher in the Study Reaches than in the Reference Reaches (as represented by CBR_{NOEC}), it is uncertain what level of adverse effects, if any, these exposures represent.

6.8.3 Mammalian Risk Description

Results of dietary modeling indicate negligible risks for all representative mammalian receptors foraging within AOC 4 except the big brown bat. Conservative deterministic modeling indicated that estimated dietary doses to all representative mammals, except the big brown bat, were comparable to or less than NOAEL TRVs, and below LOAEL

TRVs. Based on the conservative nature of the risk estimates, a cumulative HQ_{NOAEL} = 9.7 and a cumulative HQ_{LOAEL} = 5.8 are estimated for the big brown bat, indicating the potential for population-level adverse effects.

Blood and fur mercury concentrations were evaluated in mammals from a limited number of Study Reaches. Both blood and fur THg EPCs for the bat species were above the corresponding conservative "no effects" concentrations, with uncertainty on the magnitude of the potential effects because "low effects" thresholds or CBR_{LOEC} are not available.

Overall evaluations of mammalian exposures to mercury in AOC 4 indicate risk to aerial insectivorous mammals such as the big brown bat.

6.9 Special Status Species

As discussed in Section 2.3.4 and listed in Table 2-1, only two crustaceans [Madison cave amphipod (*S. stegerorum*) and Madison cave isopod (*A. lira*)] and a bivalve [Brook floater (*A. varicosa*)] are identified as threatened or endangered species in Virginia and may be found in AOC 4. Mercury effects information specifically on these species is not available for their individual assessment. Available HQ_{LOECs} are less than one for benthic invertebrates based on comparisons of media-specific EPCs to respective benchmarks, but HQ_{NOECs} are greater than for several Study Reaches. Implications of $HQ_{NOECs} > 1$ with respect to special status invertebrates, particularly the brook floater, are acknowledged. However, as discussed below, a HQ_{NOEC} that is applicable to the brook floater is likely to be overestimated.

Available literature does not indicate that bivalve species are necessarily more sensitive than fish or arthropods, on which the water quality benchmarks are generally based. A single chronic study on mercury toxicity to a freshwater bivalve species was identified (Valenti et al., 2005) that reported a chronic LOEC of 8,000 ng/L toward juvenile rainbow mussel (*Villosa iris*). This LOEC is same as the conservative LOEC benchmark selected for the evaluation of benthic invertebrates (see Section 4.1.3). Available studies on acute toxicity of mercury on freshwater bivalves also do not indicate that freshwater bivalves are more sensitive than fish and arthropods (Valenti et al., 2005; Boening, 2000). Reported acute benchmarks for the bivalves are greater than14,000 ng/L.

NOEC benchmarks for THg and MeHg (in sediment, surface water/pore water, and tissue) are based on amphipods and daphnids and are conservative (See Section 4.1 and Appendix C). For example, sediment benchmarks were based on site-specific sediment toxicity studies on *H. azteca* and *C. dilutus*. No effects were observed at the highest concentration of THg and MeHg tested—i.e., the upper bound of the NOECs may be higher. Similarly, the surface water and pore water NOEC for MeHg was based on an application of a 10-fold uncertainty factor for LOEC-to-NOEC extrapolation based on a study on daphnia reproduction. A default safety factor of 10 is typically applied for Acute-to-Chronic extrapolation, but in this case, a chronic-LOEC was extrapolated.

Hence, a combination of the similar, if not lower, sensitivity of bivalves relative to arthropods and fish and conservative nature of the NOEC benchmarks likely overestimated calculated risks for both arthropods and bivalve species. Therefore, mercury in AOC 4 is not likely to pose significant risks to the special status arthropods at an individual level. Additionally, benthic community structures along the South River are found to be more sensitive to factors unrelated to mercury. These same factors may be more critical than mercury alone with respect to potential adverse effects on the individuals of the special status species that may be potentially present in AOC 4.

Based on the above discussions, potential exposures to mercury is unlikely to cause adverse effects on the individuals of the special status species that are potentially present within AOC 4.

7.0 Uncertainty Analysis

An uncertainty analysis was performed to identify assumptions and procedures that may result in either over or under estimation of exposure or potential risks associated with mercury in AOC 4. The uncertainty analysis focuses on the major assumptions and other factors that may influence the overall findings of the ERA. Discussions of uncertainty are organized by four relevant phases of the assessment with inherent uncertainty: sampling design/data quality, effects analysis, exposure analysis, and risk characterization.

7.1 Sampling Design/Data Quality

A critical aspect of the sampling design is collecting an appropriate and adequate number of samples to answer the risk questions in Section 3.6. Although data used in this assessment were not collected specifically for this ERA, they were collected in collaboration with the SRST, VDEQ, and EPA, and frequently, in the context of EPA framework and guidance for ecological risks assessment. The USEPA *Guidance for Data Useability in Risk Assessment (Part A)* (USEPA, 1992) defines appropriate analytical methods as those which "have detection limits that meet risk assessment requirements for chemicals of potential concern and have sufficient QC measures to quantitate target compound identification and measurement." Samples for mercury analysis are collected and analyzed following a limited number of analytical methods developed by the USEPA. These methods are performance-based and promulgate standard quality assurance/quality control (QA/QC) guidelines. As such, data demonstrating that the applicable QA/QC criteria have been met are comparable.

A separate RDQA has been performed for the data used in this assessment at the request and specific direction of VDEQ (Appendix A). Among other criteria, the RDQA considered the adequacy, representativeness, relevance, and quality of the data for their usability in this assessment. Overall, the sampling design and data quality was found to be adequate to satisfy the objectives of the investigation. Uncertainty is low regarding the potential influence of analytical or other data quality on the findings of the investigation.

7.2 Effects Analysis

Effects evaluations (Section 4) generally took a conservative approach when sufficient data were not available to estimate effects benchmarks, CBRs, and/or TRVs. Such an approach likely resulted in an overestimation of overall risks. Several of these benchmarks, CBRs, and/or TRVs that are particularly likely to involve a higher degree of uncertainty are discussed below for specific receptor(s) or receptor groups.

7.2.1 Effects Benchmarks

Derivation of surface water, pore water, sediment, and soil benchmarks were generally limited to available effects data on specific organism groups. Where literature provided sufficient information to fill the data gaps, a generally conservative approach was used. For example, surface water THg and MeHg benchmarks for amphibians and aquatic vegetation were based on conservative surface water quality criteria protective of a broader range of aquatic organisms, including those that are more sensitive than amphibians and aquatic vegetation.

Generally relying on conservative, organism-group specific effects benchmarks reduces the uncertainty due to differences in group sensitivities, while still maintaining their protectiveness.

7.2.2 Critical Body Residues

Use of CBRs for toxicity assessment relies on the toxicological principle that a toxic effect is not observed unless the chemical reaches the site of action (McElroy et al., 2011). Therefore, chemical concentrations in the tissue or organism are expected to be a better and more appropriate measure of toxicity than chemical concentrations in the abiotic exposure media—particularly for bioaccumulative chemicals such as mercury. Expressing mercury toxicity based on tissue residues is conceptually attractive because it integrates mercury uptake from different exposure routes, accounts for bioavailability differences in exposure media, and addresses the potential of different toxicokinetics within various species (EPA, 2007). For several groups of organisms and focal species, this assessment derived conservative CBRs relying on available literature data. Therefore, for aquatic invertebrates, fish, birds, and mammals, the conservative CBRs likely led to an overestimation of potential risks. Specific CBRs could not be derived for amphibians; hence, fish CBRs were used as surrogates. As discussed in Section 6.4, site-specific information indicates that such an approach is appropriate, and likely to result in overestimation of risk rather than underestimation.

7.2.3 Toxicity Reference Values

Wildlife TRVs were based on reproductive, mortality, and growth endpoints, consistent with EPA guidance and risk management principles (EPA, 1997; EPA, 1999) to identify population-level impacts to ecological receptors. However, studies indicate potential sublethal effects of mercury on the physiology and behavior of birds (e.g., Bouton et al., 1999; Hoffman et al., 2005; Frederick and Jayasena, 2010; Fallacra et al., 2011; Jayasena et al., 2011) and mammals (Dansereau et al., 1999; Verschuuren et al., 1976). The potential direct and indirect implications of these physiological and behavioral endpoints on the long-term viability of receptor populations are uncertain. This uncertainty of population-level implications associated with physiological and behavioral endpoints precludes their use in ecological risk assessment and management.

Uncertainties involved in wildlife TRV derivations primarily involved the assumptions of the relative sensitivities of receptors to MeHg exposure and the appropriateness of the underlying data (and thus the extrapolations used). The procedures for wildlife TRV derivation were generally conservative; to the extent possible, attempts were made to account for species differences. For example, TRVs were derived for four categories of birds: high sensitivity piscivores/waterfowl, low-to-moderate sensitivity piscivores/waterfowl, carnivores, and passerines (see Section 8.1.1 in Appendix C) and four categories of mammals: piscivores, herbivores, terrestrial insectivores, and aerial insectivores (see Section 8.1.3 in Appendix C).

Potential uncertainties were specifically identified in derivation of avian TRVs for belted kingfisher, Eastern screech owl, and passerine birds (tree swallow and American robin):

- Belted kingfisher and Eastern screech owl were assumed to have the same sensitivity to MeHg as the high sensitivity waterfowl/piscivore (see Appendix C). In absence of specific data, this assumption is likely to be reasonable, if not overly conservative.
- For passerine birds (tree swallow and American robin), two NOAELs were identified based on field studies. The lower NOAEL (0.36 mg MeHg/kg BW/day), based on the geometric mean of the estimated NOAELs, likely represents a conservative estimate of effect (see Section 8.1.1 in Appendix C).

For mammals, the biggest uncertainty in deriving TRVs was associated with the big brown bat. Dietary studies evaluating bats exposed to mercury were not identified in the literature. Therefore, conservative UFs were applied to TRVs derived for mink, a sensitive mammalian species. The protectiveness of these TRVs is uncertain given the lack of toxicological data for bats exposed to dietary mercury.

7.3 Exposure Analysis

The following subsections review the major uncertainties associated with the exposure analysis in the current assessment.

7.3.1 Selection of Receptors

As ERAs cannot include all potential receptors, a focused list of representative ecological receptors is evaluated instead. As a result, representative receptors were selected based on trophic category, particular feeding behaviors, availability of life history information to represent several similarly exposed species, and the existence of a complete exposure pathway as identified in the ECSM. If the receptors evaluated in the assessment differ in terms of exposure to site-related constituents as compared with others representative receptor populations, the results may overestimate or underestimate overall ecological risks in AOC 4.

Overall, receptors evaluated in this assessment provide an adequate representation of potential risks to wildlife that may inhabit and/or forage in AOC 4. In addition, the focal receptors were selected in consultation and collaboration with VDEQ.

7.3.2 Designation of Exposure Areas- Assessment Reaches

As indicated in Section 3.2 and in Appendix E, the datasets for AOC 4 are partitioned spatially based on the reach breaks defined by intersecting the 2-foot LiDAR contours with the channel centerline. This approach results in a total of 16 exposure areas (Assessment Reaches). These Assessment Reaches included 14 Study Reaches, one Buffer Reach, and one Upstream Reference Reach. Since Assessment Reach boundaries are not ecologically based, it is likely that the home ranges for receptors with large home ranges do not coincide with Assessment Reach boundaries, and that the receptors move among the Assessment Reaches for foraging. Nonetheless, these Assessment Reach boundaries provide a systematic and convenient approach to incorporate the potential spatial variability in exposures.

For assessment of receptors such as plants and invertebrates that are practically sedentary, the smaller discrete exposure areas represented by each of the Assessment

Reaches are more appropriate than a site-wide exposure area. Assessment Reaches provide a level of spatial refinement that allows for evaluations of a broader distribution of potential exposures within AOC 4, despite the spatial variability that occurs within them.

For wildlife receptors, the use of an AUF to calculate Cumulative HQs accounts for the interaction among the Assessment Reaches in contributing to total exposures. Section 6.7 describes how AUF information is used for contiguous Assessment Reaches that may represent a receptor's home range.

In summary, the treatment of the Assessment Reaches as discrete exposure units within AOC 4 is not likely to affect the overall conclusions of this ERA. In addition, the approach provides a level of spatial resolution and distribution of relative risks throughout the AOC 4 study area.

7.3.3 Exposure Point Concentrations

Details of the EPCs calculations are provided in Appendix E. Several key uncertainties associated with EPCs calculations include extrapolation of EPCs for the Assessment Reaches where appropriate data were unavailable and the lack of explicit incorporation of potential temporal variability in MeHg concentrations in various media.

Concentration data from representative dietary items for food web modeling are not available for all the Assessment Reaches. Hence, estimates are based on the highest EPCs in the next adjacent Assessment Reach. For example, mercury concentration data are available for only four Assessment Reaches for small mammals (dietary component for Eastern screech owl), seven Assessment Reaches for emergent aquatic invertebrates (an important dietary component for tree swallow and big brown bat), and five Assessment Reaches for wolf spiders (assumed dietary component of tree swallow, American robin, and short-tailed shrew). Therefore, while the applied extrapolations are reasonable, they contribute to the uncertainties in the resulting risk estimates.

Temporal variability or seasonal differences in EPCs are not explicitly incorporated in the exposure estimates. For example, seasonal differences in MeHg concentrations in surface water and sediments and/or dietary preferences may result in higher average exposures during certain periods. However, the timing of exposure media sampling was intended to account for potentially greater mercury methylation in abiotic and biotic media based on seasonality.

There is uncertainty regarding the use of data collected prior to the ERA, as it is not known if the conditions at the time of sampling are representative of the current or future state of AOC 4. Much of the data (e.g., surface water) were collected at a relatively high frequency over several years, such that the data set is representative of the seasonal and annual variation in mercury concentrations. Other data were collected for a shorter duration, so there is uncertainty regarding the potential variation. The Ecological Study (URS, 2012) compared the discharges and surface water temperatures observed during the six years of the study to a 40 year record and found that the conditions observed were not anomalous in terms of precipitation or temperature. It is therefore likely that the data used for this ERA is generally representative of current conditions.

7.3.4 Food Web Modelling

The major source of uncertainties in the wildlife dietary exposure evaluations is associated with the estimates for FIRs for birds and mammals. Uncertainty in the FIR and other model parameters and their implications on the risk estimates are discussed below.

Food Ingestion Rates

FIRs were estimated for a typical (or average) receptor using applicable allometric relationships from Nagy (2001). While the basis for the allometric relationships is the field metabolic rate (FMR), several assumptions are needed to translate the FMR into FIR, such as dietary preference, moisture content and caloric values of the dietary items, and life stages. These assumptions contribute to the uncertainty of the predicted FIRs, which are reported as the average absolute difference (species deviation) between the actual FIRs and those predicted for each species using the group equations. Nagy (2001) reported that species deviations ranged from 28 to 33 percent for birds and 26 to 33 percent for the mammals represented in the current evaluations. These deviations mean that, on average, the actual FIRs were within a factor of 0.67 to 1.33 of the predicted FIRs. These levels of uncertainty in estimating FIRs would not result in a change in the overall risk conclusions regarding wildlife dietary exposure in AOC 4.

Representativeness of Dietary Items

As indicated in Appendix D, collection of all dietary items for a receptor is impractical. Use of data for limited representative dietary items invariably introduces some uncertainty in the food web modeling results. However, the primary dietary items for the focal species are well represented by the biota samples collected within AOC 4 and used in the food web modeling. More importantly, these representative dietary items are also expected to contribute the most to the receptors' exposure to mercury. Therefore, the use of the representative dietary items in the food web modeling is unlikely to have resulted in an underestimation of the overall risks.

Mercury Bioavailability and Assimilation

Bioavailability of mercury from field diet/media compared to laboratory diet/media was assumed to be the same, i.e., a relative bioavailability of 100 percent was conservatively assumed in all cases except for terrestrial plants and invertebrates. Systemic assimilation of mercury from field diet is assumed to be the same as in laboratory dosing studies that formed the basis for various effects benchmarks. These assumptions likely overestimated exposures and hence, risk estimates in the current assessment.

7.4 Risk Characterization

Uncertainties and limitations are associated with the overall risk characterization approach in the current assessment. These uncertainties and limitations are acknowledged in the following.

Uncertainties in characterizing risks are associated with the assumption that an HQ greater than 1.0 is an adequate indicator of the potential for ecological risks resulting from exposure to mercury. Given the use of conservative exposure and effects assumptions, there is minimal uncertainty, and it is highly unlikely, that the potential for ecological risks from exposure to mercury were not identified in the evaluation.

Conversely, there is a possibility of false positive identification of ecological risks associated with mercury exposure. The influence of HQs on risk characterization may underestimate, but more likely overestimate, risk.

The deterministic nature of the current risk evaluations may fail to capture the variability in exposures even for a typical receptor (with a given BW and FIR) due to: 1) daily variability in dietary composition and 2) variability in mercury content of dietary items. For example, the deterministic approach assumes that a receptor simultaneously consumes dietary items that all contain mercury at their EPCs (as defined) on a daily basis, although such a situation is unlikely. For example, the MeHg doses for the eastern screech owl based on the DMIR in this assessment of 0.256 to 0.741 mg MeHg/kg BW/day for the Assessment Reaches is more than an order of magnitude higher than the mean DMIR of 0.087 mg Hg/kg BW/day based on a probabilistic estimate (Wang and Newman, 2012). Similarly, the MeHg DMIR for the tree swallow (0.067 to 1.343 mg MeHg/kg BW/day) and American robin (0.036 to 0.319 mg MeHg/kg BW/day) are also generally considerably higher than the mean DMIR estimated for two passerines: 0.068 and 0.041 mg Hg/kg BW/day for Carolina wren and song sparrow, respectively (Wang and Newman, 2012). Hence, the DRM input parameter assumptions likely overestimated risks in the current evaluations.

Further limitations of the current risk characterization for AOC 4 include, but are not limited, to the following:

- Avian and mammalian exposure evaluations considered the adult life-stage of receptors. Risks to other life-stages (e.g., juveniles) were not explicitly evaluated. However, these other life-stages were indirectly considered in estimating TRVs that evaluated potential effects based on several generations of surrogate species.
- Wildlife exposure evaluations did not consider habitat suitability within the various Assessment Reaches of AOC 4. For example, river otters are unlikely to forage developed shorelines with inadequate cover or den sites. In addition, foraging habits of the birds are likely dictated by accessibility, availability, and abundance of dietary items within various Assessment Reaches of AOC 4. The exposure models considered the dietary items to be equally accessible, available, and abundant within an Assessment Reach regardless of physical habitat quality.

7.5 Summary of Uncertainty Analysis

The ERA used conservative assumptions and estimates to evaluate potential ecological impacts associated with exposures to mercury in AOC 4. Because conservative estimates or assumptions were made for most factors considered in the assessment, there is confidence that the conclusions of the ERA are adequately conservative to identify potential adverse effects to ecological receptor populations.

8.0 Summary of Findings

The objectives of this ERA were to:

- Evaluate potential risks to ecological receptors potentially exposed to COPECs in prey items, soil, sediment, and surface water within AOC 4; and
- Provide risk information sufficient to support risk-based remedial decision-making for AOC 4.

The overall findings of the evaluations reported in the preceding sections indicate that mercury concentrations measured in abiotic exposure media within AOC 4 are not likely to result in adverse effects on ecological receptors through direct contact pathways.

However, MeHg concentrations measured or estimated in the biota within AOC 4 may result in adverse effects on higher wildlife via the dietary exposure route. More specifically, estimated dietary exposures to MeHg indicate potential risks toward birds preying on small fish, predatory insects, and small mammals and birds, and mammals preying on emergent insects. These findings are consistent with the existing AOC 4 Aquatic and Terrestrial Conceptual System Models (CSMs) for mercury, which indicate that the greatest exposures to mercury are associated with the bioaccumulation and trophic transfer of MeHg (see AOC-4 RFI Report [URS, 2014a]). This section provides overall WOE evaluations for the three broad categories of the ecological receptors (aquatic, semi-aquatic, and terrestrial) for each of the Assessment Reaches within AOC 4 based on the measurement endpoints (MEs) for potential adverse effects that were discussed separately for individual receptors.

A WOE approach considers and integrates multiple lines-of-evidence that are closely linked to MEs for a particular assessment endpoint (AE). The ERA uses a WOE approach proposed by Menzie et al. (1996) to evaluate the overall AE of ecological health of the aquatic, semi-aquatic, and terrestrial receptors. The WOE approach is reflected in three characteristics of the MEs including (1) their weights (ME_W) which represent the importance of MEs relative to each other; (2) the potential for effects represented by the MEs; and (3) the concurrence among the outcomes of the MEs (Menzie et al., 1996).

Using hazard quotients to estimate the magnitude of risk is a common tool employed in baseline risk assessments, but the approach must be used with caution. Given that the relation between EPCs/doses and measures of effects is typically non-linear, the magnitude of the exceedance of a single benchmark does not necessarily predict the potential for or magnitude of toxic effects (Benjamin and Belluck, 2001). In the absence of defined concentration/dose-response relationships for each ME, the hazard quotient approach is applied in the WOE as an estimate of the potential magnitude of effects based on multiples of the “no effects” or “low effects” benchmarks. However, it is important to note that many of the MEs for the ERA may also be evaluated using site-specific effects data, thereby mitigating the uncertainty regarding the use of hazard quotients to estimate magnitude of risk. These site-specific effects data will be incorporated in the ERA to provide additional context regarding the potential magnitude of effects estimated using the hazard quotient approach. The following sections provide the results of the WOE evaluations for the aquatic, semi-aquatic, and terrestrial ecological receptors in AOC 4.

Further details of the WOE approach and the applicable criteria are discussed in Appendix G.

8.1 Aquatic Receptors

Evaluations were performed for the benthic/aquatic invertebrates, aquatic vegetation, and fish in the South River and a section of the SFSR located within AOC 4. These evaluations show no potential risks from exposures to mercury in the abiotic media via the direct contact pathway. However, mercury bioaccumulation in the biota (i.e., tissue residues) may potentially result in adverse effects on benthic/aquatic invertebrates and fish. Overall evaluations for AOC 4 are provided in Section 6.1 for invertebrates, Section 6.2 for fish, and Section 6.3 for aquatic vegetation. Overall, reach-specific WOE evaluations for aquatic receptors as a whole are provided in Tables 8-1a and 8-1b and are discussed below.

Evaluation of direct contact exposures to mercury in sediments, pore water, and surface water indicate that aquatic receptors are unlikely to be at risk of adverse effects in the Assessment Reaches based on the assessment described below.

- Benthic invertebrates (Table 8-1a and b): Available pore water chemistry (ME_W = 4) indicates a low potential for adverse effects. Surface water chemistry (ME_W = 3) indicates potential for adverse effects only in RRM 9.2 to 11.3, but the likelihood of potential effects is low. Sediment chemistry (ME_W = 3) indicates a medium potential for effects in RRM 1.7 to 2.7, RRM 2.7 to 4.4, and RRM 11.3 to 12.5, and a high potential for effects in RRM 4.4 to 5.2 and RRM 7.9 to 9.2. In all of these cases, presence of adverse effects is undetermined because of the lack of a sediment LOEC; the exceedance of a NOEC does not necessarily indicate risk.
- Fish (Tables 8-1a and b): Surface water chemistry (ME_W = 3) indicates a low potential for adverse effects in any of the Assessment Reaches.
- Aquatic vegetation (Tables 8-1a and b): Direct contact exposure to surface and pore water was quantitatively evaluated for aquatic vegetation. Both surface and pore water chemistry indicate a low potential for adverse effects in any of the Assessment Reaches.

Toxicity testing and community survey data also demonstrate that aquatic receptors are unlikely to be at risk of adverse effects in the Assessment Reaches as described below.

- Benthic invertebrates (Tables 8-1a and b): Both sediment toxicity tests (ME_W = 3) and benthic community analyses (ME_W = 4) that were conducted as parts of the SQT evaluations, indicate no evidence of adverse effects to invertebrates within the four representative Assessment Reaches.
- Fish (Tables 8-1a and b): Fish age/growth, condition, and community structure evaluations (ME_W = 4 for all) indicate no potential for adverse effects to fish within the representative Assessment Reaches.

Evaluation of MeHg tissue residues indicates that aquatic receptors may be at risk of adverse effects in several Assessment Reaches as described below.

- Benthic invertebrates (Tables 8-1a and b): Tissue THg in larval invertebrates (ME_W = 4) indicates a high potential for adverse effects in RRM 12.5 to 13.5. Tissue THg in emergent invertebrates (ME_W = 4) indicates a medium potential for adverse effects in RRM 7.9 to 9.2. Tissue MeHg (ME_W = 4) in larval and emergent invertebrates indicates a high potential for adverse effects in several Assessment Reaches in AOC 4, except SFSR. For SFSR, a low or medium potential for adverse effects are indicated. Presence of adverse effects, however, is undetermined because of the lack of CBR_{LOEC} for tissue MeHg; the exceedance of a NOEC does not necessarily indicate risk.
- Fish (Tables 8-1a and b): Available tissue MeHg evaluations (ME_W = 4) indicate a medium potential for adverse effects for YOY bass species and a medium potential for adverse effects for adult bass species in several Assessment Reaches. High potential for adverse effects for adult bass species are indicated at RRM 0.8 to 1.7, RRM 5.2 to 7.9, and RRM 11.3 to 13.5.

Overall, results for the aquatic receptors within AOC 4 demonstrate that mercury bioaccumulation by invertebrates and fish may pose potential threat of adverse effects. However, the direct contact exposures to sediment, pore water, and surface water mercury, along with population and community metrics show no discernible adverse effects within the Assessment Reaches in AOC 4.

8.2 Semi-aquatic Receptors

Current evaluations of semi-aquatic ecological receptors in AOC 4 indicate potential risks to amphibians due to mercury bioaccumulation, and piscivorous birds due to dietary exposures to MeHg. Evaluations of overall potential risks to individual semi-aquatic receptor groups are provided in Section 6.4 (for amphibians), Section 6.7 (for birds), and Section 6.8 (for mammals). Evaluations are discussed below for the semi-aquatic receptors as a whole for each Assessment Reach based on the WOE evaluations presented in Tables 8-2a and b. The DRM results for the WOE evaluations represent only the AUF-Adjusted HQs for MeHg exposures because DRM evaluations for THg indicated low potential for risk in any of the Assessment Reaches.

8.2.1 Amphibians

For amphibians, direct exposure to surface water (ME_W = 3) is not likely to pose a threat, but mercury bioaccumulation may pose potential risks. For direct exposure to surface water, evidence of adverse effects on amphibians is indicated for only RRM 9.2 to 11.3, but with a low potential for effects (Table 8-2a). Mercury tissue residue (ME_W = 4) evaluations based on available data on three amphibian species indicate evidence of potential adverse effects in the Assessment Reaches between RRM 1.7 to 24, with medium potential for effects in two Assessment Reaches, and a high potential for effects in the rest of the Assessment Reaches. However, the applicability of the fish tissue CBRs for the amphibian evaluation is conservative with some uncertainty. As discussed in Section 6.4.2, a comparison of a site-specific amphibian CBR_{LOEC} (0.66 mg THg/kg ww) with the fish CBR_{LOEC} (0.44 mg THg/kg ww) indicate that amphibians may be slightly more tolerant than fish. Additionally, aquatic toxicity studies also indicate that amphibians are generally more tolerant than aquatic species, based on which water quality criteria for mercury are developed for the protection of aquatic species (see Section 4.6). Differences in mercury bioaccumulation in the three species of amphibians evaluated may also indicate differences in sensitivity toward tissue mercury toxicity.

Hopkins et al. (2011) provides a synthesis of field surveys, lab studies, and outdoor mesocosm experiments on the impact of mercury on amphibians in South River. Hopkins et al. (2011) found that mercury bioaccumulation occurs through dietary uptake and maternal transfer. Elevated mercury in eggs had adverse effects on embryonic survival in some years, and caused sublethal, latent effects in larvae and metamorphosed juveniles and adults. These effects include decreases in size, an increased frequency of spinal malformations, and an increased amount of time required to complete metamorphosis during which amphibians are vulnerable to disease and predation. Of these two factors, maternal transfer was found to have a much greater negative impact than diet. No cumulative impacts of combined exposure through diet and maternal transfer in terms of either survival or individual quality (i.e., size, frequency of malformation, length of metamorphosis) were observed.

8.2.2 Piscivorous Birds

For semi-aquatic piscivorous birds represented by the belted kingfisher, DRM for MeHg (ME_W = 3) indicates a high potential for effects generally in Assessment Reaches beyond RRM 5.2. This finding is inconsistent with the tissue residue evaluations (ME_W = 4), which indicates a low potential for effects in Assessment Reaches. These results indicate that perhaps the calculated risks for belted kingfisher based on DRM for MeHg are overly conservative (as noted previously). Results of the MeHg DRM for belted kingfisher indicate a potential for adverse effects in all Assessment Reaches except RRM 0.0 to 0.8 and RRM 0.8 to 1.7 (Tables 8-2a and 2b). A high potential for effects is indicated in each of the Assessment Reaches except RRM 1.7 to 2.7 and RRM 4.4 to 5.2, in which a low potential for effects is indicated. Tissue residues (THg in blood) are not available for all the Assessment Reaches, but provide coverage of the entire AOC 4 extent. Tissue residues from two Assessment Reaches (RRM 11.3 to 12.5 and RRM 13.5 to 16.7) present a medium potential for effects. Tissue residues in the rest of the Assessment Reaches indicate a low potential for effects, with potential adverse effects indicated to be absent or undetermined in several Assessment Reaches (including SFSR).

Field studies on kingfisher reproduction (Cristol, 2006) have also shown that despite significantly higher mercury levels in South River kingfishers relative to Reference Reaches, reproductive effects are not observed in kingfishers from AOC 4. The number of fledglings per nest did not differ significantly between the AOC 4 Assessment Study Reaches (South River and SFSR), and Reference Reaches (Middle River, North River). At Study Reaches on the South River and SFSR, there was no evidence of nest failure or reduced condition of chicks relative to Reference Reaches. However, nestlings from the Study Reaches were heavier than expected for their skeletal size, which is typically indicative of improved health and condition, though this could have also resulted from altered behavior (e.g., more begging), differences in prey availability between Reference Reaches and Study Reaches (e.g. contaminated fish may be easier to catch), or a variety of other factors. One nest was abandoned by a pair of kingfishers with high (>10 mg/kg ww THg) in blood (Cristol, 2005).

Overall, the outcomes of the kingfisher MEs coupled with the results of the field study on reproduction of kingfishers in AOC 4 (Cristol, 2005 and 2006) indicate that kingfishers likely experience limited risks in AOC 4, and that the estimated deterministic HQs are likely overly conservative, owing to either exposure and/or effects components.

8.2.3 Invertivorous/Omnivorous Birds

For semi-aquatic invertivorous/omnivorous birds represented by mallard ducks, DRM for MeHg ($ME_W = 4$) indicates a medium potential for effects in RRM 12.5 to- 13.5. Results for the rest of the Assessment Reaches indicated either the absence or indeterminate potential for adverse effects, with a potential for low magnitude of effects in all the Assessment Reaches.

8.2.4 Piscivorous Mammals

Semi-aquatic piscivorous mammals represented by the river otter, absence of potential adverse effects is indicated by the MeHg DRM for all Assessment Reaches. The absence of an adequate low effect level for fur or blood represents some uncertainty regarding the potential for risks to piscivorous mammals. There has been an anecdotal report of a river otter with elevated mercury concentrations in various tissues relative to other reports in the literature; however, brain tissue was not evaluated histopathologically, so other potential causative agents for neurological conditions (e.g., toxoplasmosis) could not be ruled out (Sleeman et al., 2010).

8.2.5 Overall Findings – Semi-aquatic Receptors

Overall, the results for semi-aquatic receptors indicate potential risks of adverse effects on amphibians and piscivorous birds due to bioaccumulation and/or dietary exposures to mercury within AOC 4 Assessment Reaches beyond RRM 2.7 (see Table 8-2b). However, calculated potential risks for these groups of receptors constitute significant uncertainties biased toward overestimation of risks, except for amphibians for which the calculated potential risk may be over or underestimated.

8.3 Terrestrial Receptors

Current evaluations of terrestrial ecological receptors in AOC 4 indicate potential for effects to carnivorous birds and invertivorous songbirds due to dietary exposures to MeHg. Evaluations of overall risks to individual terrestrial receptor groups are provided in Section 6.5 (for terrestrial plants), Section 6.6 (for soil invertebrates), Section 6.7 (for birds), and Section 6.8 (for mammals). Evaluations are discussed below for the terrestrial receptors as a whole for each Assessment Reach based on the WOE evaluations presented in Tables 8-3a and b. The DRM evaluations represent only the AUF-Adjusted HQs for MeHg exposures because DRM evaluations for THg indicated no potential for adverse effects for any of the Assessment Reaches.

8.3.1 Plants and Invertebrates

Exposures to mercury via soil for terrestrial plants and soil invertebrates indicate no overall risks of adverse effects within AOC 4 floodplains. Tables 8-3a and b indicate that there is a medium potential for adverse effects for soil invertebrates in two Assessment

Reaches (RRM 0.8 to 2.7 and RRM 11.3 to 12.5). Soil invertebrates are not expected to experience substantial adverse effects in the remaining Assessment Reaches. Similarly, terrestrial plants are not expected to experience substantial adverse effects in any of the Assessment Reaches.

8.3.2 Carnivorous Birds

For terrestrial carnivorous birds represented by Eastern screech owl, DRM for MeHg (ME_W = 3) generally indicates a medium to high potential for adverse effects in the Assessment Reaches beyond RRM 2.7. Potential for adverse effects cannot be determined in the first three Assessment Reaches (within RRM 0 to 2.7) and in RRM 4.4 to 5.2, with low potential for effects (Tables 8-3a and b). For the rest of Assessment Reaches, there is a medium potential for effects within RRM 9.2 to 11.3 and RRM 11.3 to 12.5, and a high potential within the remaining Assessment Reaches.

8.3.3 Aerial Insectivorous Birds

For terrestrial aerial insectivorous birds represented by tree swallow, the DRM for MeHg (ME_W = 3) indicates a high potential for effects generally in Assessment Reaches beyond RRM 2.7. This finding is inconsistent with the tissue residue evaluations (ME_W = 4), which indicate a high potential for effects in only two Assessment Reaches (RRM 13.5 to 16.7 and RRM 16.7 to 20.9).

These results indicate that perhaps the calculated risks for tree swallow based on DRM for MeHg are overly conservative, particularly with respect to the use of an upper bound NOAEL as a surrogate for LOAEL (see Section 7.2.3). Results of the MeHg DRM for tree swallow indicate a high potential for adverse effects in all Assessment Reaches except RRM 0.0 to 0.8, RRM 0.8 to 1.7, and RRM 1.7 to 2.7 (Table 8-3a and b). Except for three Assessment Reaches (RRM 0.8 to 1.7, RRM 1.7-2.7, and SFSR), tissue residues (MeHg in blood) from all Assessment Reaches indicate presence of potential adverse effects; two Assessment Reaches (RRM 13.5 to 16.7 and RRM 16.7 to 20.9) show a high potential for effects, with the remainder demonstrating a medium potential. Presence of adverse effects are undetermined based on tissue residues in the three Assessment Reaches (RRM 0.8 to 1.7, RRM 1.7 to 2.7, and SRSF), with potential for low magnitude of effects; the tissue residue EPCs are between the CBR_{NOEC} and CBR_{LOEC}.

Although AOC 4 field studies have observed effects on biochemical parameters due to tree swallow exposures to mercury (Hawley et al. 2009; Wada et al. 2009), the available data suggest that mercury has little impact on their reproduction and survival. Brasso and Cristol (2008) quantified the accumulation of mercury and its effects on the reproductive success of birds that prey on emergent aquatic insects, using tree swallows as a representative species. In this study, reproductive success was defined as date of nest initiation, clutch size, egg volume, hatching success, proportion of eggs fledged, proportion of nestlings fledged, and number of fledglings produced. In 2005 and 2006, these parameters were compared between second year (SY) and after second year (ASY) tree swallows nesting within 50 m of the South River in AOC 4, and on Reference Reaches associated with the Middle River, North River, and a section of the South River upstream of Waynesboro. The effect of mercury on productivity was detectable only for young females in the South River that were breeding for the first time in 2006, a segment of the population that may already have been stressed by inexperience. Hallinger et al. (2011) examined the impact of mercury exposure on annual survivorship in tree swallows breeding along South River. The study concluded that there exists approximately a 1% difference in survival between the South River and Reference Reaches, though the authors also hypothesized that such a small difference is unlikely to impact population viability in a short-lived species such as tree swallows.

Overall, the ERA indicates that while AOC 4 tree swallows are exposed to elevated levels of MeHg, population level risks are uncertain in light of the available field data.

8.3.4 Terrestrial Invertivorous Birds

For terrestrial invertivorous birds represented by American robin, DRM evaluations (ME_W = 3) indicate low to medium potential for adverse effects present or undetermined in all Assessment Reaches; this finding is in consistent with the results of the tissue residue (MeHg in blood) evaluations (ME_W = 4). Tissue residue evaluations indicate absence of potential adverse effects and low potential for effects in two Assessment Reaches (RRM 4.4 to 5.2 and RRM 16.7 to 20.7) in which the DRM evaluations indicated presence of potential adverse effects and medium potential for effects (See Tables 8-3a and b). These results suggest that the calculated risks for American robin based on DRM for MeHg are overly conservative, particularly with respect to the use of an upper bound NOAEL as a surrogate for LOAEL (see Section 7.2.3). A field study on Carolina wren (*Thryothorus ludovicianus*), discussed below, has indicated few, if any, adverse effects on songbirds in AOC 4 due to mercury exposure.

Jackson and Evers (2010) used the Carolina wren as a representative species for the forest-floodplain invertivore feeding guild to examine the potential impacts of mercury contamination on breeding performance of a species that is not directly tied to the aquatic ecosystem in AOC 4. AOC 4 Carolina wrens showed higher blood mercury concentrations than wrens from reference sampling locations; the average female blood THg level for AOC 4 was 2.24 and 2.13 µg/g (in 2009 and 2010, respectively) compared to reference concentrations of 0.38 and 0.21 µg/g. Reproductive success (i.e., clutch size, brood size, number of fledglings, percent hatched, percent fledged) was monitored in 2009 and 2010 in man-made nest boxes and natural cavities along the South River. The authors concluded that AOC 4 birds produced 0.9 fewer fledglings than reference birds in the combined 2009 and 2010 data set (Jackson and Evers, 2010).

However, the differences in reproductive parameters were generally not significant or were greater between years for reference birds, suggesting that any observed effects of mercury were due to interannual variability. For example, the number of fledglings was substantially different between 2009 and 2010 within the reference sampling location [Kruskal-Wallis test (KW); $p = 0.057$]. As a result, the years should not have been combined for comparison between the reference and contaminated areas. In addition, the reference sampling location in 2009 produced 1.8 fledglings per nest compared with 3.3 in 2010, larger than the 0.9 difference cited by the authors. Nest failure was significantly higher in AOC 4 nests in 2010 ($\alpha = 0.05$), but not in 2009; in 2010, 50% of AOC 4 nests failed completely while only 16.7% of reference nests failed. However, there are numerous reasons for nest failure the most common of which are nest predation and nest parasitism, but also include interspecific competition, adverse weather, abandonment, nestling starvation, and egg failure (Etterson et al. 2007).

Given that American robins feed on terrestrial invertebrates, they may be assumed to have similar MeHg exposures and sensitivities as Carolina wrens in AOC 4. Hence, the outcome of the ERA for American robins indicating limited potential risks is consistent with the results of the field study on Carolina wrens.

8.3.5 Invertivorous Mammals

For terrestrial invertivorous mammals represented by short-tailed shrew, DRM evaluations (ME_W = 3) indicate that potential adverse effects are either absent or indeterminate (because the HQs exceed the NOAEL but not the LOAEL), with a low potential for effects throughout AOC 4. Tissue residue (Fur THg) evaluations for limited Assessment Reaches (RRM 13.5 to 16.7 and RRM 16.7 to 20.9) indicated indeterminate presence of medium potential adverse effects due to the lack of a CBR_{LOEC}.

8.3.6 Herbivorous Mammals

For terrestrial herbivorous mammals represented by white-tailed deer, DRM evaluations (ME_W = 3) indicate no potential adverse effects throughout AOC 4 (see Table 8-3a and b).

8.3.7 Aerial Insectivorous Mammals (Bats)

For terrestrial aerial insectivorous mammals represented by big brown bat, DRM evaluations generally indicate that potential adverse effects are either absent for indeterminate because the HQs exceed the NOAEL but not the LOAEL. Further, there is a low potential for effects throughout AOC 4, with the exception of two Assessment Reaches (RRM 5.2 to 7.9 and SFSR). Evaluations for RRM 5.2 to 7.9 and SFSR indicate medium and high potential for adverse effects in RRM 5.2 to 7.9 and SFSR, respectively. However, the evaluations for these Assessment Reaches involve uncertainties in exposure evaluations (see footnote in Table 8-3a and b and Section 7.3.3). Evaluation of blood and fur THg tissue residues is limited to two Assessment Reaches (RRM1.7 to 2.7 and RRM 11.3 to 2.5); further, the lack of CBR_{LOEC} prohibits the determination of whether potential adverse effects are present in these Assessment Reaches. Evaluations based on conservative CBR_{NOEC} indicate low to medium and medium to high potential for effects in these two Assessment Reaches based on fur and blood, respectively.

Various biochemical indicators of potential endocrine, immune, genetic effects on AOC 4 bats are available, although data implications are unclear with respect to individual fitness and, more importantly, population level effects. Bats in AOC 4 likely experience higher level of exposures to mercury than in areas without mercury contamination. Several investigations of endocrine disruption, immunotoxicity and genotoxicity of mercury in bats from AOC 4 indicate that mercury exposures in the South River are likely below levels causing adverse effects, corroborating the general findings of this ERA with respect to big brown bat. Studies on mammals have indicated potential endocrine disruption, immunotoxicity, and genotoxicity related adverse effects (Gaworski, 1978; Pollard, 1997; Ilback, 1991; Hawley et al., 2009; Wada et al., 2009; Yamane and Davidson, 1961; Cantoni and Costa, 1983; Wolfe et al., 1998). Bats from

AOC 4 were examined for these potential effects based on various biochemical indicators as described below.

Adrenocortical, glucocorticoid, and stress hormone responses (using plasma cortisol concentrations) were used as a measure of the relative function of the hypothalamic-pituitary-adrenal axis (i.e. adrenocortical reactivity; Wada et al., 2009). Post-lactating female big brown bats were captured at roosting sites in late June and July 2007 from the Reynes Barn within AOC 4 (RRM 18) and one reference sampling location, Grove Farm. As progesterone levels reflect gonadal activity, this hormone was used to assess reproductive activity/inactivity. Overall, the sampling location (AOC 4 vs. reference) had no effect on cortisol levels, and neither blood nor fur mercury concentrations were correlated with either progesterone or any of the cortisol levels (Yates et al., 2007). However, some uncertainties were identified that may affect the lack of correlation between mercury concentration and physiological effects (e.g., small sample size for progesterone assay, time of sampling when progesterone concentrations are expected to be low). Similarly, Wada et al. (2010) found that despite the large differences in mercury concentrations in female big brown bat tissue (blood and fur), adrenocortical responses were not different in bats from AOC 4 and nearby reference sampling location, suggesting that the bats at AOC 4 were exposed to Hg below levels causing adverse effects on their adrenal axis.

Potential for mercury-related immunotoxicity in bats from AOC 4 were evaluated via cell-mediated and innate immune function assays. Phytohemagglutinin (PHA), which affects the adaptive capabilities of the immune system, was used to measure cell-mediated adaptive immune response (Hawley et al., 2009). Blood and fur mercury concentrations did not appear to affect cell-mediated adaptive immune responses in big brown or little brown bats collected in 2007 and 2008, respectively (Yates et al. 2007, 2008). A bacterial killing assay (BKA) was used to evaluate innate immune function. Whole blood has the capacity to neutralize bacteria through the antibody-independent alternate complement pathway, which is one of the first defensive mechanisms to engage and neutralize pathogens (Yates et al. 2008). Thus any disruption to this pathway could reduce the ability of blood to destroy pathogens. Using *Escherichia coli* as the pathogen in the assay, bactericidal ability was weakest in blood from AOC 4 bats. However, no significant relationships were detected between the bactericidal ability of blood and blood or fur mercury concentration in this study (Yates et al. 2007, 2008).

Overall, tissue mercury concentrations did not affect innate or cell-mediated adaptive immune responses in big brown or little brown bats (Yates et al. 2007, 2008). The variability of immune function in big and little brown bats in AOC 4 appears to be more related to sex, reproductive stage, colony-specific variation, and/or life history traits rather than mercury tissue burdens (Yates et al., 2007 and 2008). However, the lack of correlation between tissue mercury concentrations and these measures of stress physiology in bats may be due to relatively low levels of fur and blood mercury (in 2007 and 2008) as well as a small sample size of big brown bats in 2007 (Yates et al., 2007 and 2008).

Overall, the studies of biochemical indicators show effects in AOC 4 bats compared to reference bats. However, these biochemical indicators show no clear correlations with the measures of mercury exposures (e.g., blood and fur mercury) in bats from AOC 4, indicating factors other than mercury exposures are at play for the observed differences. Consistent with these findings, the ERA also indicates limited potential risks due to mercury for the bat populations in AOC 4.

8.3.8 Overall Findings – Terrestrial Receptors

Overall, the results for terrestrial receptors indicate potential risks of adverse effects on carnivorous birds and invertivorous songbirds due to dietary exposures to mercury within AOC 4 (see Table 8-3b). However, calculated potential risks for these groups of receptors constitute significant uncertainties biased toward overestimation of risks.

9.0 Risk Management/Remedial Decision-Making

The integration of risk management and remedial decision-making couples the results of the risk assessment with other considerations, including available technologies, tradeoffs between human and ecological concerns, costs of alternative actions, and remedy selection. The remedy selection process is intended to identify a strategy that will eliminate, reduce, or control risks to human health and the environment.

These considerations have been described in the Interim Measures Design, Implementation, and Monitoring Work Plan (IM Work Plan, Anchor QEA et al., 2014), which outlines the rationale for remediating certain riverbanks downstream of the former DuPont facility in Waynesboro, Virginia, and describes the process to design and permit these actions as interim measures under the regulatory authority of RCRA. The IM Work Plan is part of a larger remedial strategy, as described in the Remediation Proposal (Anchor QEA et al., 2013), which is designed to address mercury historically released from the former DuPont Waynesboro facility to AOC 4. As summarized in the Ecological Study (URS, 2012) and Remediation Proposal (Anchor QEA et al., 2013), the largest ongoing mercury sources to the South River are riverbanks, outfalls from the former Waynesboro facility, and sediment.

This section summarizes the findings of the ERA, the remedial strategy for the aquatic and terrestrial portions of AOC 4 and the monitoring regime that will be used to evaluate remedy effectiveness.

9.1 Summary of ERA Findings

The ecological risk assessment identified areas and routes of exposure that may present the potential for effects due to mercury exposure in aquatic, semi-aquatic and terrestrial ecological receptors. The risks are summarized in Table 9-1.

For aquatic receptors, a high potential for effects was found for larval and emergent invertebrates, crayfish, YOY fish and adult fish. Primarily, these results are driven by MeHg body burden rather than exposure to abiotic media (surface water, sediment, or pore water). However, exposure to abiotic media is an important route of MeHg uptake, particularly for invertebrates and YOY fish (URS, 2012). MeHg in adult fish is primarily derived through the ingestion of MeHg from dietary items. The risks to aquatic ecological receptors were widespread, ranging from RRM 0 to the confluence with the North River.

Semi-aquatic receptors at high risk include the piscivorous birds and amphibians. For piscivorous birds, the high potential for effects was indicated through DRM; tissue (blood) mercury levels indicate low to medium potential for effects. As described in detail in Section 8.2.2, field studies in AOC 4 demonstrated no effects of elevated mercury concentrations on the survival or reproduction of the belted kingfisher. While there was evidence of individual effects to amphibians, no population-level effects were observed. The risk is driven entirely through the ingestion of aquatic food items. The risks to semi-aquatic ecological receptors were widespread, ranging from RRM 2.7 to the upstream portion of the SFS River.

Terrestrial ecological receptors are at higher risk in the South River floodplain due to MeHg concentrations in exposure media. These include the carnivorous birds, aerial insectivorous birds, and aerial insectivorous mammals. These receptors derive the majority of their MeHg either directly or indirectly from the aquatic food web. For example, DRMs indicate that screech owls derive 78-91% of their dietary MeHg through ingestion of small birds, which in turn derive the majority of their mercury from consumption of emergent aquatic insects. This finding is supported by stable isotope analysis of the terrestrial food web, but there is some uncertainty regarding the actual percentage of mercury derived from aquatic sources (Newman et al., 2011). The ERA indicates that terrestrial sources may account for a significant portion of mercury intake by terrestrial receptors. For example, earthworms accounted for 39% (on average) of estimated total MeHg DMIR for American robin. However, the areas where a high potential for effects were indicated for the American robin were relatively limited; of the four reaches with available tissue mercury data, only one indicated high risk (RRM 1.7 to 2.7). The results from DRM indicated a medium level of risk for the majority of the floodplain.

This ERA has identified that MeHg in biological tissue is the risk driver for AOC 4, either as a CBR for invertebrates and fish, or through the ingestion of food items from the aquatic and, to a lesser extent, terrestrial food web. Few, if any risks are posed by the direct contact with abiotic media. The aquatic areas where elevated risks due to the aquatic food web are observed are widespread, and extend from RRM 0 to the confluence of the South River and North River, resulting from the production and trophic transfer of MeHg. Inorganic mercury is not a limiting factor for mercury methylation. As a result, a remedy has been designed that emphasizes source controls, exposure reduction, system recovery and monitoring (Anchor QEA et al., 2013). This approach is described below.

9.2 Remedy Selection

The results of the ERA indicate that potential adverse effects to the ecological receptors are primarily due to trophic transfer of MeHg originating in the South River system—a finding that is consistent with the current understanding of the system on which the proposed remedial strategy is based. 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 for the aquatic and terrestrial portions of AOC 4 are discussed in the following sections.

9.2.1 Aquatic Portion of AOC 4

The adaptive management approach requires making and implementing response decisions based on monitoring results that inform future response decisions. This type of approach requires that the South River system be divided into manageable segments, beginning with source controls at the former Waynesboro facility, 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 interim measures in the river 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 measurements in the effectiveness of remedial measures.

The adaptive management approach is also consistent with findings of the Ecological Study (URS, 2012) and the AOC 4 RFI Report (URS, 2014), which found that the sources of mercury are primarily observed in the first 12 miles of the South River, beginning at the former DuPont Waynesboro facility at RRM 0. The main working hypothesis of the proposed adaptive management approach is that reducing the loading of legacy inorganic mercury (IHg) in the South River in a stepwise manner, beginning with source controls at the former DuPont Waynesboro facility, will result in reduced MeHg production within and downstream of that segment. Further, because mercury loading to the South River is also linked to its transfer into the terrestrial food web (See Section 9.2.3), it is expected that reducing loading to the aquatic portion of AOC 4 will not only reduce exposure in the river, but will also result in reduced transfer to the semi-aquatic and terrestrial food webs.

Following completion in early 2016 of source controls at the former Waynesboro facility, the first segment of the South River to be addressed by Phase 1 interim measures includes bank soils and in-channel sediments located immediately adjacent to and downstream of the former DuPont Waynesboro facility. 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 is approximately two miles, and was determined based on reach characteristics, implementability, safety, and adaptive management considerations, targeting an initial Phase 1 remediation construction period of approximately 1 to 2 years (Anchor QEA et al., 2013).

It is expected that following Phase 1, mercury exposure will be reduced in areas adjacent to stabilized bank deposits, and that mercury loading overall will be reduced in the aquatic system. Once source control is achieved, natural recovery processes will act to reduce the methylation of mercury. These processes are discussed in detail in Section 9.2.2. It is not known to what degree mercury loads will be reduced, or the potential area of the aquatic and terrestrial system that will respond to these load reductions. As a consequence, other potential terrestrial remedial approaches are considered and discussed in Section 9.2.3. Following implementation of Phase I, the potential impacts of loading reductions will be monitored to determine if exposure overall is declining as expected. The monitoring plan is discussed in Section 9.3.

9.2.2 Natural Recovery

The remedy for the South River outlined above includes stabilization of riverbanks to reduce IHg loading to the South River. Following control of these and other IHg sources, it is expected that natural recovery processes will reduce mercury methylation over time. Utilizing adaptive management, in-channel sediments (e.g., embedded gravel deposits) will be evaluated after remediation has been completed to track and effectively integrate lessons learned, including those that pertain to natural recovery. This section summarizes relevant natural recovery processes that will be tracked using the adaptive management approach.

As a sediment remedy, natural recovery 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 post-remediation risk reduction and ecological recovery by natural processes are occurring as expected.

There has been a degree of natural recovery to date in the South River in certain environmental compartments. The concentrations of IHg on suspended sediment have declined from a peak of approximately 1,200 mg/kg during the time that mercury was in use at the former Waynesboro facility (1929 to 1950), to less than 30 mg/kg today (Skalak and Pizzuto, 2009). The rate of recovery has slowed and is likely not to change further unless there are reductions in IHg loading or IHg concentrations in sediment.

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

- Dilution by upstream sediment with lower IHg concentrations
- 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

These processes are discussed in the following paragraphs.

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. Approximately 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 (URS, 2012). This mechanism is likely to have the greatest effect on the most upstream reaches of the South River.

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 river bank 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 (Chadwick et al. 2012; 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, relatively high-IHg-concentration sediment 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 (Fischer et al. 2002).

9.2.3 Terrestrial Portion of AOC 4

As described in Section 9.1, there are several terrestrial ecological receptors that have a high potential for effects due to ingestion of MeHg through dietary items. A portion of this MeHg dose is derived from the terrestrial food web. The ERA indicated that terrestrial sources may possibly To address the potential terrestrial pathway, DuPont has begun testing the efficacy of carbon amendments (e.g., biochar) to reduce mercury uptake by soil invertebrates. In a recently completed laboratory study (URS, 2014b) using soil from the AOC 4, biochar was found to reduce the uptake of mercury by earthworms and plants, without unintended negative consequences. Biochar is a stable, carbon-rich, charcoal, produced by thermal decomposition of various types of organic material under low/no oxygen conditions at <700 °C. It has many uses, such as reducing bioavailability/uptake of metals, including mercury.

Soil samples collected from the Augusta Forestry center (RRM 11.8) with THg concentrations of 57 mg/kg were amended with 5% or 10% biochar (by mass) and used in toxicity tests with earthworms and three species of plants following standard protocols developed by the Office of Economic Cooperation and Development (OECD). Test endpoints for earthworms included survival, weight change, and reproduction, and seedling emergence and shoot height and biomass in plants. Tests were also conducted with low THg background soils (<0.1 mg/kg THg) to serve as controls. RRM 11.8 soils also had concentrations of several metals above EPA Ecological Soil Screening Levels (Eco-SSLs). Following determination of toxicity endpoints, adult and juvenile earthworms and plants were collected for mercury analysis.

The results indicated no apparent biochar-related adverse effects on mortality, growth, or reproduction in earthworms. Biochar appeared to reduce mortality of adult earthworms in the high-THg soils from RRM 11.8, which was >30% in 0% biochar controls, but absent in 5% or 10% biochar treatments. In addition, there were apparent biochar-related increases in growth of worms in RRM 11.8 soils. The toxicity is likely due to the presence of metals, particularly manganese, which was present at concentrations approximately ten times the Eco-SSL concentration. There were no effects of biochar on plant emergence, growth, or biomass. Methylmercury concentrations in juvenile earthworms were lower in biochar treatments in both high-THg and background soils. MeHg concentrations in adult earthworms were reduced in biochar treatments in background soils, but not in RRM 11.8 soils. There were no effects on mercury concentrations in plants. In test soils, MeHg concentrations decreased by 5% to 50% over the course of the experiments, suggesting that biochar decreased mercury methylation in soil. The opposite pattern was observed in background soils, with increases of 50% to 95%.

Following the demonstration that carbon amendments can be used to reduce mercury uptake by earthworms with no observed adverse effects in the laboratory, a field demonstration is planned for 2015. Subsequent to the implementation of the IM, monitoring of mercury concentrations in terrestrial and aquatic ecological receptors will determine whether terrestrial exposure needs to be reduced over wider areas of the floodplain.

9.3 Monitoring

A central component of the overall remedial approach is the monitoring plan. It is designed to provide information related to the potential efficacy of the recommended remedial actions, as well as their ability to reduce exposure of ecological receptors (and humans) to mercury. The monitoring plan takes into account specific objectives and concerns outlined in the Consent Decree, including elements of Exhibits C, D, and E. This monitoring plan is built upon the findings of the Ecological Study (URS, 2012). This section provides a broad overview of the goals and rationale for the major components of the short-term and long-term monitoring plans (STM Plan and LTM Plan, respectively). The monitoring plan is subject to review and potential modification by regulatory agencies and the SRST during remedial design and adaptive management. The STM and LTM plans are described in detail in Appendix D and E, respectively, in the IM WP (Anchor QEA et al., 2014).

9.3.1 Objectives

The overall objective of the monitoring efforts is to provide data to assess the efficacy of the remedy in addressing mercury migration within AOC 4, 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 interim measures
- Provide input to the adaptive management framework and relative risk model to determine whether any aspect of the remedial action, monitoring strategy, remedial design, or conceptual model needs to be modified

The STM plan 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 bank management area). First and foremost, the STM plan 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 STM 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 remedial action objectives (RAOs) are being met.

In contrast, the LTM plan addresses changes in potential mercury exposures of humans and ecological receptors, as well as habitat improvements in the South River and SFSR over longer timeframes and larger spatial scales. While the STM will be focused primarily in the South River at or near those areas where remedies are being implemented, the LTM Plan is designed to cover a timeframe of many years to decades, and a much larger area (AOC 4). It will also include routine inspection of remediated areas to ensure the continued integrity and performance of the remedy, and to maintain and/or repair stabilized banks as necessary. Similar to the STM Plan, chemical and biological results from the LTM will also feed into the relative risk modeling and the adaptive management approach. In this way, both the short- and long-term information will be used as input to management decisions regarding the efficacy of remedial 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 SFSR. It is expected that once the remedial actions have been implemented, over time the mercury loading to the South River and SFSR should decline and be accompanied by a concomitant reduction in potential mercury exposures and risks to humans and ecological receptors, including terrestrial receptors which are exposed to mercury either directly or indirectly from aquatic sources. As indicated in the Remediation Proposal, community outreach programs are also integral part of the overall remedial strategy. Thus, throughout the implementation and monitoring phases of the remedial measures, there will be open and frequent outreach and communication with local communities, physicians and health clinics, and relevant public-health groups.

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Tables

Table 2-1
Special Status Species Identified in AOC 4
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Group	Scientific Name	Common Name	State Rank[a]	Global Rank[b]	Federal Status[c]	State Status[d]	Last Year Observed	Species Information
BIRDS	*Rallus limicola*	Virginia Rail	S2B,S3N	G5			1993	Found in Virginia during their breeding season, which lasts from May through June or July. Breed in wetlands, usually freshwater but occasionally brackish, usually in cattails, reeds, or deep grasses.
FISH	*Cottus cognatus*	Slimy Sculpin	S2	G5			1989	A small fish found in cool, rocky streams and deep lakes.
INSECTS	*Speyeria idalia*	Regal Fritillary	S1	G3			1978	A butterfly found in the northern half of the country, East of the Rocky Mountains. Larvae breed solely on violet plants. Usually found in open spaces, such as wet meadows, pastures, fields, and along streams in open areas.
	Pseudanophthalmus petrunkevitchi	Petrunkevitch's Cave Beetle	S1	G1G2	SOC		pre1981	An eyeless ground beetle found in caves in the South Fork Shenandoah River watershed. Typically found in the twilight zone or deeper, in moist soil near streams or drip areas.
DIPLOPODA (MILLIPEDES)	*Striaria* sp. 1	A Millipede	S1	G1	SOC		pre1981	Found in caves in the South Fork Shenandoah watershed.
	Zygonopus weyeriensis	Grand Caverns Blind Cave Millipede	S2	G3G4			pre1981	(also *Trichopetalum weyeriensis*) Found in caves in western Virginia and eastern West Virginia, including Grand Caverns, located near Grottoes, VA, in Augusta County.
CRUSTACEA (AMPHIPODS, ISOPODS, DECAPODS)	*Stygobromus stegerorum*	Madison Cave Amphipod	S1	G1	SOC	LT	1992	A cave amphipod found only in Madison's Saltpeter Cave, located near Grottoes, VA, in Augusta County.
	Antrolana lira	Madison Cave Isopod	S2	G2G4	LT	LT	2006	Found in flooded limestone caves between Lexington, VA and Charles Town, WV, including documented populations in the Waynesboro and Harrisonburg, VA areas.
BIVALVIA (MUSSELS & CLAMS)	*Alasmidonta varicosa*	Brook Floater	S1	G3		LE	1995	A freshwater mussel, generally found in creeks and small rivers, among rocks in gravel substrates and in sandy shoals. Though usually found in riffles or moderate rapids, it can be found in a variety of flow conditions, though is not common in very slow flowing areas.
ARACHNIDA (SPIDERS & PSEUDOSCORPIONS)	*Kleptochthonius* sp. 1	A Cave Pseudoscorpion	S1	G1	SOC		pre1981	Found in caves in the South Fork Shenandoah watershed.
	Apochthonius coecus	A Cave Pseudoscorpion	S1	G1G2	SOC		pre1981	
	Bathyphantes weyeri	A Cave Spider	S1	G4			pre1981	Found in caves in Kentucky, West Virginia, and Virginia, and potentially other states, including caves in the South Fork Shenandoah watershed.
TERRESTRIAL VEGETATION	*Cerastium velutinum* var. *velutinum*	Field chickweed	S2?	G5T4?			1995	A small flowering perennial herb found in open, dry habitats and disturbed areas.
	Arabis patens	Spreading rock cress	S2	G3			1991	Found in moist rocky woods, on limestone outcrops, and in shady riverbanks.
	Desmodium sessilifolium	Sessile-leaf Tick-trefoil	S2	G5			1989	Perennial wildflower that prefers dry, sandy soil, but is also found in partial sun and rocky soil.
	Sporobolus neglectus	Small Dropseed	S2	G5			1992	A small, annual grass found in dry, disturbed areas.
	Eleocharis compressa var. *compressa*	Flattened spikerush	S2	G4			1991	A perennial rush found in wetland habitats.
	Solidago rupestris	Riverbank goldenrod	S1	G4?			2004	Found in flood-scoured riverside woodlands.
	Arabis pycnocarpa var. *adpressipilis*	Hairy rock cress	S1S2	G5T4Q			1938	Found in a variety of habitats, including sand, cliffs, and rocky woods.
	Cuscuta coryli	Hazel Dodder	S2?	G5?			1975	Found in sandy, moist soils, and is parasitic on other plants, including cultivated plants.
	Quercus macrocarpa	Bur Oak	S1	G5			1991	A large deciduous tree that typically grows in the open and near waterways.
	Quercus prinoides	Dwarf Chinquapin Oak	S1	G5			1968	A shrubby oak, usually growing as a large shrub or small tree. It is usually found in sunny, well-drained locations.
WETLAND VEGETATION	*Juncus torreyi*	Torrey's Rush	S2	G5			2001	A perennial rush found in wet, open areas.
	Lythrum alatum	Winged loosestrife	S2	G5			1974	A species of flowering plant that commonly occurs in wetlands.

Notes:
a, State Rank:
S1 - Critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state. Typically 5 or fewer populations or occurrences; or very few remaining individuals (<1000).
S2 - Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the state. Typically 6 to 20 populations or occurrences or few remaining individuals (1,000 to 3,000).
S3 - Vulnerable in the state either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 populations or occurrences (1,000 to 3,000).
S4 - Apparently secure; Uncommon but not rare, and usually widespread in the state. Possible cause of long-term concern. Usually>100 populations or occurrences and more than 10,000 individuals.
S5 - Secure; Common, widespread and abundant in the state. Essentially ineradicable under present conditions. Typically with considerably more than 100 populations or occurrences and more than 10,000 individuals.
S#B - Breeding status of an animal within the state.
S#N - Non-breeding status of animal within the state. Usually applied to winter resident species.
S#? - Inexact or uncertain numeric rank.
S#S#- Range rank; A numeric range rank, (e.g. S2S3) is used to indicate the range of uncertainty about the exact status of the element. Ranges cannot skip more than one rank.
b, Global Ranks are similar to state ranks, but refer to a species' rarity throughout its total range. Global ranks are denoted with a "G" followed by a character. Note GX means the element is presumed extinct throughout its range, not relocated despite intensive searches of historical sites/appropriate habitat, and virtually no likelihood that it will be rediscovered. A "Q" in a rank indicates that a taxonomic question concerning that species exists. Ranks for subspecies are denoted with a "T". The global and state ranks combined (e.g. G2/S1) give an instant grasp of a species' known rarity.
LE - Listed endangered.
LT - Listed threatened.
SOC - Species of concern species that merit special concern (not a regulatory category).
d, State Status:
LE - Listed endangered.

Table 3-1
Assessment Reaches
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Assessment Reach[a]	Reach Length[b] (miles)	Reach Area[b] (acres)	Phase I Sampling Location[c]
Upstream Reference Reach			
RRM -2.7 to -0.7[d]	2	46.6	SR 01[f]
Buffer Reach			
RRM -0.7 to 0.0[e]	0.7	7.8	
Study Reach			
RRM 0.0 to 0.8	0.8	12.3	RRM 0.6
RRM 0.8 to 1.7	0.9	11.9	
RRM 1.7 to 2.7	1	24.4	RRM 2.0
RRM 2.7 to 4.4	1.7	87.8	RRM 3.0, RRM 4.2
RRM 4.4 to 5.2	0.8	14.5	RRM 5.2
RRM 5.2 to 7.9	2.7	76.6	RRM 7.1
RRM 7.9 to 9.2	1.3	33.2	RRM 8.7
RRM 9.2 to 11.3	2.1	34.5	
RRM 11.3 to 12.5	1.2	25.9	RRM 11.8
RRM 12.5 to 13.5	1	28.2	RRM 13.1
RRM 13.5 to 16.7	3.2	69.7	RRM 14.5
RRM 16.7 to 20.9	4.2	71.8	RRM 19.0
RRM 20.9 to 24.0	3.1	80.8	RRM 22.4
SFSR	--	--	SFSR

Notes:
RRM, Relative river miles from the outfall at former DuPont Waynesboro Plant.
SR, South River.
SFSR, South Fork Shenandoah River.
--, Not available.
a, Assessment reaches designated for the ERA; Based on the reach breaks defined by intersecting the 2-foot USGS Light Detection and Ranging (LiDAR) contours with the channel centerline and data availability (See Section 3.2.3).
b, Length of the assessment reaches in RRM and Reach Area within the 0.3-year floodplain in acres.
c, Phase I sediment and surface water sampling locations (DuPont CRG, 2006) corresponding to the ERA assessment reaches.
d, Reference reach upstream of the South River within AOC 4; Various other reference reaches (North River, Middle River, etc.) are included for applicable specific evaluations (See Section 5.3).
e, Designated as a Buffer Reach between the Reference Reach and the Study Reaches.
f, Represents one of the three reference Phase I sampling locations; The remaining two reference Phase I sampling locations (not included in the table) are located on the North River (NR 01 and NR 02).

Table 3-2
Bulk and Interstitial Sediment Mercury Screening Summary Table
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Assessment Reach	TOTAL MERCURY (THg)							METHYLMERCURY (MeHg)						
	Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (mg/kg)[c]	Maximum (mg/kg)[c]	Mean (mg/kg)[c]	# Samples > 0.18 mg/kg[a,c]	# Samples > 18.9 mg/kg[b,c]	Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (mg/kg)[c]	Maximum (mg/kg)[c]	Mean (mg/kg)[c]	# Samples > 0.102 mg/kg[b,c]
Bulk Sediment														
RRM -2.7 to -0.7	2	1	0.05	0.05	0.05	0	0	1	1	0.002	0.002	0.002	0
RRM -0.7 to 0.0	2	2	0.94	4.9	2.9	2	0	0	0	NC	NC	NC	NC
RRM 0.0 to 0.8	21	19	0.13	12.6	2.0	17	0	1	1	0.030	0.030	0.030	0
RRM 0.8 to 1.7	13	13	0.90	10.9	5.4	13	0	16	16	0.002	0.009	0.005	0
RRM 1.7 to 2.7	51	51	0.03	212	25.4	49	17	11	11	0.000	0.372	0.092	4
RRM 2.7 to 4.4	83	83	0.07	300	22.2	81	28	7	7	0.010	0.113	0.046	1
RRM 4.4 to 5.2	61	61	0.05	884	85.2	57	35	30	30	0.006	0.098	0.032	0
RRM 5.2 to 7.9	50	50	1.0	268	20.7	50	10	23	23	0.002	0.123	0.038	2
RRM 7.9 to 9.2	42	42	0.24	418	36.6	42	14	19	19	0.002	0.103	0.030	1
RRM 9.2 to 11.3	37	37	0.72	86.2	21.0	37	13	24	23	0.005	0.131	0.029	1
RRM 11.3 to 12.5	36	36	0.01	32.5	8.3	35	2	4	4	0.000	0.389	0.112	1
RRM 12.5 to 13.5	27	27	0.30	28.6	11.9	27	3	20	20	0.008	0.124	0.033	1
RRM 13.5 to 16.7	2	2	6.7	14.7	10.7	2	0	1	1	0.089	0.089	0.089	0
RRM 16.7 to 20.9	3	3	2.4	12.9	6.5	3	0	0	0	NC	NC	NC	NC
RRM 20.9 to 24.0	20	20	0.78	24.2	11.2	20	6	2	2	0.028	0.072	0.050	0
SFSR	14	14	0.19	1.4	0.67	14	0	0	0	NC	NC	NC	NC
Interstitial Sediment														
RRM -2.7 to -0.7	43	43	0.04	0.19	0.07	1	0	41	41	0.000	0.03	0.003	0
RRM -0.7 to 0.0	13	13	0.07	3.3	0.86	9	0	0	0	NC	NC	NC	NC
RRM 0.0 to 0.8	111	111	0.06	53.5	3.1	109	3	50	50	0.001	0.096	0.015	0
RRM 0.8 to 1.7	10	10	0.27	59.5	9.5	10	2	7	7	0.001	0.017	0.007	0
RRM 1.7 to 2.7	48	48	3.2	26.0	9.7	48	2	39	39	0.002	0.052	0.014	0
RRM 2.7 to 4.4	108	108	3.6	211	23.4	108	42	110	110	0.001	0.240	0.054	13
RRM 4.4 to 5.2	50	50	4.3	60.4	18.6	50	18	54	54	0.011	0.288	0.054	4
RRM 5.2 to 7.9	48	48	3.1	42.6	20.0	48	29	53	53	0.011	0.216	0.066	9
RRM 7.9 to 9.2	61	61	8.9	50.6	20.8	61	41	67	67	0.017	0.775	0.086	14
RRM 9.2 to 11.3	4	4	15.6	24.6	18.8	4	1	1	1	0.141	0.141	0.141	1
RRM 11.3 to 12.5	67	67	8.0	42.9	15.8	67	4	64	64	0.015	0.440	0.084	20
RRM 12.5 to 13.5	38	38	9.9	40.1	15.7	38	5	37	37	0.006	0.261	0.063	9
RRM 13.5 to 16.7	40	40	8.5	18.4	12.9	40	0	36	36	0.012	0.206	0.060	9
RRM 16.7 to 20.9	40	40	2.8	15.4	10.3	40	0	36	36	0.015	0.188	0.069	12
RRM 20.9 to 24.0	59	59	2.4	26.0	9.9	59	1	52	52	0.003	0.189	0.067	13
SFSR	47	47	0.37	2.5	1.2	47	0	36	36	0.001	0.045	0.013	0

Notes:
RRM, Relative river mile.
ESV, Ecological screening value.
NC, Not calculated due to insufficient sample size.
SFSR, South Fork Shenandoah River.
a, EPA Region III freshwater sediment screening value based on the consensus-based threshold effect concentration (TEC) published by MacDonald et al. (2000).
b, Site-specific ecological screening value based on the maximum sediment concentration that did not result in significantly lower survival or growth in 10-day exposures to *Hyalella azteca* and *Chironomus dilutus* (URS, 2012).
c, Based on detected samples only.

Table 3-3

Trace Metal Concentrations in Sediment Compared to Sediment Quality Guidelines

AOC 4 Ecological Risk Assessment Report

Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Phase I Study Sampling Location	Interstitial Sediment								
		Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (mg/kg)[c]	Maximum (mg/kg)[c]	Mean (mg/kg)[c]	TEC[a]	# Samples > TEC[a,c]	PEC[b]	# Samples > PEC[b,c]
Cadmium										
RRM -2.7 to -0.7	SR-01	8	8	0.19	5.5	0.91	0.99	1	5	1
RRM -0.7 to 0.0	--	--	--	--	--	--	--	--	--	--
RRM 0.0 to 0.8	RRM-0.6	8	8	0.39	185	24	0.99	2	5	1
RRM 0.8 to 1.7	--	--	--	--	--	--	--	--	--	--
RRM 1.7 to 2.7	--	--	--	--	--	--	--	--	--	--
RRM 2.7 to 4.4	RRM-3.0	8	8	0.27	7.0	1.3	0.99	1	5	1
RRM 4.4 to 5.2	--	--	--	--	--	--	--	--	--	--
RRM 5.2 to 7.9	RRM-7.1	8	8	0.31	6.4	1.2	0.99	1	5	1
RRM 7.9 to 9.2	RRM-8.7	8	8	0.35	6.2	1.2	0.99	1	5	1
RRM 9.2 to 11.3	--	--	--	--	--	--	--	--	--	--
RRM 11.3 to 12.5	--	--	--	--	--	--	--	--	--	--
RRM 12.5 to 13.5	--	--	--	--	--	--	--	--	--	--
RRM 13.5 to 16.7	--	--	--	--	--	--	--	--	--	--
RRM 16.7 to 20.9	--	--	--	--	--	--	--	--	--	--
RRM 20.9 to 24.0	--	--	--	--	--	--	--	--	--	--
SFSR	SFS-01	8	8	0.18	2.4	0.52	0.99	1	5	0
--	NR-01	8	8	0.17	4.0	0.69	0.99	1	5	0
--	NR-02	8	8	0.15	3.1	0.56	0.99	1	5	0
Chromium										
RRM -2.7 to -0.7	SR-01	8	8	40	53	46	43	5	111	0
RRM -0.7 to 0.0	--	--	--	--	--	--	--	--	--	--
RRM 0.0 to 0.8	RRM-0.6	8	8	47	109	63	43	8	111	0
RRM 0.8 to 1.7	--	--	--	--	--	--	--	--	--	--
RRM 1.7 to 2.7	--	--	--	--	--	--	--	--	--	--
RRM 2.7 to 4.4	RRM-3.0	8	8	54	101	72	43	8	111	0
RRM 4.4 to 5.2	--	--	--	--	--	--	--	--	--	--
RRM 5.2 to 7.9	RRM-7.1	8	8	62	108	80	43	8	111	0
RRM 7.9 to 9.2	RRM-8.7	8	8	60	102	88	43	8	111	0
RRM 9.2 to 11.3	--	--	--	--	--	--	--	--	--	--
RRM 11.3 to 12.5	--	--	--	--	--	--	--	--	--	--
RRM 12.5 to 13.5	--	--	--	--	--	--	--	--	--	--
RRM 13.5 to 16.7	--	--	--	--	--	--	--	--	--	--
RRM 16.7 to 20.9	--	--	--	--	--	--	--	--	--	--
RRM 20.9 to 24.0	--	--	--	--	--	--	--	--	--	--
SFSR	SFS-01	8	8	40	63	52	43	6	111	0
--	NR-01	8	8	35	48	43	43	4	111	0
--	NR-02	8	8	30	42	37	43	0	111	0
Copper										
RRM -2.7 to -0.7	SR-01	8	8	19	29	27	32	0	149	0
RRM -0.7 to 0.0	--	--	--	--	--	--	--	--	--	--
RRM 0.0 to 0.8	RRM-0.6	8	7	45	101	63	32	7	149	0
RRM 0.8 to 1.7	--	--	--	--	--	--	--	--	--	--
RRM 1.7 to 2.7	--	--	--	--	--	--	--	--	--	--
RRM 2.7 to 4.4	RRM-3.0	8	8	49	123	69	32	8	149	0
RRM 4.4 to 5.2	--	--	--	--	--	--	--	--	--	--
RRM 5.2 to 7.9	RRM-7.1	8	8	50	77	64	32	8	149	0
RRM 7.9 to 9.2	RRM-8.7	8	8	54	87	74	32	8	149	0
RRM 9.2 to 11.3	--	--	--	--	--	--	--	--	--	--
RRM 11.3 to 12.5	--	--	--	--	--	--	--	--	--	--
RRM 12.5 to 13.5	--	--	--	--	--	--	--	--	--	--
RRM 13.5 to 16.7	--	--	--	--	--	--	--	--	--	--
RRM 16.7 to 20.9	--	--	--	--	--	--	--	--	--	--
RRM 20.9 to 24.0	--	--	--	--	--	--	--	--	--	--
SFSR	SFS-01	8	8	25	36	29	32	2	149	0
--	NR-01	8	8	20	32	25	32	1	149	0
--	NR-02	8	8	17	27	21	32	0	149	0
Lead										
RRM -2.7 to -0.7	SR-01	8	8	22	26	24	35	0	128	0
RRM -0.7 to 0.0	--	--	--	--	--	--	--	--	--	--
RRM 0.0 to 0.8	RRM-0.6	8	8	0.12	105	48	35	7	128	0
RRM 0.8 to 1.7	--	--	--	--	--	--	--	--	--	--
RRM 1.7 to 2.7	--	--	--	--	--	--	--	--	--	--
RRM 2.7 to 4.4	RRM-3.0	8	8	27	46	36	35	4	128	0
RRM 4.4 to 5.2	--	--	--	--	--	--	--	--	--	--
RRM 5.2 to 7.9	RRM-7.1	8	8	29	45	36	35	4	128	0
RRM 7.9 to 9.2	RRM-8.7	8	8	24	39	33	35	4	128	0
RRM 9.2 to 11.3	--	--	--	--	--	--	--	--	--	--
RRM 11.3 to 12.5	--	--	--	--	--	--	--	--	--	--
RRM 12.5 to 13.5	--	--	--	--	--	--	--	--	--	--
RRM 13.5 to 16.7	--	--	--	--	--	--	--	--	--	--
RRM 16.7 to 20.9	--	--	--	--	--	--	--	--	--	--
RRM 20.9 to 24.0	--	--	--	--	--	--	--	--	--	--
SFSR	SFS-01	8	8	21	32	27	35	0	128	0
--	NR-01	8	8	26	32	29	35	0	128	0
--	NR-02	8	8	21	29	25	35	0	128	0
Selenium										
RRM -2.7 to -0.7	SR-01	8	4	0.33	4.3	2.0	NA	NC	NA	NC
RRM -0.7 to 0.0	--	--	--	--	--	--	--	--	--	--
RRM 0.0 to 0.8	RRM-0.6	8	5	1.4	6.9	3.2	NA	NC	NA	NC
RRM 0.8 to 1.7	--	--	--	--	--	--	--	--	--	--
RRM 1.7 to 2.7	--	--	--	--	--	--	--	--	--	--
RRM 2.7 to 4.4	RRM-3.0	8	5	0.59	5.5	2.3	NA	NC	NA	NC
RRM 4.4 to 5.2	--	--	--	--	--	--	--	--	--	--
RRM 5.2 to 7.9	RRM-7.1	8	5	0.41	2.7	1.9	NA	NC	NA	NC
RRM 7.9 to 9.2	RRM-8.7	8	5	0.40	3.8	1.9	NA	NC	NA	NC
RRM 9.2 to 11.3	--	--	--	--	--	--	--	--	--	--
RRM 11.3 to 12.5	--	--	--	--	--	--	--	--	--	--
RRM 12.5 to 13.5	--	--	--	--	--	--	--	--	--	--
RRM 13.5 to 16.7	--	--	--	--	--	--	--	--	--	--
RRM 16.7 to 20.9	--	--	--	--	--	--	--	--	--	--
RRM 20.9 to 24.0	--	--	--	--	--	--	--	--	--	--
SFSR	SFS-01	8	4	0.38	3.1	1.4	NA	NC	NA	NC
--	NR-01	8	6	0.73	7.7	2.7	NA	NC	NA	NC
--	NR-02	8	3	0.69	1.9	1.3	NA	NC	NA	NC
Zinc										
RRM -2.7 to -0.7	SR-01	8	8	68	134	105	121	3	459	0
RRM -0.7 to 0.0	--	--	--	--	--	--	--	--	--	--
RRM 0.0 to 0.8	RRM-0.6	8	8	174	346	223	121	8	459	0
RRM 0.8 to 1.7	--	--	--	--	--	--	--	--	--	--
RRM 1.7 to 2.7	--	--	--	--	--	--	--	--	--	--
RRM 2.7 to 4.4	RRM-3.0	8	8	122	183	156	121	8	459	0
RRM 4.4 to 5.2	--	--	--	--	--	--	--	--	--	--
RRM 5.2 to 7.9	RRM-7.1	8	8	133	197	151	121	8	459	0
RRM 7.9 to 9.2	RRM-8.7	8	8	109	197	151	121	7	459	0
RRM 9.2 to 11.3	--	--	--	--	--	--	--	--	--	--
RRM 11.3 to 12.5	--	--	--	--	--	--	--	--	--	--
RRM 12.5 to 13.5	--	--	--	--	--	--	--	--	--	--
RRM 13.5 to 16.7	--	--	--	--	--	--	--	--	--	--
RRM 16.7 to 20.9	--	--	--	--	--	--	--	--	--	--
RRM 20.9 to 24.0	--	--	--	--	--	--	--	--	--	--
SFSR	SFS-01	8	8	77	124	104	121	2	459	0
--	NR-01	8	8	75	170	104	121	2	459	0
--	NR-02	8	8	79	119	96	121	0	459	0

Notes:

RRM, Relative river mile.
SR, South River.
SFSR/SFS, South Fork Shenandoah River.
NR, North River.
--, Assessment Reach/ Phase I Study sampling location not identified.
NA, Not available.
NC, Not calculated due to insufficient sample size.
a, Consensus-based threshold effect concentrations (TEC) published by MacDonald et al. (2000).
b, Consensus-based probable effect concentrations (PEC) published by MacDonald et al. (2000).
c, Based on detected samples only.

Table 3-4
Derivation of Equilibrium Partitioning Sediment Benchmarks (ESB) for PAH Mixtures
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

PAH Compound	$C_{oc,PAHi,FCVi}$/ $C_{oc,PAHi,Maxi}$ [a]	NR-01 f_{oc} = 0.1368			NR-02 f_{oc} = 0.1112		
		C_{sed} (mg/kg)	C_{oc} (mg/kg$_{oc}$)	$ESBTU_{FCVi}$	C_{sed} (mg/kg)	C_{oc} (mg/kg$_{oc}$)	$ESBTU_{FCVi}$
Acenaphthene	491	0.0857	0.627	0.0013	0.078	0.701	0.0014
Acenaphthylene	452	0.0857	0.627	0.0014	0.078	0.701	0.0016
Anthracene	594	0.0857	0.627	0.0011	0.078	0.701	0.0012
Benzo(a)anthracene	841	0.0857	0.627	0.0007	0.078	0.701	0.0008
Benzo[a]pyrene	965	0.0857	0.627	0.0006	0.078	0.701	0.0007
Benzo(b)fluoranthene	979	0.0857	0.627	0.0006	0.078	0.701	0.0007
Benzo(k)fluoranthene	981	0.0857	0.627	0.0006	0.078	0.701	0.0007
Chrysene	826	0.0857	0.627	0.0008	0.078	0.701	0.0008
Fluoranthene	707	0.0993	0.726	0.0010	0.078	0.701	0.0010
Fluorene	538	0.0857	0.627	0.0012	0.078	0.701	0.0013
Naphthalene	385	0.0857	0.627	0.0016	0.078	0.701	0.0018
Phenanthrene	596	0.0964	0.705	0.0012	0.078	0.701	0.0012
Pyrene	697	0.1007	0.736	0.0011	0.078	0.701	0.0010
			Σ $ESBTU_{FCV,13}$ =	0.0132		**Σ $ESBTU_{FCV,13}$ =**	0.0143
			Σ $ESBTU_{FCV}$ [b] =	0.0895		**Σ $ESBTU_{FCV}$ [b] =**	0.0970

PAH Compound	$C_{oc,PAHi,FCVi}$/ $C_{oc,PAHi,Maxi}$ [a]	RRM 0.6 f_{oc} = 0.1206			RRM 3.0 f_{oc} = 0.1229		
		C_{sed} (mg/kg)	C_{oc} (mg/kg$_{oc}$)	$ESBTU_{FCVi}$	C_{sed} (mg/kg)	C_{oc} (mg/kg$_{oc}$)	$ESBTU_{FCVi}$
Acenaphthene	491	0.108	0.899	0.0018	0.098	0.795	0.0016
Acenaphthylene	452	0.108	0.899	0.0020	0.098	0.795	0.0018
Anthracene	594	0.148	1.223	0.0021	0.132	1.075	0.0018
Benzo(a)anthracene	841	0.694	5.758	0.0068	0.734	5.976	0.0071
Benzo[a]pyrene	965	0.884	7.333	0.0076	0.734	5.976	0.0062
Benzo(b)fluoranthene	979	1.478	12.256	0.0125	1.196	9.730	0.0099
Benzo(k)fluoranthene	981	0.578	4.794	0.0049	0.453	3.688	0.0038
Chrysene	826	1.131	9.375	0.0113	0.969	7.889	0.0096
Fluoranthene	707	1.913	15.863	0.0224	1.293	10.518	0.0149
Fluorene	538	0.113	0.934	0.0017	0.098	0.795	0.0015
Naphthalene	385	0.108	0.899	0.0023	0.098	0.795	0.0021
Phenanthrene	596	0.902	7.478	0.0125	0.663	5.397	0.0091
Pyrene	697	1.799	14.920	0.0214	1.309	10.651	0.0153
			Σ $ESBTU_{FCV,13}$ =	0.1095		**Σ $ESBTU_{FCV,13}$ =**	0.0845
			Σ $ESBTU_{FCV}$ [b] =	0.7427		**Σ $ESBTU_{FCV}$ [b] =**	0.5728

PAH Compound	$C_{oc,PAHi,FCVi}$/ $C_{oc,PAHi,Maxi}$ [a]	RRM 8.7 f_{oc} = 0.1152			SFS-01 f_{oc} = 0.1037		
		C_{sed} (mg/kg)	C_{oc} (mg/kg$_{oc}$)	$ESBTU_{FCVi}$	C_{sed} (mg/kg)	C_{oc} (mg/kg$_{oc}$)	$ESBTU_{FCVi}$
Acenaphthene	491	0.087	0.753	0.0015	0.083	0.801	0.0016
Acenaphthylene	452	0.087	0.753	0.0017	0.083	0.801	0.0018
Anthracene	594	0.096	0.834	0.0014	0.083	0.801	0.0013
Benzo(a)anthracene	841	0.134	1.165	0.0014	0.083	0.801	0.0010
Benzo[a]pyrene	965	0.148	1.286	0.0013	0.083	0.801	0.0008
Benzo(b)fluoranthene	979	0.255	2.213	0.0023	0.083	0.801	0.0008
Benzo(k)fluoranthene	981	0.105	0.910	0.0009	0.083	0.801	0.0008
Chrysene	826	0.200	1.736	0.0021	0.083	0.801	0.0010
Fluoranthene	707	0.280	2.430	0.0034	0.083	0.801	0.0011
Fluorene	538	0.087	0.753	0.0014	0.083	0.801	0.0015
Naphthalene	385	0.087	0.753	0.0020	0.083	0.801	0.0021
Phenanthrene	596	0.156	1.350	0.0023	0.083	0.801	0.0013
Pyrene	697	0.280	2.430	0.0035	0.091	0.874	0.0013
			Σ $ESBTU_{FCV,13}$ =	0.0252		**Σ $ESBTU_{FCV,13}$ =**	0.0164
			Σ $ESBTU_{FCV}$ [b] =	0.1706		**Σ $ESBTU_{FCV}$ [b] =**	0.1115

PAH Compound	$C_{oc,PAHi,FCVi}$/ $C_{oc,PAHi,Maxi}$ [a]	SR-01 f_{oc} = 0.1103		
		C_{sed} (mg/kg)	C_{oc} (mg/kg$_{oc}$)	$ESBTU_{FCVi}$
Acenaphthene	491	0.068	0.614	0.0013
Acenaphthylene	452	0.068	0.614	0.0014
Anthracene	594	0.068	0.614	0.0010
Benzo(a)anthracene	841	0.068	0.614	0.0007
Benzo[a]pyrene	965	0.068	0.614	0.0006
Benzo(b)fluoranthene	979	0.068	0.614	0.0006
Benzo(k)fluoranthene	981	0.068	0.614	0.0006
Chrysene	826	0.068	0.614	0.0007
Fluoranthene	707	0.072	0.652	0.0009
Fluorene	538	0.068	0.614	0.0011
Naphthalene	385	0.068	0.614	0.0016
Phenanthrene	596	0.068	0.614	0.0010
Pyrene	697	0.068	0.614	0.0009
			Σ $ESBTU_{FCV,13}$ =	0.0126
			Σ $ESBTU_{FCV}$ [b] =	0.0853

Notes:

Equilibrium Partitioning Sediment Benchmarks for PAH mixtures calculated as:

$$\sum ESBTU_{FCV} = \sum_i \frac{C_{OC,PAHi}}{C_{OC,PAHi,FCVi}}$$

where:

$ESBTU_{FCV}$ = Equilibrium Partitioning Sediment Benchmark Toxic Unit based on the Final Chronic Value (FCV).

$C_{OC,iPAHi}$ = Organic-carbon-normalized sediment concentration of individual PAHs.

$C_{OC,iPAHi,FCVi}$ = Critical concentration of individual PAHs in sediment from EPA (2000).

f_{oc} = Fraction of organic carbon.

a, The lower value of $C_{oc,PAHi,FCVi}$ and $C_{oc,PAHi,Maxi}$ was used in the calculation.

b, An uncertainty factor of 6.78 was multiplied to Σ $ESBTU_{FCV,13}$ to estimate $ESBTU_{FCV}$ for 34 PAHs with 80% confidence (EPA 2003).

PAH, Polycyclic aromatic hydrocarbons.
NR, North River.
RRM, Relative river mile.
SR, South River.
SFSR, South Fork Shenandoah River.

Uncertainty Factor: 6.78

Table 3-5
Baseline Flow Surface Water Mercury Screening Summary Table
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	TOTAL MERCURY (THg)						METHYLMERCURY (MeHg)					
	Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (ng/L)[c]	Maximum (ng/L)[c]	Mean (ng/L)[c]	# Samples > ESV[a,c]	Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (ng/L)[c]	Maximum (ng/L)[c]	Mean (ng/L)[c]	# Samples > ESV[b,c]
Unfiltered Surface Water												
RRM -2.7 to -0.7	279	204	0.35	41	2.0	0	114	88	0.02	0.08	0.04	0
RRM -0.7 to 0.0	33	29	0.95	99	19	0	5	5	0.03	0.06	0.04	0
RRM 0.0 to 0.8	277	276	0.65	311	16	0	119	105	0.02	1.5	0.12	0
RRM 0.8 to 1.7	62	61	1.6	149	27	0	24	24	0.02	0.73	0.31	0
RRM 1.7 to 2.7	251	250	1.9	449	47	0	139	138	0.02	4.2	0.39	1
RRM 2.7 to 4.4	84	84	3.8	179	64	0	84	84	0.06	3.4	0.71	0
RRM 4.4 to 5.2	126	126	0.35	295	61	0	52	52	0.04	7.5	0.96	1
RRM 5.2 to 7.9	162	162	3.1	550	88	0	159	158	0.07	4.0	0.90	0
RRM 7.9 to 9.2	48	48	27	2727	147	1	44	44	0.17	5.3	1.6	3
RRM 9.2 to 11.3	72	72	5.5	330	84	0	69	69	0.14	3.1	0.95	0
RRM 11.3 to 12.5	114	114	4.2	580	85	0	57	57	0.23	5.0	1.7	3
RRM 12.5 to 13.5	42	42	14	334	96	0	42	42	0.28	6.4	2.0	6
RRM 13.5 to 16.7	185	185	6.0	430	80	0	111	111	0.07	5.7	1.3	3
RRM 16.7 to 20.9	75	75	16	225	71	0	75	75	0.15	6.0	1.5	4
RRM 20.9 to 24.0	335	328	0.35	363	40	0	115	115	0.12	5.7	1.2	3
SFSR	103	103	1.5	156	17	0	41	41	0.06	1.0	0.38	0
Filtered Surface Water												
RRM -2.7 to -0.7	380	242	0	13	1.9	0	172	120	0.01	0.76	0.13	0
RRM -0.7 to 0.0	30	23	0.50	32	8.4	0	5	2	0.02	0.03	0.03	0
RRM 0.0 to 0.8	357	293	0.44	66	3.2	0	169	131	0.02	0.60	0.09	0
RRM 0.8 to 1.7	86	62	0.95	88	7.0	0	31	25	0.01	0.48	0.14	0
RRM 1.7 to 2.7	500	471	0.25	296	6.8	0	254	249	0.02	62	0.92	6
RRM 2.7 to 4.4	157	157	1.2	126	6.1	0	157	157	0.02	2.3	0.46	0
RRM 4.4 to 5.2	109	91	1.0	27	3.7	0	9	9	0.04	0.44	0.17	0
RRM 5.2 to 7.9	197	197	1.6	43	7.2	0	193	192	0.04	5.9	0.57	1
RRM 7.9 to 9.2	83	83	2.6	27	9.3	0	82	81	0.11	2.8	0.94	0
RRM 9.2 to 11.3	117	115	2.4	129	13	0	109	109	0.03	48	2.4	8
RRM 11.3 to 12.5	151	151	1.5	61	10	0	86	86	0.12	3.1	1.2	0
RRM 12.5 to 13.5	56	56	3.7	21	11	0	56	56	0.15	2.9	1.4	0
RRM 13.5 to 16.7	226	204	1.5	68	7.7	0	113	113	0.04	2.6	0.83	0
RRM 16.7 to 20.9	82	81	3.4	33	9.7	0	82	82	0.10	3.1	0.95	0
RRM 20.9 to 24.0	431	364	0.50	87	6.6	0	162	162	0.08	5.3	0.90	1
SFSR	112	96	0.50	5.6	2.2	0	41	41	0.04	0.74	0.25	0

Notes:
RRM, Relative river mile.
ESV, Ecological screening value.
SFSR, South Fork Shenandoah River.
a, Total mercury (THg) ESVs for surface water:
Unfiltered Surface Water ESV = 908 ng/L continuous chronic criterion (CCC) derived in EPA (1995) *Update Freshwater Aquatic Life Criterion for mercury*;
Expressed as total recover mercury, this value forms the basis for the filtered VAWQC/NRWQC based on a total dissolved conversion factor of 0.85.
Filtered Surface Water THg = 770 ng/L VAWQC chronic [VDEQ Numerical Water Quality Criterion (9 VAC 25-260) January 6, 2011].
b, Methylmercury (MeHg) ESV for surface water = 4 ng/L based on EPA Region III BTAG Freshwater Screening Benchmarks (filtered/unfiltered samples).
c, Based on detected samples only.

Table 3-6
Storm Flow Surface Water Mercury Screening Summary Table
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	TOTAL MERCURY (THg)						METHYLMERCURY (MeHg)					
	Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (ng/L)[c]	Maximum (ng/L)[c]	Mean (ng/L)[c]	# Samples > ESV[a,c]	Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (ng/L)[c]	Maximum (ng/L)[c]	Mean (ng/L)[c]	# Samples > ESV[b,c]
Unfiltered Surface Water												
RRM -2.7 to -0.7	38	37	0.46	27	5.5	0	34	32	0.02	0.64	0.11	0
RRM -0.7 to 0.0	2	2	3.7	46	25	0	1	1	0.49	0.49	0.49	0
RRM 0.0 to 0.8	40	40	2.3	226	33	0	36	36	0.02	0.80	0.20	0
RRM 0.8 to 1.7	1	1	45	45	45	0	0	0	NC	NC	NC	NC
RRM 1.7 to 2.7	36	36	10	1501	162	1	33	33	0.04	4.3	0.56	1
RRM 2.7 to 4.4	0	0	NC	NC	NC	NC	0	0	NC	NC	NC	NC
RRM 4.4 to 5.2	4	4	31	413	131	0	1	1	0.61	0.61	0.61	0
RRM 5.2 to 7.9	33	33	24	2775	429	3	32	32	0.11	9.6	1.4	2
RRM 7.9 to 9.2	0	0	NC	NC	NC	NC	0	0	NC	NC	NC	NC
RRM 9.2 to 11.3	36	36	57	4519	687	8	33	33	0.21	21	3.3	5
RRM 11.3 to 12.5	1	1	384	384	384	0	0	0	NC	NC	NC	NC
RRM 12.5 to 13.5	0	0	NC	NC	NC	NC	0	0	NC	NC	NC	NC
RRM 13.5 to 16.7	53	53	50	4344	731	10	27	27	0.27	17	3.2	5
RRM 16.7 to 20.9	21	21	46	4489	598	5	21	21	0.27	18	2.5	3
RRM 20.9 to 24.0	29	29	37	4656	800	7	28	28	0.25	28	4.3	6
SFSR	1	1	22	22	22	0	0	0	NC	NC	NC	NC
Filtered Surface Water												
RRM -2.7 to -0.7	35	34	0.24	2.7	1.2	0	33	29	0.02	0.06	0.04	0
RRM -0.7 to 0.0	1	1	6.7	6.7	6.7	0	1	1	0.10	0.10	0.10	0
RRM 0.0 to 0.8	37	37	0.51	17	3.2	0	34	31	0.02	0.20	0.05	0
RRM 0.8 to 1.7	1	1	3.4	3.4	3.4	0	0	0	NC	NC	NC	NC
RRM 1.7 to 2.7	34	34	1.0	11	3.8	0	33	32	0.03	0.36	0.11	0
RRM 2.7 to 4.4	0	0	NC	NC	NC	NC	0	0	NC	NC	NC	NC
RRM 4.4 to 5.2	4	4	4.1	8.0	5.3	0	1	1	0.06	0.06	0.06	0
RRM 5.2 to 7.9	32	32	0.24	34	6.8	0	32	32	0.06	0.90	0.26	0
RRM 7.9 to 9.2	0	0	NC	NC	NC	NC	0	0	NC	NC	NC	NC
RRM 9.2 to 11.3	34	34	1.5	412	27	0	33	33	0.10	2.2	0.53	0
RRM 11.3 to 12.5	1	1	8.4	8.4	8.4	0	0	0	NC	NC	NC	NC
RRM 12.5 to 13.5	0	0	NC	NC	NC	NC	0	0	NC	NC	NC	NC
RRM 13.5 to 16.7	39	39	2.6	75	8.5	0	27	27	0.11	1.6	0.53	0
RRM 16.7 to 20.9	21	21	3.3	20	7.5	0	21	20	0.15	1.2	0.44	0
RRM 20.9 to 24.0	29	29	3.8	18	8.9	0	28	28	0.15	1.8	0.61	0
SFSR	2	2	1.8	2.6	2.2	0	0	0	NC	NC	NC	NC

Notes:
RRM, Relative river mile.
ESV, Ecological screening value.
NC, not calculated due to insufficient sample size.
SFSR, South Fork Shenandoah River.
a, Total mercury (THg) ESVs for surface water:
Unfiltered Surface Water ESV = 908 ng/L continuous chronic criterion (CCC) derived in EPA (1995) *Update Freshwater Aquatic Life Criterion for mercury.*
Expressed as total recoverable mercury, this value forms the basis for the filtered VAWQC/NRWQC based on a total to dissolved conversion factor of 0.85.
Filtered Surface Water THg = 770 ng/L VAWQC chronic [VDEQ Numerical Water Quality Criterion (9 VAC 25-260) January 6, 2011].
b, Methylmercury (MeHg) ESV for surface water = 4 ng/L based on EPA Region III BTAG Freshwater Screening Benchmarks (filtered/unfiltered samples).
c, Based on detected samples only.

Table 3-7
Floodplain Soil Mercury Screening Summary Table
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Floodplain	TOTAL MERCURY (THg)											
		Surficial (0.0'- 0.5')						Sub-surface (0.5'- 2.0')					
		Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (mg/kg)[b]	Maximum (mg/kg)[b]	Mean (mg/kg)[b]	# samples > 0.18 mg/kg[a,b]	Sample Size (*n*)	Detected Sample Size (*n*)	Minimum (mg/kg)[b]	Maximum (mg/kg)[b]	Mean (mg/kg)[b]	# samples > 0.18 mg/kg[a,b]
RRM -2.7 to -0.7	0.3 Year	5	5	0.08	0.18	0.13	0	0	0	NC	NC	NC	NC
RRM -0.7 to 0.0	2 Year	5	5	0.01	0.40	0.15	2	2	2	0.10	0.60	0.35	1
	5 Year	7	7	0.01	13	2.3	5	5	5	0.01	3.1	0.92	4
RRM 0.0 to 0.8	0.3 Year	275	275	0.14	941	16	271	14	14	2.3	164	29	14
	2 Year	53	53	0.02	160	10	48	14	14	1.6	40	19	14
	5 Year	22	22	0.03	24	4	17	16	16	0.03	248	45	12
	62 Year	35	35	0.03	48	5	32	20	20	0.04	55	17	19
RRM 0.8 to 1.7	0.3 Year	378	375	0.09	817	24	374	23	23	0.53	608	64	23
	2 Year	89	89	0.03	494	28	87	9	9	0.03	231	51	7
	5 Year	86	86	0.03	307	15	82	34	34	0.11	89	12	32
	62 Year	33	33	0.16	86	6.9	32	19	19	0.05	341	64	17
RRM 1.7 to 2.7	0.3 Year	367	367	0.02	515	15	346	41	41	0.10	132	31	39
	2 Year	157	157	0.01	61	12	138	43	43	0.05	72	12	40
	5 Year	64	64	0.03	173	11	58	53	52	0.03	714	51	45
	62 Year	25	24	0.02	19	1.8	16	25	22	0.02	6.0	0.80	12
RRM 2.7 to 4.4	0.3 Year	610	609	0.02	476	16	592	71	70	0.07	403	25	68
	2 Year	31	31	0.02	78	14	24	22	20	0.07	69	13	17
	5 Year	9	9	1.9	39	8.8	9	16	16	0.10	19	3.3	14
	62 Year	7	7	0.13	1.6	0.71	6	7	7	0.01	0.48	0.16	2
RRM 4.4 to 5.2	0.3 Year	133	133	0.04	485	24	128	5	5	1.2	12	5.4	5
	2 Year	19	18	0.14	28	12	17	4	4	0.35	27	7.3	4
	5 Year	11	11	0.18	30	6.5	11	12	12	0.04	36	5.0	7
	62 Year	14	14	0.05	0.54	0.28	10	14	14	0.02	0.15	0.07	0
RRM 5.2 to 7.9	0.3 Year	100	99	0.05	120	14	98	15	15	0.19	97	17	15
	2 Year	16	16	0.47	83	13	16	10	10	0.11	22	5.1	8
	5 Year	23	23	0.05	22	4.7	21	24	24	0.05	8.9	1.2	15
	62 Year	21	21	0.02	2.8	0.21	4	21	21	0.01	0.29	0.05	1
RRM 7.9 to 9.2	0.3 Year	71	69	0.02	42	13	61	16	16	0.23	163	21	16
	2 Year	18	18	3.6	56	19	18	16	16	0.29	270	35	16
	5 Year	7	7	0.06	21	7.7	6	9	9	0.03	34	12	6
	62 Year	7	7	0.06	1.5	0.35	2	7	7	0.01	0.61	0.12	1
RRM 9.2 to 11.3	0.3 Year	42	42	0.04	80	20	41	21	21	0.61	94	24	21
	2 Year	27	27	1.1	60	17	27	17	17	0.40	58	8.7	17
	5 Year	32	32	0.20	50	16	32	37	37	0.06	124	13	34
	62 Year	16	15	0.02	21	4.5	10	17	17	0.02	14	1.7	9
RRM 11.3 to 12.5	0.3 Year	30	30	1.4	37	13	30	5	5	0.05	13	6.8	4
	2 Year	151	151	0.04	79	34	148	21	21	0.02	54	8.2	18
	5 Year	54	54	0.17	29	4.6	53	19	19	0.03	15	3.0	14
	62 Year	33	33	0.20	2.6	0.49	33	7	7	0.07	1.0	0.30	4
RRM 12.5 to 13.5	0.3 Year	8	8	0.67	13	5.8	8	6	6	0.49	10	4.5	6
	2 Year	3	3	0.21	15	7.0	3	3	3	0.07	4.5	1.6	1
	5 Year	2	2	2.2	10	6.3	2	2	2	3.1	23	13	2
	62 Year	7	7	0.03	0.56	0.20	3	7	7	0.03	0.14	0.07	0
RRM 13.5 to 16.7	0.3 Year	17	17	0.04	11	6.0	15	9	9	0.88	31	13	9
	2 Year	6	6	1.4	20	10	6	6	6	0.94	6.3	3.4	6
	5 Year	14	14	0.33	18	5.1	14	14	14	0.07	18	2.6	11
	62 Year	12	12	0.04	7.1	1.7	8	12	12	0.02	1.2	0.29	4
RRM 16.7 to 20.9	0.3 Year	56	56	0.24	22	5.9	56	15	15	0.52	19	4.8	15
	2 Year	34	33	0.04	21	7.5	32	29	28	0.05	44	4.7	27
	5 Year	35	35	0.03	23	6.0	33	37	37	0.03	17	3.0	31
	62 Year	33	33	0.01	15	2.2	24	33	33	0.02	5.5	0.58	13
RRM 20.9 to 24.0	0.3 Year	80	80	0.05	86	6.9	76	17	17	0.42	73	12	17
	2 Year	26	26	0.71	33	8.8	26	26	25	0.22	28	5.2	25
	5 Year	37	37	0.07	7.4	1.0	27	37	35	0.03	7.3	0.85	21
	62 Year	31	30	0.02	10	1.9	16	31	30	0.02	7.0	0.87	12
SFSR	NA	2	2	0.01	0.02	0.02	0	6	6	0.02	0.40	0.10	1

Notes:

a, Maximum soil concentration observed in reference reach (RRM -2.7 - -0.7).
b, Based on detected samples only.

RRM, Relative river mile.
NC, Not calculated due to insufficient sample size.

SFSR, South Fork Shenandoah River.
NA, Not available.

Table 3-8
Potentially Complete Exposure Pathways
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Potential Ecological Receptor	Potentially Complete Exposure Pathway
Aquatic	
Benthic Invertebrates	Direct Contact/Absorption of Sediment/Pore Water
	Direct Contact/Absorption of Surface Water
Fish	Direct Ingestion of Aquatic Biota
	Direct Contact/Absorption of Surface Water
Submerged Aquatic Vegetation	Direct Contact with Sediment/Pore Water
	Direct Contact with Surface Water
Semi-Aquatic	
Amphibians	Direct Ingestion of Aquatic Biota
	Direct Ingestion of Terrestrial Biota
	Direct Contact/Absorption of Sediment/Pore Water
	Direct Contact/Absorption of Surface Water
Reptiles	Direct Ingestion of Aquatic Biota
	Direct Ingestion of Terrestrial Biota
	Direct Contact/Absorption of Sediment/Pore Water
	Direct Contact/Absorption of Surface Water
Piscivorous Birds	Direct Ingestion of Aquatic Biota
Piscivorous Mammals	Direct Ingestion of Aquatic Biota
Omnivorous Birds	Direct Ingestion of Aquatic Biota
	Direct Ingestion of Terrestrial Biota
	Incidental Ingestion of Sediment/Soil
Terrestrial	
Vegetation	Direct Contact with Floodplain Soils
Soil Invertebrates	Direct Contact/Absorption of Floodplain Soils
Insectivorous Birds	Direct Ingestion of Aquatic Biota
	Direct Ingestion of Terrestrial Biota
Carnivorous birds	Direct Ingestion of Terrestrial Biota
Aerial Insectivorous Mammals	Direct Ingestion of Aquatic Biota
	Direct Ingestion of Terrestrial Biota
Invertivorous Mammals	Direct Ingestion of Terrestrial Biota
	Incidental Ingestion of Floodplain Soils
Herbivorous Mammals	Direct Ingestion of Terrestrial Biota
	Incidental Ingestion of Floodplain Soils

Table 3-9
Assessment Endpoints and Example Focal Species
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Ecological Receptor Category	Assessment Endpoint	Level of Organization	Example Focal Species
Aquatic			
Benthic Invertebrates	Survival, growth and reproduction	Population	Crayfish (*Orconectes* sp. and *Cambarus* sp.), Caddisflies (*Hydropyschidae*), Mayflies (*Baetidae*), Midges (*Chironomidae*), etc.
	Community structure	Community	
Fish	Survival, growth and reproduction	Population	Smallmouth bass (*Micropterus dolomieui*) and largemouth bass (*Micropterus salmoides*)
	Community structure	Community	
Submerged Aquatic Vegetation	Survival and growth	Population	--
	Community structure	Community	
Semi-Aquatic			
Amphibians	Survival, growth and reproduction	Population	American toad (*Bufo americanus*); wood frog (*Rana sylvatica)*
Piscivorous birds	Survival, growth and reproduction	Population	Belted kingfisher (*Megaceryle alcyon)*
Piscivorous mammals	Survival, growth and reproduction	Population	River otter (*Lontra canadensis*)
Omnivorous birds	Survival, growth and reproduction	Population	Mallard duck (*Anas platyrhynchos)*
Terrestrial			
Vegetation	Survival and growth	Population	--
Soil Invertebrates	Survival and growth	Population	Earthworms (Class *Oligochaeta*)
Insectivorous Birds	Survival, growth and reproduction	Population	Tree swallows (*Tachycineta bicolor*); American robin (*Turdus migratorius*)
Carnivorous birds	Survival, growth and reproduction	Population	Eastern screech owl (*Megascops asio*)
Aerial Insectivorous Mammals	Survival, growth and reproduction	Population	Big brown bats (*Eptesicus fuscus*)
Invertivorous Mammals	Survival, growth and reproduction	Population	Short-tailed shrew (*Blarina brevicauda*)
Herbivorous Mammals	Survival, growth and reproduction	Population	White-tailed deer (*Odocoileus virginianus*)

Table 3-10
Assessment Endpoints, Risk Questions, and Candidate Measurement Endpoints - Aquatic Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Ecological Receptor	Assessment Endpoint	Risk Question	Candidate Measurement Endpoints
Aquatic			
Benthic Invertebrates	Survival, Growth and Reproduction	Are the concentrations of mercury in sediment from AOC 4 present at concentrations that may result in adverse effects on the survival, growth or reproduction of benthic invertebrates?	Comparison of the EPCs for sediment THg and MeHg to sediment quality guidelines for the survival, growth or reproduction of benthic invertebrates.
			Statistical comparison ($p<0.05$) of the survival and growth of test organisms exposed to sediment from AOC 4 with that of organisms exposed to sediment from reference areas.
			Comparison of the EPCs for tissue THg and/or MeHg (e.g., in whole body) for larval and emergent invertebrates and crayfish from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.
	Community Structure	Are the structures of benthic invertebrate communities at sites within AOC 4 and reference areas indicative of impairment that is consistent with mercury concentrations measured in environmental media (e.g., sediment, pore water, and/or surface water)?	Statistical comparisons of benthic community metrics ($p<0.05$) including, richness, composition, tolerance/intolerance, feeding and habit metrics from sites in AOC 4 to sites in reference areas.
			Multivariate statistical comparisons ($p<0.05$) of benthic community structure based on species-abundance data from sites in AOC 4 to sites in reference areas.
Fish	Survival, Growth and Reproduction	Are the concentrations of mercury in surface water from AOC 4 present at concentrations that may result in adverse effects on survival, growth or reproduction of fish?	Comparison of the EPCs for surface water THg and MeHg to water-quality criteria for the survival, growth or reproduction of fish.
		Are the concentrations of mercury in fish tissue from AOC 4 present at concentrations that may result in adverse effects on survival, growth or reproduction of fish?	Comparison of the EPCs for tissue THg and/or MeHg (e.g., whole body) for fish from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.
		Is the age and growth in fish from AOC 4 different or lower compared to the same metrics in reference rivers?	Statistical comparison ($p<0.05$) of the age and growth of fish from AOC 4 to rivers in the region or state.
		Is the body condition of fish from AOC 4 different or lower compared to the same metrics in reference rivers?	Statistical comparison ($p<0.05$) of the condition of fish from AOC 4 to rivers in the region or state.
	Community Structure	Are the structures of the fish communities at sites within AOC 4 and reference areas indicative of impairment that is consistent with mercury concentrations measured in environmental media (e.g., surface water)?	Statistical comparisons ($p<0.05$) of fish community metrics, including total abundance, total richness, family-level and feeding guild distribution from sites in AOC 4 to rivers in the region.
		Does the recruitment and survival of fish in AOC 4 differ qualitatively from that in other rivers in Virginia?	Statistical comparisons ($p<0.05$) of recruitment and survival for fish from AOC 4 to fish from other rivers in the region.
Submerged Aquatic Vegetation (SAV)	Survival and Growth	Are the concentrations of mercury in sediment, or surface water from AOC 4 greater than the concentrations expected to cause adverse effects to plants?	Comparison of the EPCs for surface water and pore water THg and MeHg against corresponding benchmarks for the survival and growth of aquatic plants.

Notes:
AOC, Area of concern; THg, Total mercury; MeHg, Methylmercury; EPC, Exposure point concentration; SAV, Submerged aquatic vegetation.

Table 3-11
Assessment Endpoints, Risk Questions, and Candidate Measurement Endpoints - Semi-Aquatic Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Ecological Receptor	Assessment Endpoint	Risk Question	Candidate Measurement Endpoints
Semi-aquatic			
Amphibians	Survival, Growth and Reproduction	Are the concentrations of mercury in sediment, surface water, pore water or soil from AOC 4 greater than benchmarks for the survival, growth or reproduction of amphibians?	Comparison of the EPCs for THg and MeHg in pore water, surface water and soil from AOC 4 to benchmarks for the survival, growth, or reproduction of amphibians.
Piscivorous Birds	Survival, Growth and Reproduction	Is mercury present in dietary items at levels where effects to survival, growth or reproduction to piscivorous birds may be expected?	Comparison of the estimated daily mercury intake rate (DMIR) concentrations based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).
			Comparison of the EPCs for tissue THg and/or MeHg (e.g., in blood) for birds from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.
Omnivorous Birds	Survival, Growth and Reproduction	Is mercury present at levels in the dietary items or incidentally-ingested sediment where effects to survival, growth or reproduction to omnivorous birds may be expected?	Comparison of the estimated DMIR concentrations based on dose-rate modeling and EPCs in dietary items to corresponding TRVs.
Piscivorous Mammals	Survival, Growth and Reproduction	Is mercury present in dietary items at levels where effects to survival, growth or reproduction to piscivorous mammals may be expected?	Comparison of the estimated DMIR concentrations based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values TRVs.

Notes:
AOC, Area of concern; THg, Total mercury; IHg, Inorganic mercury; MeHg, Methylmercury; EPC, Exposure point concentration; DMIR, Daily mercury intake rate; TRV, Toxicity reference values; CBR, Critical body residue.

Table 3-12
Assessment Endpoints, Risk Questions, and Candidate Measurement Endpoints - Terrestrial Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Ecological Receptor	Assessment Endpoint	Risk Question	Candidate Measurement Endpoints
Terrestrial			
Vegetation	Survival and Growth	Are the mercury concentrations in soil from AOC 4 present at concentrations that may result in adverse effects on the survival or growth of terrestrial plants?	Comparison of the EPCs for soil THg to benchmarks for the survival and growth of plants.
Soil Invertebrates	Survival and Growth	Are the concentrations of mercury in soil from AOC 4 present at concentrations that may result in adverse effects on the survival or growth of soil invertebrates?	Comparison of the EPCs for soil THg to benchmarks for the survival and growth of soil invertebrates.
Invertivorous Birds	Survival, Growth and Reproduction	Is mercury present in dietary items at levels where effects to survival, growth or reproduction to insectivorous birds may be expected?	Comparison of the estimated daily mercury intake rate (DMIR) concentrations based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).
			Comparison of the EPCs for tissue THg and/or MeHg (e.g., in blood) for birds from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.
Carnivorous Birds	Survival, Growth and Reproduction	Is mercury present in dietary items at levels where effects to survival, growth or reproduction to carnivorous birds may be expected?	Comparison of the estimated daily mercury intake rate (DMIR) concentrations based on dose-rate modeling and EPCs in dietary items to corresponding toxicity reference values (TRVs).
Aerial Insectivorous Mammals	Survival, Growth and Reproduction	Is mercury present in dietary items at levels where effects to survival, growth or reproduction to aerial insectivorous mammals may be expected?	Comparison of the estimated DMIR concentrations based on dose-rate modeling and EPCs in dietary items to corresponding TRVs.
			Comparison of the EPCs for tissue THg and/or MeHg (e.g., in blood) for bats from AOC 4 to corresponding CBRs associated with effects on growth, survival, and reproduction.
Terrestrial Invertivorous Mammals	Survival, Growth and Reproduction	Is mercury present in dietary items and incidentally-ingested soil at levels where effects to survival, growth or reproduction to terrestrial invertivorous mammals may be expected?	Comparison of the estimated DMIR concentrations based on dose-rate modeling and EPCs in dietary items to corresponding TRVs.
Herbivorous Mammals	Survival, Growth and Reproduction	Is mercury present in dietary items and incidentally-ingested soil at levels where effects to survival, growth or reproduction to herbivorous mammals may be expected?	Comparison of the estimated DMIR concentrations based on dose-rate modeling and EPCs in dietary items to corresponding TRVs.

Notes:
AOC, Area of concern; THg, Total mercury; IHg, Inorganic mercury; MeHg, Methylmercury; EPC, Exposure point concentration; DMIR, Daily mercury intake rate; TRV, Toxicity reference values; CBR, Critical body residue.

Table 5-1
Environmental Media Requiring Mercury EPCs for Direct Comparisons with Ecological Effects Benchmarks
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Media	Basis/Tissue Types	Mercury Species	
Abiotic Media			
Sediment[a]	dw	THg	MeHg
Soil[b]	dw	THg	MeHg
Surface Water	total and filtered	THg	MeHg
Pore Water	total and filtered	THg	MeHg
Biotic Media			
Aquatic Invertebrates - Larval (Pooled)[c]	ww - whole body	THg	MeHg
Aquatic Invertebrates - Emergent (Pooled)[d]	ww - whole body	THg	MeHg
Crayfish (*Orconectes* sp. and *Cambarus* sp.)	ww - whole body	THg	MeHg
Bass (TL < 130 mm)[e]	ww - whole body	THg	MeHg
Bass (TL > 130 mm)[e]	ww - whole body	THg	MeHg
Amphibians (Focal Species)[f]	ww - whole body	THg	MeHg
Birds (Focal Species)[g]	ww - blood	THg	MeHg
Mammals (Focal Species)[h]	ww - blood and/or fur	THg	--

Notes:

EPC, Exposure point concentration; dw, Dry weight basis; ww, Wet weight basis; THg, Total Mercury; MeHg, Methylmercury; total, Total concentrations; filtered, Dissolved (< 0.45 um) concentrations; TL, Total length; mm, Millimeter.

a, Includes surficial sediment (0-12").

b, Includes surficial soil (0-6") and subsurface soil (6"-24").

c, Includes the following orders: *Basommatophora, Coleoptera, Diptera, Ephemeroptera, Megaloptera, Neotaenioglossa, Odonata, Plecoptera, Trichoptera, and Veneroida.*

d, Includes the following orders: *Diptera, Ephemeroptera,* and *Trichoptera*.

e, Includes pooled data for all bass species [smallmouth bass (*Micropterus dolomieu*) and largemouth bass (Micropterus salmoides)] in two different size categories TL < 130 mm [representing Young-of-the-Year (YOY)] TL > 130 mm (representing adult fish).

f, Includes data on three amphibian species [American toad (*Anaxyrus americanus*), northern two-lined (Eurycea bislineata), and red back salamander (Plethodon cinereus)].

g, For focal species based on data availability; includes belted kingfisher, tree swallow, and American robin.

h, For focal species based on data availability; includes big brown bat.

Table 5-2
Environmental Media Requiring Mercury EPCs for Dose Rate Models (DRMs)
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Media	Basis/Tissue Types	Mercury Species	
Abiotic Media			
Sediment[a]	dw	MeHg	IHg
Soil[a]	dw	MeHg	IHg
Surface Water	total	MeHg	IHg
Biotic Media			
Aquatic Invertebrates - Larval (Pooled)[b]	ww - whole body	MeHg	IHg
Aquatic Invertebrates - Emergent (Pooled)[c]	ww - whole body	MeHg	IHg
Crayfish (*Orconectes* sp. and *Cambarus* sp.)	ww - whole body	MeHg	IHg
Fish (TL < 130 mm)[d]	ww - whole body	MeHg	IHg
Fish (130 mm < TL < 350 mm)[d]	ww - whole body	MeHg	IHg
Amphibians[e]	ww - whole body	MeHg	IHg
Earthworms[f]	ww - whole body	MeHg	IHg
Spiders[g]	ww - whole body	MeHg	IHg
Terrestrial Plants[h]	ww	MeHg	IHg
Aquatic Plants[i]	ww	MeHg	IHg
Small Birds[j]	ww - muscle	MeHg	IHg
Small Mammals[j]	ww - muscle	MeHg	IHg

Notes:

EPC, Exposure point concentrations; dw, Dry weight basis; ww, Wet weight basis; MeHg, Methylmercury; IHg, Inorganic mercury; total, Total concentrations; TL, Total length; mm, Millimeter.

a, Includes only surficial samples: sediment (0-12") and soil (0-6").

b, Includes the following orders: *Basommatophora, Coleoptera, Diptera, Ephemeroptera, Megaloptera, Neotaenioglossa, Odonata, Plecoptera, Trichoptera, and Veneroida.*

c, Includes the following orders: *Diptera, Ephemeroptera, and Trichoptera*.

d, Data pooled for all fish species sampled.

e, Includes data on three amphibian species [American toad (*Anaxyrus americanus*), northern two-lined salamander (Eurycea bislineata), and red back salamander (Plethodon cinereus)].

f, Includes class *Oligochaeta*.

g, Includes family *Lycosidae*.

h, Includes various garden crops, honeysuckle, grass, and violets.

i, Includes data for the following plants: submerged aquatic vegetation, periphyton and algae.

j, Represents small birds (mean adult body weight less than 40 g) and small mammals (deer mouse and pine vole) that are likely consumed by eastern screech owl.

Table 6-1a
Risk Estimates for Benthic Invertebrates - Direct Contact to Surface Water Mercury under Baseline Flow Conditions
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks[c] (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks[d] (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	12.9	1.9	1.9	4000	7000	< 1	< 1	0.76	0.16	0.16	4	40	< 1	< 1
RRM -0.7 to 0.0[b]	32.2	8.7	8.7	4000	7000	< 1	< 1	0.03	0.03	0.03	4	40	< 1	< 1
RRM 0.0 to 0.8	66.1	3.2	3.2	4000	7000	< 1	< 1	0.60	0.09	0.09	4	40	< 1	< 1
RRM 0.8 to 1.7	87.7	8.4	8.4	4000	7000	< 1	< 1	0.48	0.17	0.17	4	40	< 1	< 1
RRM 1.7 to 2.7	296	8.1	8.1	4000	7000	< 1	< 1	62.4	2.04	2.04	4	40	< 1	< 1
RRM 2.7 to 4.4	126	9.9	9.9	4000	7000	< 1	< 1	2.30	0.60	0.60	4	40	< 1	< 1
RRM 4.4 to 5.2	27.1	3.9	3.9	4000	7000	< 1	< 1	0.44	0.37	0.37	4	40	< 1	< 1
RRM 5.2 to 7.9	43.4	9.1	9.1	4000	7000	< 1	< 1	5.94	0.77	0.77	4	40	< 1	< 1
RRM 7.9 to 9.2	27.0	12.1	12.1	4000	7000	< 1	< 1	2.77	1.04	1.04	4	40	< 1	< 1
RRM 9.2 to 11.3	129	15.8	15.8	4000	7000	< 1	< 1	48.2	5.45	5.45	4	40	**1.4**	< 1
RRM 11.3 to 12.5	61.4	13.1	13.1	4000	7000	< 1	< 1	3.05	1.32	1.32	4	40	< 1	< 1
RRM 12.5 to 13.5	20.8	14.5	14.5	4000	7000	< 1	< 1	2.90	1.93	1.93	4	40	< 1	< 1
RRM 13.5 to 16.7	67.5	7.9	7.9	4000	7000	< 1	< 1	2.61	1.13	1.13	4	40	< 1	< 1
RRM 16.7 to 20.9	32.7	10.5	10.5	4000	7000	< 1	< 1	3.06	1.33	1.33	4	40	< 1	< 1
RRM 20.9 to 24.0	87.0	6.3	6.3	4000	7000	< 1	< 1	5.31	1.01	1.01	4	40	< 1	< 1
SFSR	5.6	2.2	2.2	4000	7000	< 1	< 1	0.74	0.31	0.31	4	40	< 1	< 1

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
ng/L, nanograms per liter.
a, Upstream Reference Reach.
b, Buffer Reach.
c, Bounded NOEC and LOEC derived based on the relative growth of benthic macroinvertebrates evaluated in Chibunda (2009); Azevedo-Pereira and Soares (2010); Valenti et al. (2005) (See section 4.1.3) .
d, NOEC represents the CCME Water Quality Guideline for the Protection of Aquatic Life derived based on a LOEC of 40 ng/L for daphnid reproduction and a safety factor of 10 (CCME,2003) (See section 4.1.3).

Table 6-1b
Risk Estimates for Benthic Invertebrates - Direct Contact to Surface Water Mercury under Storm Flow Conditions
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks[c] (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks[d] (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	UCL_{mean}	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	2.7	1.1	1.1	4000	7000	< 1	< 1	0.06	0.04	0.04	4.0	40.0	< 1	< 1
RRM -0.7 to 0.0[b]	6.7	NC	6.7	4000	7000	< 1	< 1	0.10	NC	0.10	4.0	40.0	< 1	< 1
RRM 0.0 to 0.8	17.3	4.1	4.1	4000	7000	< 1	< 1	0.20	0.06	0.06	4.0	40.0	< 1	< 1
RRM 0.8 to 1.7	3.4	NC	3.4	4000	7000	< 1	< 1	NA	--	--	4.0	40.0	--	--
RRM 1.7 to 2.7	10.7	4.6	4.6	4000	7000	< 1	< 1	0.36	0.13	0.13	4.0	40.0	< 1	< 1
RRM 2.7 to 4.4	NA	--	--	4000	7000	--	--	NA	--	--	4.0	40.0	--	--
RRM 4.4 to 5.2	8.0	7.4	7.4	4000	7000	< 1	< 1	0.06	NC	0.06	4.0	40.0	< 1	< 1
RRM 5.2 to 7.9	33.8	9.0	9.0	4000	7000	< 1	< 1	0.90	0.43	0.43	4.0	40.0	< 1	< 1
RRM 7.9 to 9.2	NA	--	--	4000	7000	--	--	NA	--	--	4.0	40.0	--	--
RRM 9.2 to 11.3	412	82.8	82.8	4000	7000	< 1	< 1	2.15	0.67	0.67	4.0	40.0	< 1	< 1
RRM 11.3 to 12.5	8.4	NC	8.4	4000	7000	< 1	< 1	NA	--	--	4.0	40.0	--	--
RRM 12.5 to 13.5	NA	--	--	4000	7000	--	--	NA	--	--	4.0	40.0	--	--
RRM 13.5 to 16.7	75.4	16.6	16.6	4000	7000	< 1	< 1	1.58	0.71	0.71	4.0	40.0	< 1	< 1
RRM 16.7 to 20.9	19.6	9.0	9.0	4000	7000	< 1	< 1	1.24	0.75	0.75	4.0	40.0	< 1	< 1
RRM 20.9 to 24.0	17.7	10.0	10.0	4000	7000	< 1	< 1	1.78	1.01	1.01	4.0	40.0	< 1	< 1
SFSR	2.6	NC	2.6	4000	7000	< 1	< 1	NA	--	--	4.0	40.0	--	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
NC, Not calculated due to insufficient number of samples.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, Bounded NOEC and LOEC derived based on the relative growth of benthic macroinvertebrates evaluated in Chibunda (2009); Azevedo-Pereira and Soares (2010); Valenti et al. (2005) (See section 4.1.3) .
d, NOEC represents the CCME Water Quality Guideline for the Protection of Aquatic Life derived based on a LOEC of 40 ng/L for daphnid reproduction and a safety factor of 10 (CCME,2003) (See section 4.1.3).

Table 6-2
Risk Estimates for Benthic Invertebrates - Direct Contact to Pore Water Mercury
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks[c] (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks[d] (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentration)														
RRM -2.7 to -0.7[a]	NA	--	--	4000	7000	--	--	NA	--	--	4	40	--	--
RRM -0.7 to 0.0[b]	3.91	1.47	1.47	4000	7000	< 1	< 1	NA	--	--	4	40	--	--
RRM 0.0 to 0.8	294	27	27	4000	7000	< 1	< 1	22.1	2.80	2.80	4	40	< 1	< 1
RRM 0.8 to 1.7	NA	--	--	4000	7000	--	--	NA	--	--	4	40	**--**	--
RRM 1.7 to 2.7	1502	257	257	4000	7000	< 1	< 1	14.2	NC	14.2	4	40	**3.5**	< 1
RRM 2.7 to 4.4	2180	256	256	4000	7000	< 1	< 1	78.5	21.9	21.9	4	40	**5.5**	< 1
RRM 4.4 to 5.2	NA	--	--	4000	7000	--	--	NA	--	--	4	40	**--**	--
RRM 5.2 to 7.9	348	NC	348	4000	7000	< 1	< 1	17.4	NC	17.4	4	40	**4.4**	< 1
RRM 7.9 to 9.2	3227	228	228	4000	7000	< 1	< 1	34.3	6.79	6.79	4	40	**1.7**	< 1
RRM 9.2 to 11.3	292	NC	292	4000	7000	< 1	< 1	4.86	NC	4.86	4	40	**1.2**	< 1
RRM 11.3 to 12.5	151	58.6	58.6	4000	7000	< 1	< 1	24.1	5.57	5.57	4	40	**1.4**	< 1
RRM 12.5 to 13.5	NA	--	--	4000	7000	--	--	NA	--	--	4	40	**--**	--
RRM 13.5 to 16.7	NA	--	--	4000	7000	--	--	NA	--	--	4	40	**--**	--
RRM 16.7 to 20.9	NA	--	--	4000	7000	--	--	NA	--	--	4	40	**--**	--
RRM 20.9 to 24.0	306	44.5	44.5	4000	7000	< 1	< 1	48.6	6.56	6.56	4	40	**1.6**	< 1
SFSR	NA	--	--	4000	7000	--	--	NA	--	--	4	40	**--**	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
NC, Not calculated due to insufficient number of samples.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, Bounded NOEC and LOEC derived based on the relative growth of benthic macroinvertebrates evaluated in Chibunda (2009); Azevedo-Pereira and Soares (2010); Valenti et al. (2005) (See section 4.1.3) .
d, NOEC represents the CCME Water Quality Guideline for the Protection of Aquatic Life derived based on a LOEC of 40 ng/L for daphnid reproduction and a safety factor of 10 (CCME,2003) (See section 4.1.3).

Table 6-3
Risk Estimates for Benthic Invertebrates - Direct Contact to Sediment Mercury
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (mg/kg dw)			THg Benchmarks[c] (mg/kg dw)		Hazard Quotient (HQ)		MeHg Concentrations (mg/kg dw)			MeHg Benchmarks[c] (mg/kg dw)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
Bulk Sediment														
RRM -2.7 to -0.7[a]	0.05	NC	0.05	18.90	NA	< 1	--	0.00	NC	0.00	0.10	NA	< 1	--
RRM -0.7 to 0.0[b]	4.89	NC	4.89	18.90	NA	< 1	--	NA	--	--	0.10	NA	--	--
RRM 0.0 to 0.8	12.6	4.71	4.71	18.90	NA	< 1	--	0.03	NC	0.03	0.10	NA	< 1	--
RRM 0.8 to 1.7	10.9	7.82	7.82	18.90	NA	< 1	--	0.01	0.01	0.01	0.10	NA	< 1	--
RRM 1.7 to 2.7	212	38.1	38.1	18.90	NA	**2.0**	--	0.37	0.33	0.33	0.10	NA	**3.3**	--
RRM 2.7 to 4.4	300	41.7	41.7	18.90	NA	**2.2**	--	0.11	0.08	0.08	0.10	NA	< 1	--
RRM 4.4 to 5.2	884	200	200	18.90	NA	**10.6**	--	0.10	0.05	0.05	0.10	NA	< 1	--
RRM 5.2 to 7.9	268	27.8	27.8	18.90	NA	**1.5**	--	0.12	0.06	0.06	0.10	NA	< 1	--
RRM 7.9 to 9.2	418	84.3	84.3	18.90	NA	**4.5**	--	0.10	0.05	0.05	0.10	NA	< 1	--
RRM 9.2 to 11.3	86.2	27.6	27.6	18.90	NA	**1.5**	--	0.13	0.06	0.06	0.10	NA	< 1	--
RRM 11.3 to 12.5	32.5	13.9	13.9	18.90	NA	< 1	--	0.39	0.33	0.33	0.10	NA	**3.2**	--
RRM 12.5 to 13.5	28.6	14.1	14.1	18.90	NA	< 1	--	0.12	0.05	0.05	0.10	NA	< 1	--
RRM 13.5 to 16.7	14.7	NC	14.7	18.90	NA	< 1	--	0.09	NC	0.09	0.10	NA	< 1	--
RRM 16.7 to 20.9	12.9	16.0	12.9	18.90	NA	< 1	--	NA	--	--	0.10	NA	--	--
RRM 20.9 to 24.0	24.2	14.3	14.3	18.90	NA	< 1	--	0.07	NC	0.07	0.10	NA	< 1	--
SFSR	1.36	0.82	0.82	18.90	NA	< 1	--	NA	--	--	0.10	NA	--	--
Interstitial Sediment														
RRM -2.7 to -0.7[a]	0.19	0.07	0.07	18.90	NA	< 1	--	0.03	0.01	0.01	0.10	NA	< 1	--
RRM -0.7 to 0.0[b]	3.34	1.76	1.76	18.90	NA	< 1	--	NA	--	--	0.10	NA	--	--
RRM 0.0 to 0.8	53.5	3.92	3.92	18.90	NA	< 1	--	0.10	0.02	0.02	0.10	NA	< 1	--
RRM 0.8 to 1.7	59.5	68.4	59.5	18.90	NA	**3.1**	--	0.02	0.01	0.01	0.10	NA	< 1	--
RRM 1.7 to 2.7	26.0	10.8	10.8	18.90	NA	< 1	--	0.05	0.02	0.02	0.10	NA	< 1	--
RRM 2.7 to 4.4	211	34.2	34.2	18.90	NA	**1.8**	--	0.24	0.06	0.06	0.10	NA	< 1	--
RRM 4.4 to 5.2	60.4	20.9	20.9	18.90	NA	**1.1**	--	0.29	0.06	0.06	0.10	NA	< 1	--
RRM 5.2 to 7.9	42.6	21.9	21.9	18.90	NA	**1.2**	--	0.22	0.08	0.08	0.10	NA	< 1	--
RRM 7.9 to 9.2	50.6	22.2	22.2	18.90	NA	**1.2**	--	0.77	0.15	0.15	0.10	NA	**1.4**	--
RRM 9.2 to 11.3	24.6	23.6	23.6	18.90	NA	**1.2**	--	0.14	NC	0.14	0.10	NA	**1.4**	--
RRM 11.3 to 12.5	42.9	16.9	16.9	18.90	NA	< 1	--	0.44	0.13	0.13	0.10	NA	**1.2**	--
RRM 12.5 to 13.5	40.1	17.2	17.2	18.90	NA	< 1	--	0.26	0.11	0.11	0.10	NA	< 1	--
RRM 13.5 to 16.7	18.4	13.5	13.5	18.90	NA	< 1	--	0.21	0.08	0.08	0.10	NA	< 1	--
RRM 16.7 to 20.9	15.4	11.1	11.1	18.90	NA	< 1	--	0.19	0.11	0.11	0.10	NA	**1.1**	--
RRM 20.9 to 24.0	26.0	10.6	10.6	18.90	NA	< 1	--	0.19	0.08	0.08	0.10	NA	< 1	--
SFSR	2.47	1.59	1.59	18.90	NA	< 1	--	0.05	0.02	0.02	0.10	NA	< 1	--

Notes:

RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg dw, milligram per kilogram dry weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NC, Not calculated due to insufficient number of samples.
NA, Not available.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, NOECs based on SQT investigations; LOECs not identified (See section 4.1.3).

Table 6-4
Sediment Quality Triad (SQT) Investigation - Summary of SQT Lines of Evidence
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SQT Site Sampling Location	Bulk Chemistry			Sediment Toxicity Testing				Benthic Community Structure Metric Analyses								
				Chironomus		*Hyalella*										
	Mercury (µg/g dry weight)	Other Metals	Heptachlor	10-day Survival	10-day Growth	10-day Survival	10-day Growth	Taxa Richness	EPT Richness*	% EPT	% Ephemeroptera	% Trichoptera	% Diptera	% Dominant Taxon	Shannon's Diversity (H')	Pielou's Evenness (J')
RRM 0.1	+ (0.943)	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
RRM 3.5	+ (18.9)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
RRM 11.8	+ (16.7)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
RRM 23.5	+ (12.5)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Key:	+	–
Sediment Chemistry	Site sampling location concentration > reference concentrations and ecological benchmark	Site sampling location concentration < reference concentrations and ecological benchmark
Sediment Toxicity Testing	Endpoint significantly lower than pooled reference replicates	Endpoint not significantly lower than pooled reference replicates
Benthic Community Structure	Metric significantly different than pooled reference replicates	Metric not significantly different than pooled reference replicates

Notes:
* One-way analysis of variance (ANOVA) indicated significant differences (p=0.034) between reference and site sampling locations; however, Tukey HSD multi-comparison testing did not detect statistically significant pairwise comparisons.
RRM, Relative river mile.
Data were collected in May 2010. See Ecological Study Data Matrix [Table 1-3 in Ecological Study Report (URS, 2012)] for more information regarding study details.
[Source: Table 6-6 in Ecological Study Report (URS, 2012)].

Table 6-5
Risk Estimates for Benthic/Aquatic Invertebrates Based on Tissue Mercury Concentrations
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Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (mg/kg ww)			THg Benchmarks[b] (mg/kg ww)		Hazard Quotient (HQ)		MeHg Concentrations (mg/kg ww)			MeHg Benchmarks[c] (mg/kg ww)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}
Larval Aquatic Invertebrates														
MR Middle[a]	0.03	0.03	0.03	1.53	2.33	< 1	< 1	0.02	0.02	0.02	0.037	NA	< 1	--
NR Upper[a]	0.02	0.01	0.01	1.53	2.33	< 1	< 1	0.02	0.01	0.01	0.037	NA	< 1	--
RRM -2.7 to -0.7[a]	0.03	0.02	0.02	1.53	2.33	< 1	< 1	0.03	0.01	0.01	0.037	NA	< 1	--
RRM 0.0 to 0.8	1.10	0.38	0.38	1.53	2.33	< 1	< 1	0.30	0.18	0.18	0.037	NA	**4.9**	--
RRM 0.8 to 1.7	1.08	0.22	0.22	1.53	2.33	< 1	< 1	0.24	0.16	0.16	0.037	NA	**4.4**	--
RRM 1.7 to 2.7	2.72	0.57	0.57	1.53	2.33	< 1	< 1	0.24	0.07	0.07	0.037	NA	**1.8**	--
RRM 2.7 to 4.4	5.79	1.49	1.49	1.53	2.33	< 1	< 1	0.59	0.16	0.16	0.037	NA	**4.3**	--
RRM 5.2 to 7.9	2.19	0.86	0.86	1.53	2.33	< 1	< 1	0.44	0.19	0.19	0.037	NA	**5.1**	--
RRM 7.9 to 9.2	4.40	0.55	0.55	1.53	2.33	< 1	< 1	1.24	0.21	0.21	0.037	NA	**5.6**	--
RRM 9.2 to 11.3	23.6	0.82	0.82	1.53	2.33	< 1	< 1	3.18	0.22	0.22	0.037	NA	**6.0**	--
RRM 11.3 to 12.5	2.26	0.65	0.65	1.53	2.33	< 1	< 1	0.93	0.42	0.42	0.037	NA	**11**	--
RRM 12.5 to 13.5	12.00	5.53	5.53	1.53	2.33	**3.6**	**2.4**	8.88	4.04	4.04	0.037	NA	**109**	--
RRM 13.5 to 16.7	0.71	0.40	0.40	1.53	2.33	< 1	< 1	0.55	0.27	0.27	0.037	NA	**7.2**	--
RRM 16.7 to 20.9	0.63	0.40	0.40	1.53	2.33	< 1	< 1	0.45	0.33	0.33	0.037	NA	**9.0**	--
RRM 20.9 to 24.0	0.63	0.45	0.45	1.53	2.33	< 1	< 1	0.54	0.22	0.22	0.037	NA	**5.9**	--
SFSR	0.23	0.08	0.08	1.53	2.33	< 1	< 1	0.13	0.06	0.06	0.037	NA	**1.6**	--
Emergent (Adult) Aquatic Invertebrates														
RRM 1.7 to 2.7	0.47	0.32	0.32	1.53	2.33	< 1	< 1	0.08	0.06	0.06	0.037	NA	**1.6**	--
RRM 2.7 to 4.4	3.47	2.02	2.02	1.53	2.33	**1.3**	< 1	1.19	0.73	0.73	0.037	NA	**20**	--
RRM 7.9 to 9.2	5.09	2.66	2.66	1.53	2.33	**1.7**	**1.1**	3.18	1.85	1.85	0.037	NA	**50**	--
RRM 11.3 to 12.5	1.17	0.67	0.67	1.53	2.33	< 1	< 1	0.82	0.64	0.64	0.037	NA	**17**	--
RRM 16.7 to 20.9	1.58	1.32	1.32	1.53	2.33	< 1	< 1	0.58	0.31	0.31	0.037	NA	**8.4**	--
RRM 20.9 to 24.0	0.64	0.40	0.40	1.53	2.33	< 1	< 1	0.42	0.23	0.23	0.037	NA	**6.3**	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg ww, milligram per kilogram wet weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
CBR_{NOEC}, No effects critical body residue.
CBR_{LOEC}, Lowest effect critical body residue.
NC, Not calculated due to insufficient number of samples.
NA, Not available.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Reference Reaches: Middle Middle River (MR Middle), Upper North River (NR Upper), and Upstream Reference Reach (RRM -2.7- -0.7).
b, Based on the lowest bounded endpoints for daphnid (Besinger et al., 1982) (See section 4.1.3).
c, CBR_{NOEC} based on growth of hexagenid mayfly nymphs (Namio et al., 2000) CBR_{LOEC} not identified (See section 4.1.3).

Table 6-6
Risk Estimates for Crayfish Based on Tissue Mercury Concentrations
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Assessment Reach	THg Concentrations (mg/kg ww)			THg Benchmarks[b] (mg/kg ww)		Hazard Quotient (HQ)		MeHg Concentrations (mg/kg ww)			MeHg Benchmarks[c] (mg/kg ww)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}
MR Lower[a]	0.025	NC	0.025	1.53	2.33	< 1	< 1	0.025	NC	0.025	0.037	NA	< 1	--
MR Middle[a]	0.023	0.022	0.022	1.53	2.33	< 1	< 1	0.020	0.019	0.019	0.037	NA	< 1	--
NR Upper[a]	0.674	0.104	0.104	1.53	2.33	< 1	< 1	0.056	0.012	0.012	0.037	NA	< 1	--
RRM -2.7 to -0.7[a]	0.023	0.016	0.016	1.53	2.33	< 1	< 1	0.017	0.013	0.013	0.037	NA	< 1	--
RRM 0.0 to 0.8	0.484	0.186	0.186	1.53	2.33	< 1	< 1	0.105	0.068	0.068	0.037	NA	**1.8**	--
RRM 0.8 to 1.7	0.226	0.159	0.159	1.53	2.33	< 1	< 1	0.095	0.104	0.095	0.037	NA	**2.6**	--
RRM 1.7 to 2.7	0.543	0.245	0.245	1.53	2.33	< 1	< 1	0.332	0.166	0.166	0.037	NA	**4.5**	--
RRM 2.7 to 4.4	1.129	0.529	0.529	1.53	2.33	< 1	< 1	0.619	0.351	0.351	0.037	NA	**9.5**	--
RRM 4.4 to 5.2	NA	--	--	1.53	2.33	--	--	NA	--	--	0.037	NA	**--**	--
RRM 5.2 to 7.9	1.050	0.523	0.523	1.53	2.33	< 1	< 1	0.582	0.367	0.367	0.037	NA	**9.9**	--
RRM 7.9 to 9.2	0.670	0.565	0.565	1.53	2.33	< 1	< 1	0.566	0.424	0.424	0.037	NA	**11**	--
RRM 9.2 to 11.3	0.713	0.561	0.561	1.53	2.33	< 1	< 1	0.269	0.280	0.269	0.037	NA	**7.3**	--
RRM 11.3 to 12.5	0.636	0.502	0.502	1.53	2.33	< 1	< 1	0.543	0.433	0.433	0.037	NA	**12**	--
RRM 12.5 to 13.5	0.856	0.622	0.622	1.53	2.33	< 1	< 1	0.655	0.464	0.464	0.037	NA	**13**	--
RRM 13.5 to 16.7	0.851	0.606	0.606	1.53	2.33	< 1	< 1	0.953	0.555	0.555	0.037	NA	**15**	--
RRM 16.7 to 20.9	0.742	0.505	0.505	1.53	2.33	< 1	< 1	0.708	0.480	0.480	0.037	NA	**13**	--
RRM 20.9 to 24.0	0.665	0.516	0.516	1.53	2.33	< 1	< 1	0.597	0.433	0.433	0.037	NA	**12**	--
SFSR	0.391	0.201	0.201	1.53	2.33	< 1	< 1	0.289	0.137	0.137	0.037	NA	**3.7**	--

Notes:

RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methlymercury.
mg/kg ww, milligram per kilogram wet weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
CBR, critical body residue.
CBR_{NOEC}, No effects critical body residue.
CBR_{LOEC}, Lowest effect critical body residue.
NC, Not calculated due too insufficient number of samples.
NA, Not available.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Reference Reaches: Lower Middle River (MR Lower), Middle Middle River (MR Middle), Upper North River (NR Upper), and Upstream Reference Reach (RRM -2.7- -0.7).
b, Based on the lowest bounded endpoints for daphnid (Besinger et al., 1982) (See section 4.3.1).
c, CBR_{NOEC} based on growth of hexagenid mayfly nymphs (Namio et al., 2000) CBR_{LOEC} not identified (See section 4.1.3).

Table 6-7
Weight of Evidence (WOE) Evaluation for Benthic/Aquatic Invertebrates
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Assessment Reach	Measurement Endpoints (MEs)										
	Chemistry			Sediment Toxicity[d]	Benthic Community Assessment[e]	Tissue Chemistry (Whole Body)					
	Sediment[a]	Porewater[b]	Surfacewater[c]			LI - THg[f]	LI - MeHg[f]	EI - THg[f]	EI - MeHg[f]	Crayfish - THg[g]	Crayfish - MeHg[g]
RRM 0.0 to 0.8	No Low 3	No Low 4	No Low 3	No Low 3	No Low 4	No Low 4	Un High 4	--	--	No Low 4	Un Low 4
RRM 0.8 to 1.7	No Low 3	--	No Low 3	--	--	No Low 4	Un High 4	--	--	No Low 4	Un Medium 4
RRM 1.7 to 2.7	Un Medium 3	No Low 4	No Low 3	--	--	No Low 4	Un Low 4	No Low 4	Un Low 4	No Low 4	Un High 4
RRM 2.7 to 4.4	Un Medium 3	No Low 4	No Low 3	--	--	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4
RRM 4.4 to 5.2	Un High 3	--	No Low 3	No Low 3	No Low 4	--	--	--	--	--	--
RRM 5.2 to 7.9	Un Low 3	No Low 4	No Low 3	--	--	No Low 4	Un High 4	--	--	No Low 4	Un High 4
RRM 7.9 to 9.2	Un High 3	No Low 4	No Low 3	--	--	No Low 4	Un High 4	Yes Medium 4	Un High 4	No Low 4	Un High 4
RRM 9.2 to 11.3	Un Low 3	No Low 4	Yes Low 3	--	--	No Low 4	Un High 4		--	No Low 4	Un High 4
RRM 11.3 to 12.5	Un Medium 3	No Low 4	No Low 3	No Low 3	No Low 4	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4
RRM 12.5 to 13.5	No Low 3	--	No Low 3	--	--	Yes High 4	Un High 4	--	--	No Low 4	Un High 4
RRM 13.5 to 16.7	No Low 3	--	No Low 3	--	--	No Low 4	Un High 4	--	--	No Low 4	Un High 4
RRM 16.7 to 20.9	Un Low 3	--	No Low 3	--	--	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4
RRM 20.9 to 24.0	No Low 3	No Low 4	No Low 3	No Low 3	No Low 4	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4
SFSR	No Low 3	--	No Low 3	--	--	No Low 4	Un Low 4	--	--	No Low 4	Un Medium 4

Notes:
--, Not evaluated.
WOE Evaluation Elements (See Appendix G):
Presence of Potential Adverse Effects (Yes, Undetermined, No).
Potential for Effects (Low, Medium, High).
Relative Weight of ME (1, 2, 3, 4, 5).
Un, Undetermined presence/absence of potential adverse effects (because $HQ_{NOEC} > 1$ but $HQ_{LOEC} < 1$).
a, Conservatively based on the results in Table 6-3.
b, Based on results in Table 6-2.
c, Conservatively based on the results for methylmercury (MeHg) on Tables 6-1a and 6-1b.
d, Based on sediment toxicity test evaluations in Table 6-4.
e, Based on Benthic Community Structure Metric Analyses results in Table 6-4.
f, Based on the results in Table 6-5; Tissue residues of total mercury (THg) and MeHg in larval (LI) and emergent invertebrates (EI);
MeHg - LI results are undetermined because low-effect based Hazard Quotient (HQ) is not available.
g, Based on the results in Table 6-6; Tissue residues of THg and MeHg in crayfish.

Table 6-8a
Risk Estimates for Fish - Direct Contact to Surface Water Mercury under Baseline Flow Conditions
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Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks[c] (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks[d] (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	12.9	1.9	1.9	770	NA	< 1	--	0.76	0.16	0.16	290	NA	< 1	--
RRM -0.7 to 0.0[b]	32.2	8.7	8.7	770	NA	< 1	--	0.03	0.03	0.03	290	NA	< 1	--
RRM 0.0 to 0.8	66.1	3.2	3.2	770	NA	< 1	--	0.60	0.09	0.09	290	NA	< 1	--
RRM 0.8 to 1.7	87.7	8.4	8.4	770	NA	< 1	--	0.48	0.17	0.17	290	NA	< 1	--
RRM 1.7 to 2.7	296.0	8.1	8.1	770	NA	< 1	--	62.36	2.04	2.04	290	NA	< 1	--
RRM 2.7 to 4.4	126.0	9.9	9.9	770	NA	< 1	--	2.30	0.60	0.60	290	NA	< 1	--
RRM 4.4 to 5.2	27.1	3.9	3.9	770	NA	< 1	--	0.44	0.37	0.37	290	NA	< 1	--
RRM 5.2 to 7.9	43.4	9.1	9.1	770	NA	< 1	--	5.94	0.77	0.77	290	NA	< 1	--
RRM 7.9 to 9.2	27.0	12.1	12.1	770	NA	< 1	--	2.77	1.04	1.04	290	NA	< 1	--
RRM 9.2 to 11.3	129.0	15.8	15.8	770	NA	< 1	--	48.20	5.45	5.45	290	NA	< 1	--
RRM 11.3 to 12.5	61.4	13.1	13.1	770	NA	< 1	--	3.05	1.32	1.32	290	NA	< 1	--
RRM 12.5 to 13.5	20.8	14.5	14.5	770	NA	< 1	--	2.90	1.93	1.93	290	NA	< 1	--
RRM 13.5 to 16.7	67.5	7.9	7.9	770	NA	< 1	--	2.61	1.13	1.13	290	NA	< 1	--
RRM 16.7 to 20.9	32.7	10.5	10.5	770	NA	< 1	--	3.06	1.33	1.33	290	NA	< 1	--
RRM 20.9 to 24.0	87.0	6.3	6.3	770	NA	< 1	--	5.31	1.01	1.01	290	NA	< 1	--
SFSR	5.6	2.2	2.2	770	NA	< 1	--	0.74	0.31	0.31	290	NA	< 1	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methymercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NA, Not available.
--, Not applicable.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC
HQ_{LOEC} = EPC/LOEC
a, Upstream Reference Reach.
b, Buffer Reach.
c, National Recommended Ambient Water Quality Criteria (NRWQC) (EPA 2014)/Virginia State Water Quality Criteria (VASWQC) of 770 ng/L (filtered) represents a conservative benchmark for fish exposure at various life stages (see section 4.5.3).
d, Lowest chronic toxicity value observed in a multi-generational exposure for brook trout (McKim et al. 1976) (See section 4.5.3).

Table 6-8b
Risk Estimates for Fish - Direct Contact to Surface Water Mercury under Storm Flow Conditions
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Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks[c] (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks[d] (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	2.7	1.1	1.1	770	NA	< 1	--	0.06	0.04	0.04	290	NA	< 1	--
RRM -0.7 to 0.0[b]	6.7	NC	6.7	770	NA	< 1	--	0.10	NC	0.10	290	NA	< 1	--
RRM 0.0 to 0.8	17.3	4.1	4.1	770	NA	< 1	--	0.20	0.06	0.06	290	NA	< 1	--
RRM 0.8 to 1.7	3.4	NC	3.4	770	NA	< 1	--	NA	--	--	290	NA	--	--
RRM 1.7 to 2.7	10.7	4.6	4.6	770	NA	< 1	--	0.36	0.13	0.13	290	NA	< 1	--
RRM 2.7 to 4.4	NA	--	--	770	NA	--	--	NA	--	--	290	NA	--	--
RRM 4.4 to 5.2	8.0	7.4	7.4	770	NA	< 1	--	0.06	NC	0.06	290	NA	< 1	--
RRM 5.2 to 7.9	33.8	9.0	9.0	770	NA	< 1	--	0.90	0.43	0.43	290	NA	< 1	--
RRM 7.9 to 9.2	NA	--	--	770	NA	--	--	NA	--	--	290	NA	--	--
RRM 9.2 to 11.3	412.0	82.8	82.8	770	NA	< 1	--	2.15	0.67	0.67	290	NA	< 1	--
RRM 11.3 to 12.5	8.4	NC	8.4	770	NA	< 1	--	NA	--	--	290	NA	--	--
RRM 12.5 to 13.5	NA	--	--	770	NA	--	--	NA	--	--	290	NA	--	--
RRM 13.5 to 16.7	75.4	16.6	16.6	770	NA	< 1	--	1.58	0.71	0.71	290	NA	< 1	--
RRM 16.7 to 20.9	19.6	9.0	9.0	770	NA	< 1	--	1.24	0.75	0.75	290	NA	< 1	--
RRM 20.9 to 24.0	17.7	10.0	10.0	770	NA	< 1	--	1.78	1.01	1.01	290	NA	< 1	--
SFSR	2.6	NC	2.6	770	NA	< 1	--	NA	--	--	290	NA	--	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
NC, Not calculated due to insufficient number of samples.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, National Recommended Ambient Water Quality Criteria (NRWQC) (EPA 2014)/Virginia State Water Quality Criteria (VASWQC) of 770 ng/L (filtered) represents a conservative benchmark for fish exposure at various life stages (See section 4.5.3).
d, Lowest chronic toxicity value observed in a multi-generational exposure for brook trout (McKim et al. 1976) (See section 4.5.3).

Table 6-9
Risk Estimates for Fish Based on Tissue Mercury Concentrations
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations			THg Benchmarks		Hazard Quotient		MeHg Concentrations			MeHg Benchmarks[d]		Hazard Quotient	
	Maximum	95% UCL	EPC	CBR_{NOEC}[b]	CBR_{LOEC}[c]	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}
Bass Species (TL ≤ 130 mm)														
RRM 0.0 to 0.8	0.09	NC	0.09	0.21	0.44	< 1	< 1	0.08	NC	0.08	0.21	0.44	< 1	< 1
RRM 2.7 to 4.4	1.33	NC	1.33	0.21	0.44	**6.3**	**3.0**	1.20	NC	1.20	0.21	0.44	**5.7**	**2.7**
RRM 9.2 to 11.3	1.72	1.54	1.54	0.21	0.44	**7.3**	**3.5**	1.44	1.37	1.37	0.21	0.44	**6.5**	**3.1**
RRM 11.3 to 12.5	1.40	NC	1.40	0.21	0.44	**6.7**	**3.2**	1.26	NC	1.26	0.21	0.44	**6.0**	**2.9**
RRM 16.7 to 20.9	1.15	NC	1.15	0.21	0.44	**5.5**	**2.6**	1.11	NC	1.11	0.21	0.44	**5.3**	**2.5**
SFSR	0.21	NC	0.21	0.21	0.44	< 1	< 1	0.19	NC	0.19	0.21	0.44	< 1	< 1
Bass Species (TL > 130 mm)														
RRM -2.7 to -0.7[a]	1.81	0.41	0.41	0.21	0.44	**1.9**	**< 1**	1.74	0.39	0.39	0.21	0.44	**1.9**	**< 1**
RRM 0.0 to 0.8	2.25	0.57	0.57	0.21	0.44	**2.7**	**1.3**	2.16	0.55	0.55	0.21	0.44	**2.6**	**1.3**
RRM 0.8 to 1.7	2.17	0.88	0.88	0.21	0.44	**4.2**	**2.0**	2.08	0.84	0.84	0.21	0.44	**4.0**	**1.9**
RRM 1.7 to 2.7	4.49	1.43	1.43	0.21	0.44	**6.8**	**3.2**	4.28	1.36	1.36	0.21	0.44	**6.5**	**3.1**
RRM 2.7 to 4.4	4.32	1.33	1.33	0.21	0.44	**6.4**	**3.0**	4.15	1.28	1.28	0.21	0.44	**6.1**	**2.9**
RRM 4.4 to 5.2	3.02	2.04	2.04	0.21	0.44	**9.7**	**4.6**	2.90	1.95	1.95	0.21	0.44	**9.3**	**4.4**
RRM 5.2 to 7.9	4.99	2.69	2.69	0.21	0.44	**13**	**6.1**	4.80	2.54	2.54	0.21	0.44	**12**	**5.8**
RRM 9.2 to 11.3	3.23	2.20	2.20	0.21	0.44	**10**	**5.0**	3.10	2.10	2.10	0.21	0.44	**10**	**4.8**
RRM 11.3 to 12.5	3.59	1.66	1.66	0.21	0.44	**7.9**	**3.8**	3.50	1.59	1.59	0.21	0.44	**7.6**	**3.6**
RRM 13.5 to 16.7	2.81	2.14	2.14	0.21	0.44	**10**	**4.9**	2.69	2.06	2.06	0.21	0.44	**9.8**	**4.7**
RRM 16.7 to 20.9	2.36	1.62	1.62	0.21	0.44	**7.7**	**3.7**	2.26	1.55	1.55	0.21	0.44	**7.4**	**3.5**
RRM 20.9 to 24.0	3.55	1.47	1.47	0.21	0.44	**7.0**	**3.3**	3.41	1.41	1.41	0.21	0.44	**6.7**	**3.2**
SFSR	2.28	0.79	0.79	0.21	0.44	**3.8**	**1.8**	1.88	0.76	0.76	0.21	0.44	**3.6**	**1.7**

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
CBR_{NOEC}, No effects critical body residue.
CBR_{LOEC}, Lowest effect critical body residue.
NC, Not calculated due to insufficient number of samples.
HQ, Hazard quotient.
$HQ_{NOEC} = EPC/CBR_{NOEC}$.
$HQ_{LOEC} = EPC/CBR_{LOEC}$.
a, Upstream Reference Reach (RRM -2.7- -0.7).
b, Based on Beckvar et al. (2005) (See section 4.5.3).
c, Derived from data compiled by Beckvar et al. (2005) (See section 4.5.3).
d, Values for MeHg are equivalent to THg based on assumption that nearly all mercury in fish is methylated (See section 4.5.3).

Table 6-10
Historical Fish Taxa Identified in the South River
AOC 4 Ecological Risks Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Sampling Area Description						Sample Numbers			
ERA Assessment Reach	Sampling Location	Assessment River Segment	End RRM	Total RRM	VDEQ Stations	Bass	Sunfish	Sucker	Total Number of Fish
--	SRB	--	-0.6	--	2	81	136	145	362
RRM 0.8 to 1.7	SR1	USR	1	1	1	78	120	142	340
RRM 2.7 to 4.4	SR2		3	2	2	73	50	61	184
RRM 5.2 to 7.9	SR3		6	3	1	79	169	118	366
RRM 12.5 to 13.5	SR4	LSR	13	7	3	93	499	149	741
RRM 20.9 to 24.0	SR5		24	11	3	104	146	129	379

Notes:
USR, Upper South River; LSR, Lower South River; SR, South River; RRM, Relative river mile.
Sample total numbers include VADEQ fillet database from 1981-2007 and South River Science Team Study data of individual whole body bass, sunfish, and sucker.

Table 6-11
Assessment River Segments for Fish Age, Growth, and Condition Evaluations
AOC 4 Ecological Risks Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Evaluation Approach	Representative Species (Trophic Group)	Statistically Significant Differences in Assessment River Segments Relative to Reference Sampling Locations		
		Age/Size Class	USR	LSR
Statistical comparison of age and growth data in Assessment River Segments relative to Reference Sampling Location NR (R)	Smallmouth bass (piscivore)	Age 1		
		Age 2		
		Age 3		
		Age 4		
		Age 5		
		Age 6		
		Age 7		
		Age 8		
	Redbreast sunfish (invertivore)	Age 1		
		Age 2	---	-
		Age 3	---	
		Age 4	---	
		Age 5	-	
Statistical comparison of fish condition metrics (W_r or K_{TL}) in Assessment River Segments relative to Reference Sampling Locations: SR (R) compared to USR and LSR	Smallmouth bass (piscivore)	150 mm to >430 mm		
	Redbreast sunfish (invertivore)	50 mm to 250 mm		
	White sucker (omnivore)	100 mm to >500 mm	SR (R): +++	SR (R): +++

Notes:
Shaded cells indicate no significant difference from Reference Sampling Location(s).
USR, Upper South River Assessment River Segment, containing:
(ERA Assessment Reaches: RRM 0.8- 1.7, RRM 2.7- 4.4, RRM 5.2- 7.9),
(Sampling Locations: SR1, SR2, SR3).
LSR, Lower South River Assessment River Segment, containing:
(ERA Assessment Reaches: RRM 12.5- 13.5, RRM 20.9- 24.0),
(Sampling Locations: SR4, SR5).
SR (R), South River Reference Sampling Location.
NR (R), North River Reference Sampling Location.

Statistical significance of Assessment River Segment relative to Reference Sampling Location:

Alpha (α)	Lower than Reference	Greater than Reference
< 0.05	-	+
< 0.01	--	++
<0.001	---	+++

Table 6-12a
Fish Species Abundance - Spring, 2010[a]
AOC 4 Ecological Risks Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Common Name	Genus / Species	Sampling Locations					
		Study Area (AOC 4)				Reference	
		RRM 0.1	RRM 3.5	RRM 11.8	RRM 23.5	SR-01	MR-01
Anguillidae							
American eel	*Anguilla rostrata*	1		2			
Catostomidae							
White sucker	*Catostomus commersoni*	254	47	91	36	112	26
Northern hog sucker	*Hypentelium nigricans*	109	65	37	19	19	32
Torrent sucker	*Thoburnia rhothoeca*	137	86	9		79	
Cypirinidae							
Central stoneroller	*Campostoma anomalum*	23	5	2		35	
Rosyside dace	*Clinostomus funduloides*	5				2	
Satinfin shiner	*Cyprinella analostana*		2	21	27		38
Common carp	*Cyprinus carpio*	12		20	17		
Cutlips minnow	*Exoglossum maxillingua*	8	7			69	1
Common shiner	*Luxilus cornutus*	561	502	430	49	211	90
Rosefin shiner	*Lythrurus ardens*					1	
Bluehead chub	*Nocomis leptocephalus*	61	288	57	32	29	170
River chub	*Nocomis micropogon*				36		8
Bull chub	*Nocomis raneyi*			58			1
Golden shiner	*Notemigonus crysoleucas*		1				
Spottail shiner	*Notropis hudsonius*	158	44	175	12	47	198
Rosyface shiner	*Notropis rubellus*	13	83	88	6	24	129
Mountain redbelly dace	*Phoxinus oreas*						
Bluntnose minnow	*Pimephales notatus*	35	20	68	24	64	98
Fathead minnow	*Pimephales promelas*	23				7	
Blacknose dace	*Rhinichthys atratulus*	44	18		2	75	
Longnose dace	*Rhinichthys cataractae*	28	69	8	26	48	2
Fallfish	*Semotilus corporalis*	143	108	139	15	259	
Ictaluridae							
Yellow bullhead	*Ameiurus natalis*	10	13	15	8	2	7
Channel catfish	*Ictalurus punctatus*				1		
Margined madtom	*Noturus insignis*			25	15		28
Fundulidae							
Banded killifish	*Fundulus diaphanus*		1				
Centrarchidae							
Rock bass	*Ambloplites rupestris*	142	44	10	5	84	17
Redbreast sunfish	*Lepomis auritus*	24	47	89	19	5	96
Green sunfish	*Lepomis cyanellus*	13	2	6	1	7	25
Pumpkinseed	*Lepomis gibbosus*	1					
Bluegill	*Lepomis macrochirus*	7		3	4	2	
Redear sunfish	*Lepomis microlophus*						
Hybrid sunfish	*Lepomis sp.*			1			
Smallmouth bass	*Micropterus dolomieu*	43	9	68	41	0	68
Largemouth bass	*Micropterus salmoides*	23	5	8	6	1	
Black crappie	*Pomoxis nigromaculatus*			1			
Cottidae							
Mottled sculpin	*Cottus bairdi*	189	135	1	24	204	
Potomac sculpin	*Cottus girardi*		21		1		
Percidae							
Fantail Darter	*Etheostoma flabellare*	41					
	Total Abundance	1820	1535	1321	381	1237	1034
	Taxa Richness	27	24	26	24	24	18

Notes:
See Ecological Study Data Matrix [Table 1-3 in Ecological Study Report (URS, 2012)] for more information regarding study details.
RRM, Relative river mile.
a, Source: Table 5-19 in Ecological Study Report (URS, 2012).

Table 6-12b
Fish Species Abundance - Summer, 2010[a]
AOC 4 Ecological Risks Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Common Name	Genus / Species	Sampling Locations					
		Study Area (AOC 4)				Reference	
		RRM 0.1	RRM 3.5	RRM 11.8	RRM 23.5	SR-01	MR-01
Anguillidae							
American eel	*Anguilla rostrata*	1		1	2		
Catostomidae							
White sucker	*Catostomus commersoni*	636	112	101	53	189	109
Northern hog sucker	*Hypentelium nigricans*	173	105	77	72	40	198
Torrent sucker	*Thoburnia rhothoeca*	123	30	7		179	
Cypirinidae							
Central stoneroller	*Campostoma anomalum*	100	171		3	33	
Rosyside dace	*Clinostomus funduloides*	1					
Satinfin shiner	*Cyprinella analostana*	15	4	76	8		107
Common carp	*Cyprinus carpio*			7			
Cutlips minnow	*Exoglossum maxillingua*	26	5			128	17
Common shiner	*Luxilus cornutus*	1106	347	103	49	343	254
Rosefin shiner	*Lythrurus ardens*						
Bluehead chub	*Nocomis leptocephalus*	133	369	211	52	36	302
River chub	*Nocomis micropogon*		97	11	17		156
Bull chub	*Nocomis raneyi*						
Golden shiner	*Notemigonus crysoleucas*	2					
Spottail shiner	*Notropis hudsonius*	61	101	113	4	185	564
Rosyface shiner	*Notropis rubellus*	73	69	10	120	156	189
Mountain redbelly dace	*Phoxinus oreas*	49					
Bluntnose minnow	*Pimephales notatus*	202	66	52	7	183	362
Fathead minnow	*Pimephales promelas*	57				3	
Blacknose dace	*Rhinichthys atratulus*	92	11			249	
Longnose dace	*Rhinichthys cataractae*	479	158	18	22	500	20
Fallfish	*Semotilus corporalis*	910	303	92	26	292	
Ictaluridae							
Yellow bullhead	*Ameiurus natalis*	12	13	53	19		62
Channel catfish	*Ictalurus punctatus*						
Margined madtom	*Noturus insignis*	2	3	17	25		106
Centrarchidae							
Rock bass	*Ambloplites rupestris*	227	25	19	8	106	27
Redbreast sunfish	*Lepomis auritus*	34	25	61	79	1	217
Green sunfish	*Lepomis cyanellus*	27	5	15	8	5	15
Pumpkinseed	*Lepomis gibbosus*	3		1			
Bluegill	*Lepomis macrochirus*	92	1	8	1	1	
Redear sunfish	*Lepomis microlophus*	1					
Hybrid Sunfish	*Lepomis sp.*				1		
Smallmouth bass	*Micropterus dolomieu*	98	22	140	128	9	135
Largemouth bass	*Micropterus salmoides*	23	10	54	15	3	
Black crappie	*Pomoxis nigromaculatus*						
Cottidae							
Mottled sculpin	*Cottus bairdi*	1277	422	3	53	1249	
Potomac sculpin	*Cottus girardi*	1	20	5		25	
Percidae							
Fantail Darter	*Etheostoma flabellare*	219				31	
Tessellated darter	*Etheostoma olmstedi*		2	1			1
	Total Abundance	6255	2496	1256	772	3946	2841
	Taxa Richness	32	26	26	23	23	18

Notes:
See Ecological Study Data Matrix [Table 1-3 in Ecological Study Report (URS, 2012)] for more information regarding study details.
RRM, Relative river mile.
a, Source: Table 5-20 in Ecological Study Report (URS, 2012).

Table 6-13a
Fish Population Estimates[a]
AOC 4 Ecological Risks Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Season	River	Sampling Location	Species	Total Catch	Population Estimate[b]	Adjusted 95% Confidence Interval	pa[c]	CPUE[d]	f/ha
Spring	South River	SR-01	All fish	1391	1484	1453 - 1515	0.60	1551	7052
		RRM 0.1		2108	2607	2490 - 2724	0.42	1012	3789
		RRM 3.5		1622	1719	1688 - 1750	0.62	1070	4617
		RRM 11.8		1432	1470	1454 - 1486	0.70	832	2454
		RRM 23.5		426	492	457 - 527	0.49	381	988
	Middle River	MR-01		1034	1068	1052 - 1084	0.68	726	1955
Summer	South River	SR-01	All fish	3946	4235	4179 - 4291	0.59	1553	20125
		RRM 0.1		6255	8382	8083 - 8681	0.37	1816	12184
		RRM 3.5		2496	2525	2512 - 2538	0.77	1166	6782
		RRM 11.8		1256	1351	1318 - 1384	0.59	476	2256
		RRM 23.5		772	904	852 - 956	0.47	279	1816
	Middle River	MR-01		2841	3095	3039 - 3151	0.56	1069	5665

Notes:
f/ha, Fish per hectare.
RRM, Relative river mile.
Data were collected in May and September 2010. See Ecological Study Data Matrix [Table 1-3 in Ecological Study Report (URS, 2012)] for more information regarding study details.
a, Source: Table 5-21 in Ecological Study Report (URS, 2012).
b, Population estimate calculated using Microfish 3.0-based on the Burnham maximum likelihood estimation theory.
c, Probability of capture.
d, Catch Per Unit Effort (CPUE) based on fish caught during the first pass.

Table 6-13b

Smallmouth Bass Population Estimates[a]

AOC 4 Ecological Risks Assessment Report

Former DuPont Waynesboro Plant, Waynesboro, Virginia

	River	Sampling Location	Total Catch	Population Estimate[b]	Adjusted 95% Confidence Interval	pa[c]	CPUE[d]	f/ha	kg/ha
Spring	South River	RRM 0.1	43	50	43 - 62	0.47	19	73	7.9
		RRM 3.5	9	9	9 - 9	1.00	9	24	2.0
		RRM 11.8	68	73	68 - 81	0.58	33	122	6.9
		RRM 23.5	41	49	41 - 63	0.45	32	98	9.0
		SR-01	0	0	0	0.00	0	0	0.0
	Middle River	MR-01	68	72	68 - 79	0.61	39	132	5.6
	River	Sampling Location	Total Catch	Population Estimate[b]	Adjusted 95% Confidence Interval	pa[c]	CPUE[d]	f/ha	kg/ha
Summer	South River	RRM 0.1	98	114	98 - 132	0.48	35	166	11.0
		RRM 3.5	22	29	22 - 47	0.37	22	78	6.9
		RRM 11.8	140	150	140 - 161	0.59	73	250	19.7
		RRM 23.5	127	174	128 - 220	0.36	87	350	19.9
		SR-01	9	9	9 - 11	0.64	7	43	2.5
	Middle River	MR-01	135	145	135 - 156	0.58	71	265	12.2

Notes:

f/ha, Fish per hectare.

kg/ha, Kilogram per hectare.

RRM, Relative river mile.

Data were collected in May and September 2010. See Ecological Study Data Matrix [Table 1-3 in Ecological Study Report (URS, 2012)] for more information regarding study details.

a, Source: Table 5-21 in Ecological Study Report (URS, 2012).

b, Population estimate calculated using Microfish 3.0-based on the Burnham maximum likelihood estimation theory.

c, Probability of capture.

d, Catch Per Unit Effort (CPUE) based on fish caught during the first pass.

Table 6-14
Weight of Evidence (WOE) Evaluation for Fish
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach						
	Surfacewater[a]	Age/Growth[b]	Condition[b]	[c]	Tissue Chemistry	
RRM 0.0 to 0.8	No Low	--	--	No Low	No Low	Yes Low
RRM 0.8 to 1.7	No Low	No Low	No Low	--	--	Yes Low
RRM 1.7 to 2.7	No Low	--	--	--	--	Yes High
RRM 2.7 to 4.4	No Low	No Low	No Low	No Low	Yes High	Yes High
RRM 4.4 to 5.2	No Low	--	--	--	--	Yes High
RRM 5.2 to 7.9	No Low	No Low	No Low	--	--	Yes High
RRM 7.9 to 9.2	No Low	--	--	--	--	--
RRM 9.2 to 11.3	No Low	--	--	--	Yes High	Yes High
RRM 11.3 to 12.5	No Low	--	--	No Low	Yes High	Yes High
RRM 12.5 to 13.5	No Low	No Low	No Low	--	--	--
RRM 13.5 to 16.7	No Low	--	--	--	--	Yes High
RRM 16.7 to 20.9	No Low	--	--	--	Yes High	Yes High
RRM 20.9 to 24.0	No Low	No Low	No Low	No Low	--	Yes High
SFSR	No Low	--	--	--	No Low	Yes Medium

Notes:
--, Not evaluated.
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
WOE Evaluation Elements (See Appendix G):
Presence of Potential Adverse Effects (Yes, Undetermined, No).
Potential for Effects (Low, Medium, High).
Relative Weight of ME (1, 2, 3, 4, 5).
a, Based on the results in Table 6-8a and 6-8b.

(see Section 6.2.3, Table 6-11, and Figures 6-1 through 6-3).
c, Based on fish population metrics evaluation discussed in Section 6.2.4.
LOEC
Table 6-9).

Table 6-15a
Risk Estimates for Aquatic Vegetation - Direct Contact to Surface Water Mercury under Baseline Flow Conditions
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC[c]	LOEC[d]	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC[e]	LOEC[d]	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	12.9	1.9	1.9	770	1000	< 1	< 1	0.76	0.16	0.16	100	1000	< 1	< 1
RRM -0.7 to 0.0[b]	32.2	8.7	8.7	770	1000	< 1	< 1	0.03	0.03	0.03	100	1000	< 1	< 1
RRM 0.0 to 0.8	66.1	3.2	3.2	770	1000	< 1	< 1	0.60	0.09	0.09	100	1000	< 1	< 1
RRM 0.8 to 1.7	87.7	8.4	8.4	770	1000	< 1	< 1	0.48	0.17	0.17	100	1000	< 1	< 1
RRM 1.7 to 2.7	296.0	8.1	8.1	770	1000	< 1	< 1	62.36	2.04	2.04	100	1000	< 1	< 1
RRM 2.7 to 4.4	126.0	9.9	9.9	770	1000	< 1	< 1	2.30	0.60	0.60	100	1000	< 1	< 1
RRM 4.4 to 5.2	27.1	3.9	3.9	770	1000	< 1	< 1	0.44	0.37	0.37	100	1000	< 1	< 1
RRM 5.2 to 7.9	43.4	9.1	9.1	770	1000	< 1	< 1	5.94	0.77	0.77	100	1000	< 1	< 1
RRM 7.9 to 9.2	27.0	12.1	12.1	770	1000	< 1	< 1	2.77	1.04	1.04	100	1000	< 1	< 1
RRM 9.2 to 11.3	129.0	15.8	15.8	770	1000	< 1	< 1	48.20	5.45	5.45	100	1000	< 1	< 1
RRM 11.3 to 12.5	61.4	13.1	13.1	770	1000	< 1	< 1	3.05	1.32	1.32	100	1000	< 1	< 1
RRM 12.5 to 13.5	20.8	14.5	14.5	770	1000	< 1	< 1	2.90	1.93	1.93	100	1000	< 1	< 1
RRM 13.5 to 16.7	67.5	7.9	7.9	770	1000	< 1	< 1	2.61	1.13	1.13	100	1000	< 1	< 1
RRM 16.7 to 20.9	32.7	10.5	10.5	770	1000	< 1	< 1	3.06	1.33	1.33	100	1000	< 1	< 1
RRM 20.9 to 24.0	87.0	6.3	6.3	770	1000	< 1	< 1	5.31	1.01	1.01	100	1000	< 1	< 1
SFSR	5.6	2.2	2.2	770	1000	< 1	< 1	0.74	0.31	0.31	100	1000	< 1	< 1

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methlymercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, National Ambient Water Quality Criteria (NRWQC) (EPA 2014)/Virginia State Water Quality Criteria (VASWQC) of 770 ng/L represents a conservative benchmark for SAV exposure (See section 4.2).
d, Based on Canadian Water Quality Guideline for the Protection of Aquatic Life (CCME 2003) 1000 ng/L was selected as a LOEC for both THg and MeHg (See section 4.2).
e, Based on the lowest chronic effects concentrations of 1000 ng/L identified (CCME 2003) for aquatic plants divided by a safety factor of 10 (See section 4.2).

Table 6-15b
Risk Estimates for Aquatic Vegetation - Direct Contact to Surface Water Mercury under Storm Flow Conditions
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC[c]	LOEC[d]	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC[e]	LOEC[d]	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	2.7	1.1	1.1	770	1000	< 1	< 1	0.06	0.04	0.04	100	1000	< 1	< 1
RRM -0.7 to 0.0[b]	6.7	NC	6.7	770	1000	< 1	< 1	0.10	NC	0.10	100	1000	< 1	< 1
RRM 0.0 to 0.8	17.3	4.1	4.1	770	1000	< 1	< 1	0.20	0.06	0.06	100	1000	< 1	< 1
RRM 0.8 to 1.7	3.4	NC	3.4	770	1000	< 1	< 1	NA	--	--	100	1000	--	--
RRM 1.7 to 2.7	10.7	4.6	4.6	770	1000	< 1	< 1	0.36	0.13	0.13	100	1000	< 1	< 1
RRM 2.7 to 4.4	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 4.4 to 5.2	8.0	7.4	7.4	770	1000	< 1	< 1	0.06	NC	0.06	100	1000	< 1	< 1
RRM 5.2 to 7.9	33.8	9.0	9.0	770	1000	< 1	< 1	0.90	0.43	0.43	100	1000	< 1	< 1
RRM 7.9 to 9.2	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 9.2 to 11.3	412.0	82.8	82.8	770	1000	< 1	< 1	2.15	0.67	0.67	100	1000	< 1	< 1
RRM 11.3 to 12.5	8.4	NC	8.4	770	1000	< 1	< 1	NA	--	--	100	1000	--	--
RRM 12.5 to 13.5	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 13.5 to 16.7	75.4	16.6	16.6	770	1000	< 1	< 1	1.58	0.71	0.71	100	1000	< 1	< 1
RRM 16.7 to 20.9	19.6	9.0	9.0	770	1000	< 1	< 1	1.24	0.75	0.75	100	1000	< 1	< 1
RRM 20.9 to 24.0	17.7	10.0	10.0	770	1000	< 1	< 1	1.78	1.01	1.01	100	1000	< 1	< 1
SFSR	2.6	NC	2.6	770	1000	< 1	< 1	NA	--	--	100	1000	--	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No bbserved effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
NC, Not calculated due to insufficient number of samples.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, National Ambient Water Quality Criteria (NRWQC) (EPA 2014)/Virginia State Water Quality Criteria (VASWQC) of 770 ng/L represents a conservative benchmark for SAV exposure (See section 4.2).
d, Based on Canadian Water Quality Guideline for the Protection of Aquatic Life (CCME 2003) 1000 ng/L was selected as a LOEC for both THg and MeHg (See section 4.2).
e, Based on the lowest chronic effects concentrations of 1000 ng/L identified (CCME 2003) for aquatic plants divided by a safety factor of 10 (See section 4.2).

Table 6-16
Risk Estimates for Aquatic Vegetation - Direct Contact to Pore Water Mercury
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC[c]	LOEC[d]	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC[e]	LOEC[d]	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentration)														
RRM -2.7 to -0.7[a]	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM -0.7 to 0.0[b]	3.91	1.47	1.47	770	1000	< 1	< 1	NA	--	--	100	1000	--	--
RRM 0.0 to 0.8	294	27	27	770	1000	< 1	< 1	22.1	2.80	2.80	100	1000	< 1	< 1
RRM 0.8 to 1.7	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 1.7 to 2.7	1502	257	257	770	1000	< 1	< 1	14.2	NC	14.2	100	1000	< 1	< 1
RRM 2.7 to 4.4	2180	256	256	770	1000	< 1	< 1	78.5	21.9	21.9	100	1000	< 1	< 1
RRM 4.4 to 5.2	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 5.2 to 7.9	348	NC	348	770	1000	< 1	< 1	17.4	NC	17.4	100	1000	< 1	< 1
RRM 7.9 to 9.2	3227	228	228	770	1000	< 1	< 1	34.3	6.79	6.79	100	1000	< 1	< 1
RRM 9.2 to 11.3	292	NC	292	770	1000	< 1	< 1	4.86	NC	4.86	100	1000	< 1	< 1
RRM 11.3 to 12.5	151	58.6	58.6	770	1000	< 1	< 1	24.1	5.57	5.57	100	1000	< 1	< 1
RRM 12.5 to 13.5	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 13.5 to 16.7	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 16.7 to 20.9	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--
RRM 20.9 to 24.0	306	44.5	44.5	770	1000	< 1	< 1	48.6	6.56	6.56	100	1000	< 1	< 1
SFSR	NA	--	--	770	1000	--	--	NA	--	--	100	1000	--	--

Notes:

RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
NC, Not calculated due to insufficient number of samples.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, National Ambient Water Quality Criteria (NRWQC) (EPA 2014)/Virginia State Water Quality Criteria (VASWQC) of 770 ng/L represents a conservative benchmark for SAV exposure (See section 4.2).
d, Based on Canadian Water Quality Guideline for the Protection of Aquatic Life (CCME 2003) 1000 ng/L was selected as a LOEC for both THg and MeHg (See section 4.2).
e, Based on the lowest chronic effects concentrations of 1000 ng/L identified (CCME 2003) for aquatic plants divided by a safety factor of 10 (See section 4.2).

Table 6-17a
Risk Estimates for Amphibians - Direct Contact to Surface Water Mercury under Baseline Flow Conditions
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC[c]	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC[d]	LOEC	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	12.9	1.9	1.9	770	NA	< 1	--	0.76	0.16	0.16	4	NA	< 1	--
RRM -0.7 to 0.0[b]	32.2	8.7	8.7	770	NA	< 1	--	0.03	0.03	0.03	4	NA	< 1	--
RRM 0.0 to 0.8	66.1	3.2	3.2	770	NA	< 1	--	0.60	0.09	0.09	4	NA	< 1	--
RRM 0.8 to 1.7	87.7	8.4	8.4	770	NA	< 1	--	0.48	0.17	0.17	4	NA	< 1	--
RRM 1.7 to 2.7	296.0	8.1	8.1	770	NA	< 1	--	62.36	2.04	2.04	4	NA	< 1	--
RRM 2.7 to 4.4	126.0	9.9	9.9	770	NA	< 1	--	2.30	0.60	0.60	4	NA	< 1	--
RRM 4.4 to 5.2	27.1	3.9	3.9	770	NA	< 1	--	0.44	0.37	0.37	4	NA	< 1	--
RRM 5.2 to 7.9	43.4	9.1	9.1	770	NA	< 1	--	5.94	0.77	0.77	4	NA	< 1	--
RRM 7.9 to 9.2	27.0	12.1	12.1	770	NA	< 1	--	2.77	1.04	1.04	4	NA	< 1	--
RRM 9.2 to 11.3	129.0	15.8	15.8	770	NA	< 1	--	48.20	5.45	5.45	4	NA	**1.4**	--
RRM 11.3 to 12.5	61.4	13.1	13.1	770	NA	< 1	--	3.05	1.32	1.32	4	NA	< 1	--
RRM 12.5 to 13.5	20.8	14.5	14.5	770	NA	< 1	--	2.90	1.93	1.93	4	NA	< 1	--
RRM 13.5 to 16.7	67.5	7.9	7.9	770	NA	< 1	--	2.61	1.13	1.13	4	NA	< 1	--
RRM 16.7 to 20.9	32.7	10.5	10.5	770	NA	< 1	--	3.06	1.33	1.33	4	NA	< 1	--
RRM 20.9 to 24.0	87.0	6.3	6.3	770	NA	< 1	--	5.31	1.01	1.01	4	NA	< 1	--
SFSR	5.6	2.2	2.2	770	NA	< 1	--	0.74	0.31	0.31	4	NA	< 1	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, National Recommended Ambient Water Quality Criteria (NRWQC) (EPA 2014)/Virginia State Water Quality Criteria (VASWQC) of 770 ng/L (filtered) represents a conservative benchmark for fish exposure at various life stages (see section 4.6.3).
d, NOEC represents the CCME Water Quality Guideline for the Protection of Aquatic Life derived based on a LOEC of 40 ng/L for daphnid reproduction and a safety factor of 10 (CCME,2003) (See section 4.1.3).

Table 6-17b
Risk Estimates for Amphibians - Direct Contact to Surface Water Mercury under Storm Flow Conditions
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (ng/L)			THg Benchmarks (ng/L)		Hazard Quotient (HQ)		MeHg Concentrations (ng/L)			MeHg Benchmarks (ng/L)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	NOEC[c]	LOEC	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	NOEC[d]	LOEC	HQ_{NOEC}	HQ_{LOEC}
Filtered (Dissolved Concentrations)														
RRM -2.7 to -0.7[a]	2.7	1.1	1.1	770	NA	< 1	--	0.06	0.04	0.04	4	NA	< 1	--
RRM -0.7 to 0.0[b]	6.7	NC	6.7	770	NA	< 1	--	0.10	NC	0.10	4	NA	< 1	--
RRM 0.0 to 0.8	17.3	4.1	4.1	770	NA	< 1	--	0.20	0.06	0.06	4	NA	< 1	--
RRM 0.8 to 1.7	3.4	NC	3.4	770	NA	< 1	--	NA	--	--	4	NA	--	--
RRM 1.7 to 2.7	10.7	4.6	4.6	770	NA	< 1	--	0.36	0.13	0.13	4	NA	< 1	--
RRM 2.7 to 4.4	NA	--	--	770	NA	--	--	NA	--	--	4	NA	--	--
RRM 4.4 to 5.2	8.0	7.4	7.4	770	NA	< 1	--	0.06	NC	0.06	4	NA	< 1	--
RRM 5.2 to 7.9	33.8	9.0	9.0	770	NA	< 1	--	0.90	0.43	0.43	4	NA	< 1	--
RRM 7.9 to 9.2	NA	--	--	770	NA	--	--	NA	--	--	4	NA	--	--
RRM 9.2 to 11.3	412.0	82.8	82.8	770	NA	< 1	--	2.15	0.67	0.67	4	NA	< 1	--
RRM 11.3 to 12.5	8.4	NC	8.4	770	NA	< 1	--	NA	--	--	4	NA	--	--
RRM 12.5 to 13.5	NA	--	--	770	NA	--	--	NA	--	--	4	NA	--	--
RRM 13.5 to 16.7	75.4	16.6	16.6	770	NA	< 1	--	1.58	0.71	0.71	4	NA	< 1	--
RRM 16.7 to 20.9	19.6	9.0	9.0	770	NA	< 1	--	1.24	0.75	0.75	4	NA	< 1	--
RRM 20.9 to 24.0	17.7	10.0	10.0	770	NA	< 1	--	1.78	1.01	1.01	4	NA	< 1	--
SFSR	2.6	NC	2.6	770	NA	< 1	--	NA	--	--	4	NA	--	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
ng/L, nanograms per liter.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
NC, Not calculated due to insufficient number of samples.
--, Not applicable.
HQ, Hazard quotient.
HQ_{NOEC} = EPC/NOEC.
HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, National Recommended Ambient Water Quality Criteria (NRWQC) (EPA 2014)/Virginia State Water Quality Criteria (VASWQC) of 770 ng/L (filtered) represents a conservative benchmark for fish exposure at various life stages (see section 4.6.3).
d, NOEC represents the CCME Water Quality Guideline for the Protection of Aquatic Life derived based on a LOEC of 40 ng/L for daphnid reproduction and a safety factor of 10 (CCME,2003) (See section 4.1.3).

Table 6-18
Risk Estimates for Amphibians Based on Tissue (Whole Body) Mercury Concentrations
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (mg/kg ww)			THg Benchmarks (mg/kg ww)		Hazard Quotient (HQ)		MeHg Concentrations (mg/kg ww)			MeHg Benchmarks[d] (mg/kg ww)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	CBR_{NOEC}[b]	CBR_{LOEC}[c]	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}
American Toad (*Bufo americanus*)														
SR WNP Lower[a]	0.04	0.05	0.04	0.21	0.44	< 1	< 1	0.02	NA	0.02	0.21	0.44	< 1	< 1
RRM -2.7 to -0.7[a]	0.05	0.05	0.05	0.21	0.44	< 1	< 1	0.03	0.03	0.03	0.21	0.44	< 1	< 1
RRM 4.4 to 5.2	0.08	0.05	0.05	0.21	0.44	< 1	< 1	0.03	0.03	0.03	0.21	0.44	< 1	< 1
RRM 7.9 to 9.2	0.48	0.26	0.26	0.21	0.44	**1.2**	< 1	0.04	NA	0.04	0.21	0.44	< 1	< 1
RRM 16.7 to 20.9	0.52	0.33	0.33	0.21	0.44	**1.6**	< 1	0.34	0.20	0.20	0.21	0.44	< 1	< 1
Northern Two-lined Salamander (*Eurycea bislineata*)														
SR WNP Lower[a]	0.13	0.07	0.07	0.21	0.44	< 1	< 1							
RRM 1.7 to 2.7	0.59	0.57	0.57	0.21	0.44	**2.7**	**1.3**							
RRM 4.4 to 5.2	1.51	1.38	1.38	0.21	0.44	**6.6**	**3.1**							
RRM 7.9 to 9.2	1.08	0.96	0.96	0.21	0.44	**4.6**	**2.2**							
RRM 11.3 to 12.5	0.95	NA	0.95	0.21	0.44	**4.5**	**2.1**							
RRM 13.5 to 16.7	1.29	1.13	1.13	0.21	0.44	**5.4**	**2.6**							
RRM 16.7 to 20.9	1.65	1.46	1.46	0.21	0.44	**6.9**	**3.3**							
RRM 20.9 to 24.0	1.07	1.07	1.07	0.21	0.44	**5.1**	**2.4**							
SFSR	0.50	0.41	0.41	0.21	0.44	**2.0**	< 1							
Red-back Salamander (*Plethodon cinereus*)														
SR WNP Lower[a]	0.03	0.03	0.03	0.21	0.44	< 1	< 1							
RRM 0.0 to 0.8	0.09	0.08	0.08	0.21	0.44	< 1	< 1							
RRM 12.5 to 13.5	0.82	0.49	0.49	0.21	0.44	**2.3**	**1.1**							
RRM 16.7 to 20.9	0.19	0.16	0.16	0.21	0.44	< 1	< 1							

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg ww, milligram per kilogram wet weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
CBR_{NOEC}, No effects critical body residue.
CBR_{LOEC}, Lowest effect critical body residue.
HQ, Hazard quotient.
$HQ_{NOEC} = EPC/CBR_{NOEC.}$
$HQ_{LOEC} = EPC/CBR_{LOEC.}$
a, Reference Reach: Lower South River Waynesboro Nursery Property (SR WNP Lower), Upstream Reference Reach (RRM -2.7- -0.7).
b, Based on Beckvar et al. (2005) for fish (See section 4.6.3).
c, Derived from data compiled in Beckvar et al. (2005) for fish (See section 4.6.3).
d, Values for MeHg are equivalent to THg based on assumption that nearly all mercury in amphibians is methylated (See section 4.6.3).

Table 6-19
Risk Estimates for Terrestrial Plants - Direct Contact to Surficial Soil Mercury
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Surficial Soil						
	THg Concentrations (mg/kg dw)			THg Benchmarks[d] (mg/kg dw)		EPC-Based HQ	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
0.3 Year Floodplain							
RRM -2.7 to -0.7[a]	0.2	0.2	0.2	54.0	87.0	< 1	< 1
RRM -0.7 to 0.0[b]	NA	--	--	54.0	87.0	--	--
RRM 0.0 to 0.8	941.0	36.3	36.3	54.0	87.0	< 1	< 1
RRM 0.8 to 1.7	817.0	47.2	47.2	54.0	87.0	< 1	< 1
RRM 1.7 to 2.7	515.0	23.8	23.8	54.0	87.0	< 1	< 1
RRM 2.7 to 4.4	476.0	22.1	22.1	54.0	87.0	< 1	< 1
RRM 4.4 to 5.2	485.0	42.0	42.0	54.0	87.0	< 1	< 1
RRM 5.2 to 7.9	120.0	17.0	17.0	54.0	87.0	< 1	< 1
RRM 7.9 to 9.2	42.4	14.5	14.5	54.0	87.0	< 1	< 1
RRM 9.2 to 11.3	80.2	25.6	25.6	54.0	87.0	< 1	< 1
RRM 11.3 to 12.5	36.6	15.1	15.1	54.0	87.0	< 1	< 1
RRM 12.5 to 13.5	12.5	8.3	8.3	54.0	87.0	< 1	< 1
RRM 13.5 to 16.7	11.1	7.4	7.4	54.0	87.0	< 1	< 1
RRM 16.7 to 20.9	22.2	7.2	7.2	54.0	87.0	< 1	< 1
RRM 20.9 to 24.0	85.7	12.6	12.6	54.0	87.0	< 1	< 1
2 Year Floodplain							
RRM -2.7 to -0.7[a]	NA	--	--	54.0	87.0	--	--
RRM -0.7 to 0.0[b]	0.4	0.3	0.3	54.0	87.0	< 1	< 1
RRM 0.0 to 0.8	160.0	32.0	32.0	54.0	87.0	< 1	< 1
RRM 0.8 to 1.7	494.0	61.7	61.7	54.0	87.0	**1.1**	< 1
RRM 1.7 to 2.7	60.9	14.8	14.8	54.0	87.0	< 1	< 1
RRM 2.7 to 4.4	77.5	26.0	26.0	54.0	87.0	< 1	< 1
RRM 4.4 to 5.2	28.0	14.2	14.2	54.0	87.0	< 1	< 1
RRM 5.2 to 7.9	83.4	26.3	26.3	54.0	87.0	< 1	< 1
RRM 7.9 to 9.2	55.6	25.2	25.2	54.0	87.0	< 1	< 1
RRM 9.2 to 11.3	60.2	23.5	23.5	54.0	87.0	< 1	< 1
RRM 11.3 to 12.5	79.3	41.5	41.5	54.0	87.0	< 1	< 1
RRM 12.5 to 13.5	14.9	19.5	14.9	54.0	87.0	< 1	< 1
RRM 13.5 to 16.7	20.0	16.3	16.3	54.0	87.0	< 1	< 1
RRM 16.7 to 20.9	21.2	8.9	8.9	54.0	87.0	< 1	< 1
RRM 20.9 to 24.0	33.1	12.3	12.3	54.0	87.0	< 1	< 1
5 Year Floodplain							
RRM -2.7 to -0.7[a]	NA	--	--	54.0	87.0	--	--
RRM -0.7 to 0.0[b]	12.7	36.4	12.7	54.0	87.0	< 1	< 1
RRM 0.0 to 0.8	24.3	12.9	12.9	54.0	87.0	< 1	< 1
RRM 0.8 to 1.7	307.0	35.7	35.7	54.0	87.0	< 1	< 1
RRM 1.7 to 2.7	173.0	15.1	15.1	54.0	87.0	< 1	< 1
RRM 2.7 to 4.4	38.7	21.1	21.1	54.0	87.0	< 1	< 1
RRM 4.4 to 5.2	29.9	38.0	29.9	54.0	87.0	< 1	< 1
RRM 5.2 to 7.9	22.3	8.3	8.3	54.0	87.0	< 1	< 1
RRM 7.9 to 9.2	21.2	14.0	14.0	54.0	87.0	< 1	< 1
RRM 9.2 to 11.3	50.4	18.7	18.7	54.0	87.0	< 1	< 1
RRM 11.3 to 12.5	28.9	6.0	6.0	54.0	87.0	< 1	< 1
RRM 12.5 to 13.5	10.3	NC	10.3	54.0	87.0	< 1	< 1
RRM 13.5 to 16.7	18.1	7.4	7.4	54.0	87.0	< 1	< 1
RRM 16.7 to 20.9	22.5	8.6	8.6	54.0	87.0	< 1	< 1
RRM 20.9 to 24.0	7.4	6.1	6.1	54.0	87.0	< 1	< 1
62 Year Floodplain							
RRM -2.7 to -0.7[a]	NA	--	--	54.0	87.0	--	--
RRM -0.7 to 0.0[b]	NA	--	--	54.0	87.0	--	--
RRM 0.0 to 0.8	47.5	13.6	13.6	54.0	87.0	< 1	< 1
RRM 0.8 to 1.7	85.7	11.7	11.7	54.0	87.0	< 1	< 1
RRM 1.7 to 2.7	19.3	9.9	9.9	54.0	87.0	< 1	< 1
RRM 2.7 to 4.4	1.6	1.1	1.1	54.0	87.0	< 1	< 1
RRM 4.4 to 5.2	0.5	0.4	0.4	54.0	87.0	< 1	< 1
RRM 5.2 to 7.9	2.8	0.8	0.8	54.0	87.0	< 1	< 1
RRM 7.9 to 9.2	1.5	1.2	1.2	54.0	87.0	< 1	< 1
RRM 9.2 to 11.3	20.9	11.0	11.0	54.0	87.0	< 1	< 1
RRM 11.3 to 12.5	2.6	0.8	0.8	54.0	87.0	< 1	< 1
RRM 12.5 to 13.5	0.6	0.3	0.3	54.0	87.0	< 1	< 1
RRM 13.5 to 16.7	7.1	4.8	4.8	54.0	87.0	< 1	< 1
RRM 16.7 to 20.9	15.3	3.8	3.8	54.0	87.0	< 1	< 1
RRM 20.9 to 24.0	10.0	7.1	7.1	54.0	87.0	< 1	< 1
SFSR[c]	0.02	NC	0.02	54.0	87.0	< 1	< 1

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg dw, milligram per kilogram dry weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NC, Not calculated due to insufficient number of samples
NA, Not available.
--, Not applicable.

HQ, Hazard quotient.
Max-Based HQ_{NOEC} = Maximum/NOEC.
Max-Based HQ_{LOEC} = Maximum/LOEC.
EPC-Based HQ_{NOEC} = EPC/NOEC.
EPC-Based HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, Floodplain information not available for SFSR.
d, Based on geometric mean of select NOECs and LOECs from soil studies in Table C-2 in Appendix C and a site-specific bioavailability factor of 3 (See section 4.3).

Table 6-20
Risk Estimates for Terrestrial Invertebrates - Direct Contact to Surficial Soil Mercury
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Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Surficial Soil						
	THg Concentrations (mg/kg dw)			THg Benchmarks[d] (mg/kg dw)		EPC-Based HQ	
	Maximum	95% UCL	EPC	NOEC	LOEC	HQ_{NOEC}	HQ_{LOEC}
0.3 Year Floodplain							
RRM -2.7 to -0.7[a]	0.2	0.2	0.2	18.0	36.0	< 1	< 1
RRM -0.7 to 0.0[b]	NA	--	--	18.0	36.0	**--**	--
RRM 0.0 to 0.8	941.0	36.3	36.3	18.0	36.0	**2.0**	< 1
RRM 0.8 to 1.7	817.0	47.2	47.2	18.0	36.0	**2.6**	**1.3**
RRM 1.7 to 2.7	515.0	23.8	23.8	18.0	36.0	**1.3**	< 1
RRM 2.7 to 4.4	476.0	22.1	22.1	18.0	36.0	**1.2**	< 1
RRM 4.4 to 5.2	485.0	42.0	42.0	18.0	36.0	**2.3**	**1.2**
RRM 5.2 to 7.9	120.0	17.0	17.0	18.0	36.0	< 1	< 1
RRM 7.9 to 9.2	42.4	14.5	14.5	18.0	36.0	< 1	< 1
RRM 9.2 to 11.3	80.2	25.6	25.6	18.0	36.0	**1.4**	< 1
RRM 11.3 to 12.5	36.6	15.1	15.1	18.0	36.0	< 1	< 1
RRM 12.5 to 13.5	12.5	8.3	8.3	18.0	36.0	< 1	< 1
RRM 13.5 to 16.7	11.1	7.4	7.4	18.0	36.0	< 1	< 1
RRM 16.7 to 20.9	22.2	7.2	7.2	18.0	36.0	< 1	< 1
RRM 20.9 to 24.0	85.7	12.6	12.6	18.0	36.0	< 1	< 1
2 Year Floodplain							
RRM -2.7 to -0.7[a]	NA	--	--	18.0	36.0	--	--
RRM -0.7 to 0.0[b]	0.4	0.3	0.3	18.0	36.0	< 1	< 1
RRM 0.0 to 0.8	160.0	32.0	32.0	18.0	36.0	**1.8**	< 1
RRM 0.8 to 1.7	494.0	61.7	61.7	18.0	36.0	**3.4**	**1.7**
RRM 1.7 to 2.7	60.9	14.8	14.8	18.0	36.0	< 1	< 1
RRM 2.7 to 4.4	77.5	26.0	26.0	18.0	36.0	**1.4**	< 1
RRM 4.4 to 5.2	28.0	14.2	14.2	18.0	36.0	< 1	< 1
RRM 5.2 to 7.9	83.4	26.3	26.3	18.0	36.0	**1.5**	< 1
RRM 7.9 to 9.2	55.6	25.2	25.2	18.0	36.0	**1.4**	< 1
RRM 9.2 to 11.3	60.2	23.5	23.5	18.0	36.0	**1.3**	< 1
RRM 11.3 to 12.5	79.3	41.5	41.5	18.0	36.0	**2.3**	**1.2**
RRM 12.5 to 13.5	14.9	19.5	14.9	18.0	36.0	< 1	< 1
RRM 13.5 to 16.7	20.0	16.3	16.3	18.0	36.0	< 1	< 1
RRM 16.7 to 20.9	21.2	8.9	8.9	18.0	36.0	< 1	< 1
RRM 20.9 to 24.0	33.1	12.3	12.3	18.0	36.0	< 1	< 1
5 Year Floodplain							
RRM -2.7 to -0.7[a]	NA	--	--	18.0	36.0	--	--
RRM -0.7 to 0.0[b]	12.7	36.4	12.7	18.0	36.0	< 1	< 1
RRM 0.0 to 0.8	24.3	12.9	12.9	18.0	36.0	< 1	< 1
RRM 0.8 to 1.7	307.0	35.7	35.7	18.0	36.0	**2.0**	< 1
RRM 1.7 to 2.7	173.0	15.1	15.1	18.0	36.0	< 1	< 1
RRM 2.7 to 4.4	38.7	21.1	21.1	18.0	36.0	**1.2**	< 1
RRM 4.4 to 5.2	29.9	38.0	29.9	18.0	36.0	**1.7**	< 1
RRM 5.2 to 7.9	22.3	8.3	8.3	18.0	36.0	< 1	< 1
RRM 7.9 to 9.2	21.2	14.0	14.0	18.0	36.0	< 1	< 1
RRM 9.2 to 11.3	50.4	18.7	18.7	18.0	36.0	< 1	< 1
RRM 11.3 to 12.5	28.9	6.0	6.0	18.0	36.0	< 1	< 1
RRM 12.5 to 13.5	10.3	NC	10.3	18.0	36.0	< 1	< 1
RRM 13.5 to 16.7	18.1	7.4	7.4	18.0	36.0	< 1	< 1
RRM 16.7 to 20.9	22.5	8.6	8.6	18.0	36.0	< 1	< 1
RRM 20.9 to 24.0	7.4	6.1	6.1	18.0	36.0	< 1	< 1
62 Year Floodplain							
RRM -2.7 to -0.7[a]	NA	--	--	18.0	36.0	--	--
RRM -0.7 to 0.0[b]	NA	--	--	18.0	36.0	--	--
RRM 0.0 to 0.8	47.5	13.6	13.6	18.0	36.0	< 1	< 1
RRM 0.8 to 1.7	85.7	11.7	11.7	18.0	36.0	< 1	< 1
RRM 1.7 to 2.7	19.3	9.9	9.9	18.0	36.0	< 1	< 1
RRM 2.7 to 4.4	1.6	1.1	1.1	18.0	36.0	< 1	< 1
RRM 4.4 to 5.2	0.5	0.4	0.4	18.0	36.0	< 1	< 1
RRM 5.2 to 7.9	2.8	0.8	0.8	18.0	36.0	< 1	< 1
RRM 7.9 to 9.2	1.5	1.2	1.2	18.0	36.0	< 1	< 1
RRM 9.2 to 11.3	20.9	11.0	11.0	18.0	36.0	< 1	< 1
RRM 11.3 to 12.5	2.6	0.8	0.8	18.0	36.0	< 1	< 1
RRM 12.5 to 13.5	0.6	0.3	0.3	18.0	36.0	< 1	< 1
RRM 13.5 to 16.7	7.1	4.8	4.8	18.0	36.0	< 1	< 1
RRM 16.7 to 20.9	15.3	3.8	3.8	18.0	36.0	< 1	< 1
RRM 20.9 to 24.0	10.0	7.1	7.1	18.0	36.0	< 1	< 1
SFSR[c]	0.02	NC	0.02	18.0	36.0	< 1	< 1

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg dw, milligram per kilogram dry weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
NOEC, No observed effects concentration.
LOEC, Lowest observed effects concentration.
NA, Not available.
NC, Not calculated due to insufficient number of samples.
--, Not applicable.
HQ, Hazard quotient.
Max-Based HQ_{NOEC} = Maximum/NOEC.
Max-Based HQ_{LOEC} = Maximum/LOEC.
EPC-Based HQ_{NOEC} = EPC/NOEC.
EPC-Based HQ_{LOEC} = EPC/LOEC.
a, Upstream Reference Reach.
b, Buffer Reach.
c, Floodplain information not available for SFSR.
d, Based on geometric mean of select NOECs and LOECs from soil studies in Table C-3 in Appendix C and a site-specific bioavailability factor of 3 (See section 4.4).

Table 6-21
Summary of Dose Rate Modeling Results - Avian Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Receptor Group	Focal Species	Inorganic Mercury (IHg)						Methylmercury (MeHg)					
		HQ Range[a]		AUF-Adjusted HQ Range[a,b]		Cumulative HQ[c]		HQ Range[a]		AUF-Adjusted HQ Range[a,b]		Cumulative HQ[c]	
		HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Semi-Aquatic Piscivorous Birds	Belted Kingfisher	0.1-1.1	0.1-0.6	0.0-0.3	0.0-0.1	0.3 (0.1)	0.1 (0.0)	5.6-75	1.7-23	1.1-48	0.3-15	63 (3.6)	20 (1.1)
Semi-Aquatic Omnivorous Birds	Mallard Duck	0.1-1.0	0.0-0.5	0.0-0.4	0.0-0.2	0.2 (0.0)	0.1 (0.0)	0.6-13	0.2-4.0	0.1-3.9	0.0-1.2	5.9 (0.1)	1.8 (0.0)
Terrestrial Carnivorous Birds	Eastern Screech Owl	0.3-1.6	0.1-0.8	0.0-0.6	0.0-0.3	0.7 (0.0)	0.3 (0.0)	14-44	4.5-13	1.2-18	0.4-5.5	38 (3.6)	12 (1.1)
Terrestrial Aerial Insectivorous Bird	Tree Swallow	0.4-2.0	0.2-1.0	0.1-2.0	0.0-1.0	2.0 (0.0)	1.0 (0.0)	1.9-37	0.9-17	0.3-37	0.1-17	37 (0.2)	17 (0.1)
Terrestrial Insectivorous Bird	American Robin	1.0-3.4	0.5-1.7	--	--	3.4 (0.1)	1.7 (0.1)	1.1-3.7	0.5-1.7	--	--	3.7 (0.0)	1.7 (0.0)

Notes:
--, Not evaluated or not applicable.
HQ, Hazard quotient (HQ = 0.0 represents HQ<0.05).
NOAEL, No observed adverse effects level.
LOAEL, Lowest observed adverse effects level.
HQ_{NOAEL}, NOAEL-based HQ.
HQ_{LOAEL}, LOAEL-based HQ.
AUF, Area use factor.
a, Ranges representing only the Assessment Reaches between RRM 0.00 and RRM 24.0.
b, Weighted reach-specific HQs based on AUFs.
c, Maximum possible HQ; Cumulative AUF-weighted HQs within one or more contiguous reaches representing a total area equal to the receptors home range (i.e. $\Sigma HQ_i \times AUF_i$, where i = Exposure Areas and $\Sigma AUF_i = 1$);
HQ for the Reference Reach (RRM -2.7- -0.7) is shown in parenthesis.

Table 6-22
Risk Estimates for Avian Receptors Based on Tissue (Blood) Mercury Concentrations
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (mg/kg ww)			THg Benchmarks[b] (mg/kg ww)		Hazard Quotient (HQ)		MeHg Concentrations (mg/kg ww)			MeHg Benchmarks[c] (mg/kg ww)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}	Maximum	95% UCL	EPC	CBR_{NOEC}	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}
Belted Kingfisher (*Megaceryl alcyon*)														
MR Lower[a]	3.19	1.32	1.32	1.0	3.0	**1.2**	< 1	2.81	1.16	1.16	NA	NA	--	--
MR Middle[a]	1.16	0.24	0.24	1.0	3.0	< 1	< 1	1.02	0.21	0.21	NA	NA	--	--
MR Upper[a]	0.31	NC	0.31	1.0	3.0	< 1	< 1	0.28	NC	0.28	NA	NA	--	--
NR Lower[a]	10.70	9.04	9.04	1.0	3.0	**8.0**	**2.7**	9.42	7.96	7.96	NA	NA	--	--
NR Upper[a]	0.32	0.14	0.14	1.0	3.0	< 1	< 1	0.28	0.12	0.12	NA	NA	--	--
SR RRM 16.7- 20.9[a]	3.06	NC	3.06	1.0	3.0	**2.7**	< 1	2.69	NC	2.69	NA	NA	--	--
RRM 0.8 to 1.7	1.85	1.00	1.00	1.0	3.0	< 1	< 1	1.63	0.88	0.88	NA	NA	--	--
RRM 2.7 to 4.4	2.84	1.79	1.79	1.0	3.0	**1.6**	< 1	2.50	1.57	1.57	NA	NA	--	--
RRM 4.4 to 5.2	4.60	2.94	2.94	1.0	3.0	**2.6**	< 1	4.05	2.59	2.59	NA	NA	--	--
RRM 5.2 to 7.9	4.49	NC	4.49	1.0	3.0	**4.0**	**1.3**	3.95	NC	3.95	NA	NA	--	--
RRM 7.9 to 9.2	5.74	2.84	2.84	1.0	3.0	**2.5**	< 1	5.05	2.50	2.50	NA	NA	--	--
RRM 9.2 to 11.3	4.66	4.79	4.66	1.0	3.0	**4.1**	**1.4**	4.10	4.21	4.10	NA	NA	--	--
RRM 11.3 to 12.5	8.39	NC	8.39	1.0	3.0	**7.4**	**2.5**	7.38	NC	7.38	NA	NA	--	--
RRM 13.5 to 16.7	9.99	436	9.99	1.0	3.0	**8.8**	**2.9**	8.79	368	8.79	NA	NA	--	--
SFSR	1.23	0.31	0.31	1.0	3.0	< 1	< 1	1.08	0.28	0.28	NA	NA	--	--
Mallard Duck (*Anas platyrhychos*)														
MR Upper[a]	0.06	NC	0.06	NA	NA	--	--	0.05	NC	0.05	NA	NA	--	--
NR Upper[a]	0.06	0.04	0.04	NA	NA	--	--	0.05	0.03	0.03	NA	NA	--	--
RRM 1.7 to 2.7	2.34	0.95	0.95	NA	NA	--	--	2.06	0.83	0.83	NA	NA	--	--
RRM 4.4 to 5.2	1.11	NC	1.11	NA	NA	--	--	0.98	NC	0.98	NA	NA	--	--
RRM 5.2 to 7.9	1.89	1.69	1.69	NA	NA	--	--	1.66	1.49	1.49	NA	NA	--	--
RRM 9.2 to 11.3	4.44	2.84	2.84	NA	NA	--	--	3.90	2.50	2.50	NA	NA	--	--
RRM 11.3 to 12.5	5.41	2.35	2.35	NA	NA	--	--	4.76	2.07	2.07	NA	NA	--	--
RRM 16.7 to 20.9	2.28	1.04	1.04	NA	NA	--	--	2.01	0.91	0.91	NA	NA	--	--
RRM 20.9 to 24.0	1.11	NC	1.11	NA	NA	--	--	0.98	NC	0.98	NA	NA	--	--
Eastern Screech Owl (*Megascops asio*)														
MR Middle[a]	0.23	0.23	0.23	NA	NA	--	--	0.20	0.20	0.20	NA	NA	--	--
NR Lower[a]	2.26	NC	2.26	NA	NA	--	--	1.99	NA	1.99	NA	NA	--	--
NR Upper[a]	0.20	0.19	0.19	NA	NA	--	--	0.18	0.16	0.16	NA	NA	--	--
RRM -2.7 to -0.7[a]	0.62	NC	0.62	NA	NA	--	--	0.55	NC	0.55	NA	NA	--	--
RRM 0.8 to 1.7	1.62	NC	1.62	NA	NA	--	--	1.43	NC	1.43	NA	NA	--	--
RRM 1.7 to 2.7	2.32	NC	2.32	NA	NA	--	--	2.19	NC	2.19	NA	NA	--	--
RRM 2.7 to 4.4	3.47	3.81	3.47	NA	NA	--	--	3.05	3.35	3.05	NA	NA	--	--
RRM 11.3 to 12.5	1.64	1.48	1.48	NA	NA	--	--	1.44	1.28	1.28	NA	NA	--	--
RRM 13.5 to 16.7	0.82	NC	0.82	NA	NA	--	--	0.72	NC	0.72	NA	NA	--	--
RRM 16.7 to 20.9	3.35	4.19	3.35	NA	NA	--	--	2.95	3.68	2.95	NA	NA	--	--
RRM 20.9 to 24.0	4.13	3.75	3.75	NA	NA	--	--	3.63	3.31	3.31	NA	NA	--	--
Tree Swallow (*Tachycineta bicolor*)														
MR Middle[a]	2.19	0.20	0.20	NA	NA	--	--	1.92	0.18	0.18	0.7	1.4	< 1	< 1
MR Upper[a]	1.44	0.14	0.14	NA	NA	--	--	1.27	0.12	0.12	0.7	1.4	< 1	< 1
NR Lower[a]	1.48	0.72	0.72	NA	NA	--	--	1.30	0.63	0.63	0.7	1.4	< 1	< 1
NR Upper[a]	3.67	0.23	0.23	NA	NA	--	--	3.23	0.20	0.20	0.7	1.4	< 1	< 1
SR WNP Lower[a]	0.27	0.22	0.22	NA	NA	--	--	0.24	0.19	0.19	0.7	1.4	< 1	< 1
SR WNP Upper[a]	0.97	0.20	0.20	NA	NA	--	--	0.85	0.17	0.17	0.7	1.4	< 1	< 1
RRM -2.7 to -0.7[a]	1.23	0.38	0.38	NA	NA	--	--	1.08	0.34	0.34	0.7	1.4	< 1	< 1
RRM 0.8 to 1.7	3.54	1.38	1.38	NA	NA	--	--	3.12	1.21	1.21	0.7	1.4	**1.7**	< 1
RRM 1.7 to 2.7	4.44	1.42	1.42	NA	NA	--	--	3.91	1.25	1.25	0.7	1.4	**1.8**	< 1
RRM 2.7 to 4.4	5.02	1.93	1.93	NA	NA	--	--	4.42	1.70	1.70	0.7	1.4	**2.4**	**1.2**
RRM 4.4 to 5.2	4.97	2.00	2.00	NA	NA	--	--	4.37	1.76	1.76	0.7	1.4	**2.5**	**1.3**
RRM 5.2 to 7.9	2.43	4.12	2.43	NA	NA	--	--	2.14	3.63	2.14	0.7	1.4	**3.1**	**1.5**
RRM 7.9 to 9.2	4.34	2.55	2.55	NA	NA	--	--	3.82	2.25	2.25	0.7	1.4	**3.2**	**1.6**
RRM 9.2 to 11.3	11.90	2.71	2.71	NA	NA	--	--	10.47	2.38	2.38	0.7	1.4	**3.4**	**1.7**
RRM 11.3 to 12.5	6.92	2.64	2.64	NA	NA	--	--	6.09	2.32	2.32	0.7	1.4	**3.3**	**1.7**
RRM 13.5 to 16.7	7.71	3.27	3.27	NA	NA	--	--	6.78	2.88	2.88	0.7	1.4	**4.1**	**2.1**
RRM 16.7 to 20.9	10.80	3.26	3.26	NA	NA	--	--	9.50	2.87	2.87	0.7	1.4	**4.1**	**2.1**
RRM 20.9 to 24.0	9.18	2.66	2.66	NA	NA	--	--	8.08	2.34	2.34	0.7	1.4	**3.3**	**1.7**
SFSR	1.73	1.39	1.39	NA	NA	--	--	1.52	1.22	1.22	0.7	1.4	**1.7**	< 1
American Robin (*Turdus migratorius*)														
MR Middle[a]	0.04	NC	0.04	NA	NA	--	--	0.04	NC	0.04	0.7	1.4	< 1	< 1
NR Upper[a]	0.03	NC	0.03	NA	NA	--	--	0.03	NC	0.03	0.7	1.4	< 1	< 1
SR WNP Lower[a]	0.09	NC	0.09	NA	NA	--	--	0.08	NC	0.08	0.7	1.4	< 1	< 1
RRM 1.7 to 2.7	4.63	3.14	3.14	NA	NA	--	--	4.40	2.98	2.98	0.7	1.4	**4.3**	**2.1**
RRM 4.4 to 5.2	0.77	NC	0.77	NA	NA	--	--	0.68	NC	0.68	0.7	1.4	< 1	< 1
RRM 16.7 to 20.9	0.36	NC	0.36	NA	NA	--	--	0.35	NC	0.35	0.7	1.4	< 1	< 1
RRM 20.9 to 24.0	0.26	NC	0.26	NA	NA	--	--	0.23	NC	0.23	0.7	1.4	< 1	< 1

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg ww, miligram per kilogram wet weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
CBR, Critical body residue.
CBR_{NOEC}, No effects critical body residue.
CBR_{LOEC}, Lowest effect critical body residue.
NC, Not calculated due to insufficient number of samples.
NA, Not available.
--, Not applicable.
HQ, Hazard quotient.
$HQ_{NOEC} = EPC/CBR_{NOEC}$.
$HQ_{LOEC} = EPC/CBR_{LOEC}$.
a, Reference Reaches: Lower Middle River (MR Lower), Middle Middle River (MR Middle), Upper Middle River (MR Upper), Lower North River (NR Lower), Upper North River (NR Upper), Upstream Reference Reach (RRM -2.7- -0.7), Floodplain Reference Reach Outside of 62-year floodplain (SR RRM 16.7- 20.9), Lower South River Waynesboro Nursery Property (SR WNP Lower), and Upper South River Waynesboro Nursery Property (SR WNP Upper).
b, Values based on common loons, Evers (2008) (See section 4.7.7).
c, Values based on embryo toxicity of MeHg injected in tree swallow eggs (Heinz et al., 2009) and egg to blood extrapolation based on Evers (2009) (See section 4.7.7).

Table 6-23
Summary of Dose Rate Modeling Results - Mammalian Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Receptor Group	Focal Species	Inorganic Mercury (IHg)						Methylmercury (MeHg)					
		HQ Range[a]		AUF-Adjusted HQ Range[a,b]		Cumulative HQ[c]		HQ Range[a]		AUF-Adjusted HQ Range[a,b]		Cumulative HQ[c]	
		HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Semi-Aquatic Piscivorous Mammals	River Otter	0.0-0.1	--	0.0-0.0	--	0.0 (0.0)	--	0.3-2.6	0.1-1.5	0.0-0.3	0.0-0.2	1.0 (0.1)	0.6 (0.1)
Terrestrial Insectivorous Mammals	Short-Tailed Shrew	0.3-1.2	--	--	--	1.2 (0.0)	--	0.4-1.7	0.1-0.4	--	--	1.7 (0.0)	0.4 (0.0)
Terrestrial Herbivorous Mammals	White-Tailed Deer	0.0-0.0	--	0.0-0.0	--	0.0 (0.0)	--	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0 (0.0)	0.0 (0.0)
Terrestrial Aerial Insectivorous Mammal	Big Brown Bat	0.1-0.5	--	0.0-0.1	--	0.3 (0.0)	--	0.9-29	0.6-17	0.0-3.7	0.0-2.2	9.7 (0.2)	5.8 (0.1)

Notes:
--, Not evaluated or not applicable.
HQ, Hazard quotient (HQ = 0.0 represents <0.05).
NOAEL, No observed adverse effects level.
LOAEL, Lowest observed adverse effects level.
HQ_{NOAEL}, NOAEL-based HQ.
HQ_{LOAEL}, LOAEL-based HQ.
AUF, Area use factor.
a, Ranges and representing only the Assessment Reaches between RRM 0.00 and RRM 24.0.
b, Weighted HQs based on AUFs.
c, Maximum possible HQ; Cumulative AUF-weighted HQs within one or more contiguous reaches representing a total area equal to the receptors home range (i.e. $\Sigma HQ_i \times AUF_i$, where i = Exposure Areas and $\Sigma AUF_i = 1$);
HQ for the Reference Reach (RRM -2.7- -0.7) is shown in parenthesis.

Table 6-24
Risk Estimates for Mammals Based on Tissue (Blood) Mercury Concentrations
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	**THg Concentrations (mg/kg ww)**			**THg Benchmarks (mg/kg ww)**		**Hazard Quotient (HQ)**	
	Maximum	**95% UCL**	**EPC**	**CBR_{NOEC}[b]**	**CBR_{LOEC}**	**HQ_{NOEC}**	**HQ_{LOEC}**
Big Brown Bat (*Eptesicus fuscus*)							
MR Middle[a]	0.04	0.03	0.03	0.042	NA	< 1	--
SR Fisherville[a]	0.10	0.05	0.05	0.042	NA	**1.2**	--
SR RRM 16.7 to 20.9a	0.89	0.19	0.19	0.042	NA	**4.5**	--
RRM 1.7 to 2.7	0.29	0.13	0.13	0.042	NA	**3.1**	--
RRM 11.3 to 12.5	0.82	0.43	0.43	0.042	NA	**10.1**	--
Little Brown Bat (*Myotis lucifugus*)							
MR Middle[a]	0.09	NC	0.09	0.042	NA	**2.2**	--
MR Lower[a]	0.91	0.17	0.17	0.042	NA	**4.1**	--
NR Moscow[a]	0.06	0.03	0.03	0.042	NA	< 1	--
NR Upper[a]	0.03	0.03	0.03	0.042	NA	< 1	--
RRM 16.7 to 20.9	3.76	1.57	1.57	0.042	NA	**37.5**	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg ww, milligram per kilogram wet weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
CBR_{NOEC}, No effects critical body residue.
CBR_{LOEC}, Lowest effect critical body residue.
NC, Not calculated due to insufficient number of samples.
NA, Not available.
--, Not applicable.
HQ, Hazard quotient.
$HQ_{NOEC} = EPC/CBR_{NOEC}$.
$HQ_{LOEC} = EPC/CBR_{LOEC}$.

a, Reference Reaches: Lower Middle River (MR Lower), Middle Middle River (MR Middle), Upper North River (NR Upper), Floodplain Reference Reach Outside of 62-year floodplain (SR RRM 16.7- 20.9),South River near Fisherville (SR Fisherville), and North River near Moscow (NR Moscow).

b, Based on big brown bats from reference conditions in South River (Wada et al., 2010) (See section 4.7.7).

Table 6-25
Risk Estimates for Mammals Based on Tissue (Fur) Mercury Concentrations
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	THg Concentrations (mg/kg ww)			THg Benchmarks (mg/kg ww)		Hazard Quotient (HQ)	
	Maximum	95% UCL	EPC	CBR_{NOEC}[b]	CBR_{LOEC}	HQ_{NOEC}	HQ_{LOEC}
Big Brown Bat (*Eptesicus fuscus*)							
MR Middle[a]	4.8	4.6	4.6	10.9	NA	< 1	--
SR Fisherville[a]	13.4	10.4	10.4	10.9	NA	< 1	--
SR RRM 16.7 to 20.9	200.0	42.2	42.2	10.9	NA	**3.9**	--
RRM 1.7 to 2.7	49.1	20.4	20.4	10.9	NA	**1.9**	--
RRM 11.3 to 12.5	42.2	25.2	25.2	10.9	NA	**2.3**	--
Short-Tailed Shrew (*Blarina brevicauda*)							
RRM 13.5 to 16.7	31.5	23.7	23.7	10.9	NA	**2.2**	--
RRM 16.7 to 20.9	88.4	40.7	40.7	10.9	NA	**3.7**	--
Little Brown Bat (*Myotis lucifugus*)							
NR Moscow[a]	14.9	3.3	3.3	10.9	NA	< 1	--
MR Lower[a]	320.8	49.9	49.9	10.9	NA	**4.6**	--
NR Upper[a]	5.4	3.3	3.3	10.9	NA	< 1	--
RRM 1.7 to 2.7	96.8	NC	96.8	10.9	NA	**8.9**	--
RRM 16.7 to 20.9	707.6	257.2	257.2	10.9	NA	**24**	--

Notes:
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
THg, Total mercury.
MeHg, Methylmercury.
mg/kg ww, milligram per kilogram wet weight.
Maximum, Maximum detected.
95% UCL, 95% Upper confidence limit of the mean.
EPC, Exposure point concentration.
CBR_{NOEC}, No effects critical body residue.
CBR_{LOEC}, Lowest effect critical body residue.
NC, Not calculated due to insufficient number of samples.
NA, Not available.
--, Not applicable.
HQ, Hazard quotient.
$HQ_{NOEC} = EPC/CBR_{NOEC.}$
$HQ_{LOEC} = EPC/CBR_{LOEC.}$
a, Reference Reaches: Lower Middle River (MR Lower), Middle Middle River (MR Middle), Upper North River (NR Upper), Floodplain Reference Reach Outside of 62-year floodplain (SR RRM 16.7- 20.9),South River near Fisherville (SR Fisherville), and North River near Moscow (NR Moscow).
b, Based on big brown bats from reference conditions in the South River (Wada et al., 2010) (See section 4.7.7).

Table 8-1a
Weight of Evidence (WOE) Evaluation for Aquatic Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Measurement Endpoints (MEs)																		
	Abiotic Chemistry											Tissue Chemistry (Whole Body)							
	Benthic Sediment[a]	Benthic Porewater[b]	Aquatic Vegetation Porewater[c]	Benthic Surface water[d]	Aquatic Vegetation Surface water[e]	Fish Surface water[f]	Sediment Toxicity[g]	Benthic Community Assessment[h]	Fish Age/Growth[b]	Fish Condition[b]	Fish Community Structure[j]	LI - THg[k]	LI - MeHg[k]	EI - THg[k]	EI - MeHg[k]	Crayfish - THg[l]	Crayfish - MeHg[l]	YOY Bass[m]	Adult Bass[m]
RRM 0.0 to 0.8	No Low 3	No Low 4	No Low 3	No Low 3	No Low 3	No Low 3	No Low 3	No Low 4	--	--	No Low 4	No Low 4	Un High 4	--	--	No Low 4	Un Low 4	No Low 4	Yes Low 4
RRM 0.8 to 1.7	No Low 3	--	--	No Low 3	No Low 3	No Low 3	--	--	No Low 4	No Low 4	--	No Low 4	Un High 4	--	--	No Low 4	Un Medium 4	--	Yes Low 4
RRM 1.7 to 2.7	Un Medium 3	No Low 4	No Low 3	No Low 3	No Low 3	No Low 3	--	--	--	--	--	No Low 4	Un Low 4	No Low 4	Un Low 4	No Low 4	Un High 4	--	Yes High 4
RRM 2.7 to 4.4	Un Medium 3	No Low 4	No Low 3	No Low 3	No Low 3	No Low 3	No Low 3	No Low 4	No Low 4	No Low 4	No Low 4	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4	Yes High 4	Yes High 4
RRM 4.4 to 5.2	Un High 3	--	--	No Low 3	No Low 3	No Low 3	--	--	--	--	--	--	--	--	--	--	--	--	Yes High 4
RRM 5.2 to 7.9	Un Low 3	No Low 4	No Low 3	No Low 3	No Low 3	No Low 3	--	--	No Low 4	No Low 4	--	No Low 4	Un High 4	--	--	No Low 4	Un High 4	--	Yes High 4
RRM 7.9 to 9.2	Un High 3	No Low 4	No Low 3	No Low 3	No Low 3	No Low 3	--	--	--	--	--	No Low 4	Un High 4	Yes Medium 4	Un High 4	No Low 4	Un High 4	--	--
RRM 9.2 to 11.3	Un Low 3	No Low 4	No Low 3	Yes Low 3	No Low 3	No Low 3	--	--	--	--	--	No Low 4	Un High 4	--	--	No Low 4	Un High 4	Yes High 4	Yes High 4
RRM 11.3 to 12.5	Un Medium 3	No Low 4	No Low 3	No Low 3	No Low 3	No Low 3	No Low 3	No Low 4	--	--	No Low 4	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4	Yes High 4	Yes High 4
RRM 12.5 to 13.5	No Low 3	--	--	No Low 3	No Low 3	No Low 3	--	--	No Low 4	No Low 4	--	Yes High 4	Un High 4	--	--	No Low 4	Un High 4	--	--
RRM 13.5 to 16.7	No Low 3	--	--	No Low 3	No Low 3	No Low 3	--	--	--	--	--	No Low 4	Un High 4	--	--	No Low 4	Un High 4	--	Yes High 4
RRM 16.7 to 20.9	Un Low 3	--	--	No Low 3	No Low 3	No Low 3	--	--	--	--	--	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4	Yes High 4	Yes High 4
RRM 20.9 to 24.0	No Low 3	No Low 4	No Low 3	No Low 3	No Low 3	No Low 3	No Low 3	No Low 4	No Low 4	No Low 4	No Low 4	No Low 4	Un High 4	No Low 4	Un High 4	No Low 4	Un High 4	--	Yes High 4
SFSR	No Low 3	--	No Low 3	No Low 3	No Low 3	No Low 3	--	--	--	--	--	No Low 4	Un Low 4	--	--	No Low 4	Un Medium 4	No Low 4	Yes Medium 4

Notes:

RRM, Relative river mile.

Un, Undetermined presence or absence of potential adverse effects (i.e., $HQ_{No\ Effects} > 1$, but $HQ_{Low\ Effects} < 1$).

--, Not evaluated. LI, Larval invertebrates.

SFSR, South Fork Shenandoah River. EI, Emergent invertebrates.

WOE Evaluation Elements (See Appendix G): THg, Total mercury.

Presence of Potential Adverse Effects (Yes, Undetermined, No). MeHg, Methylmercury.

Potential for Effects (Low, Medium, High). YOY, Young of the year.

Relative Weight of ME (1, 2, 3, 4, 5).

a, Conservatively based on the results in Table 6-3. h, Based on Benthic Community Structure Metric Analyses results in Table 6-4.

b, Based on results in Table 6-2. i, Based on fish age, growth, and condition evaluations discussed in Section 6.2.3.

c, Based on the results in Table 6-16. j, Based on fish community structure evaluation discussed in Section 6.2.4.

d, Conservatively based on the results for MeHg on Tables 6-1a and 6-1b. k, Based on the results in Table 6-5; Presence/absence of potential adverse effects are undetermined (Un) because low-effect based Hazard Quotients (HQs) are not available.

e, Based on the results in Table 6-15a. l, Based on the results in Table 6-6.

f, Based on the Fish results in Table 6-8a and 6-8b.

m, Based on HQ_{LOEC} from Table 6-9.

g, Based on sediment toxicity test evaluations in Table 6-4.

Table 8-1b
Reach-Specific Weight of Evidence (WOE) Evaluation for Aquatic Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

RRM 0.0-0.8		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} C^{No} D^{No} E^{No} Q^{No} R^{No}	B^{No} F^{No} I^{No} M^{No} O^{No} P^{Yes} S^{No}	
	Medium					
	High				J^{Un}	

RRM 0.8-1.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} C^{No} D^{No} R^{No}	G^{No} H^{No} I^{No} M^{No} P^{Yes}	
	Medium				N^{Un}	
	High				J^{Un}	

RRM 1.7-2.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			C^{No} D^{No} Q^{No} R^{No}	B^{No} I^{No} K^{No} M^{No} L^{Un}	
	Medium			A^{Un}		
	High				N^{Un} P^{Yes}	

RRM 2.7-4.4		ME_W				
		1	2	3	4	5
Potential for Effects	Low			C^{No} D^{No} E^{No} Q^{No} R^{No}	B^{No} F^{No} G^{No} H^{No} I^{No} K^{No} M^{No} S^{No}	
	Medium			A^{Un}		
	High				J^{Un} L^{Un} N^{Un} O^{Yes} P^{Yes}	

RRM 4.4-5.2		ME_W				
		1	2	3	4	5
Potential for Effects	Low			C^{No} D^{No} R^{No}		
	Medium					
	High			A^{Un}	P^{Yes}	

RRM 5.2-7.9		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{Un} C^{No} D^{No} Q^{No} R^{No}	B^{No} G^{No} H^{No} I^{No} M^{No}	
	Medium					
	High				J^{Un} N^{Un} P^{Yes}	

RRM 7.9-9.2		ME_W				
		1	2	3	4	5
Potential for Effects	Low			C^{No} D^{No} Q^{No} R^{No}	B^{No} I^{No} M^{No}	
	Medium				K^{Yes}	
	High			A^{Un}	J^{Un} L^{Un} N^{Un}	

RRM 9.2-11.3		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{Un} C^{Yes} D^{No} Q^{No} R^{No}	B^{No} I^{No} M^{No}	
	Medium					
	High				J^{Un} N^{Un} O^{Yes} P^{Yes}	

RRM 11.3-12.5		ME_W				
		1	2	3	4	5
Potential for Effects	Low			C^{No} D^{No} E^{No} Q^{No} Q^{No} R^{No}	B^{No} F^{No} I^{No} K^{No} M^{No} S^{No}	
	Medium			A^{Un}		
	High				J^{Un} L^{Un} N^{Un} O^{Yes} P^{Yes}	

RRM 12.5-13.5		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} C^{No} D^{No} R^{No}	G^{No} H^{No} M^{No}	
	Medium					
	High				I^{Yes} J^{Un} N^{Un}	

RRM 13.5-16.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} D^{No} D^{No} R^{No}	I^{No} M^{No}	
	Medium					
	High				J^{Yes} N^{yes} P^{Yes}	

RRM 16.7-20.9		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{Un} C^{No} D^{No} R^{No}	I^{No} K^{No} M^{No}	
	Medium				P^{Yes}	
	High				J^{Un} L^{Un} N^{Un} O^{Yes} P^{Yes}	

RRM 20.9-24.0		ME_W				
		1 234512345				
Potential for Effects	Low			A^{No} C^{No} D^{No} E^{No} Q^{No} R^{No}	B^{No} F^{No} G^{No} H^{No} I^{No} M^{No} S^{No}	
	Medium					
	High				J^{Un} L^{Un} N^{Un} P^{Yes}	

SFSR		ME_W				
Potential for Effects	Low			A^{No} C^{No} D^{No} Q^{No} R^{No}	I^{No} J^{Un} M^{No} O^{No} P^{Yes}	
	Medium				N^{Un}	
	High					

Notes:

RRM, Relative river mile; $ME_{W,}$ Weight of the Measurement Endpoint; SFSR, South Fork Shenandoah River.

ME Designations:

A - Sediment Chemistry (Benthic Invertebrates); B - Pore water Chemistry (Benthic Invertebrates); C - Surface water Chemistry (Benthic Invertebrates); D - Surface water Chemistry (Fish); E - Sediment Toxicity (Benthic Invertebrates); F - Benthic Community Assessment; G - Fish Age/Growth; H - Fish Condition; I - Tissue Chemistry (THg in Larval Invertebrates); J - Tissue Chemistry (MeHg in Larval Invertebrates); K - Tissue Chemistry (THg in Emergent Invertebrates); L - Tissue Chemistry (MeHg in Emergent Invertebrates); M - Tissue Chemistry (THg in Crayfish); N- Tissue Chemistry (MeHg in Crayfish); O - Tissue Chemistry (THg/MeHg in Young-of-the-Year bass species); P - Tissue Chemistry (THg/MeHg in adult bass species); Q - Pore water Chemistry (Aquatic Vegetation); R - Surface water Chemistry (Aquatic Vegetation); S - Fish Community Structure.

The values for ME_W, the Presence of Potential Adverse Effects (Yes/Undetermined/No) and the Potential for Effects (Low/Medium/High) are provided in Table 8-1a, which are based on the criteria developed for the WOE evaluation (see Appendix G).

Table 8-2a
Weight of Evidence (WOE) Evaluation for Semi-Aquatic Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Measurement Endpoints (MEs)					
	Amphibians		Belted Kingfisher		Mallard Duck	River Otter
	Surface Water Chemistry[a]	Tissue Chemistry[b] (Whole Body)	DRM[c]	Tissue Chemistry[d] (Blood)	DRM[c]	DRM[c]
RRM 0.0 to 0.8	No Low 3	No Low 4	No Low 3	No Low 4	No Low 4	No Low 3
RRM 0.8 to 1.7	No Low 3	--	Un Low 3	--	No Low 4	No Low 3
RRM 1.7 to 2.7	No Low 3	Yes Medium 4	Yes Medium 3	--	No Low 4	No Low 3
RRM 2.7 to 4.4	No Low 3	--	Yes High 3	Un Low 4	Un Low 4	No Low 3
RRM 4.4 to 5.2	No Low 3	Yes[e] High[e] 4	Yes Medium 3	Un Low 4	No Low 4	No Low 3
RRM 5.2 to 7.9	No Low 3	--	Yes High 3	Yes Low 4	Un Low 4	No Low 3
RRM 7.9 to 9.2	No Low 3	Yes[f] High[f] 4	Yes High 3	Un Low 4	No Low 4	No Low 3
RRM 9.2 to 11.3	Yes Low 3	--	Yes High 3	Yes Low 4	No Low 4	No Low 3
RRM 11.3 to 12.5	No Low 3	Yes High 4	Yes High 3	Yes Medium 4	No Low 4	No Low 3
RRM 12.5 to 13.5	No Low 3	Yes Medium 4	Yes High 3	--	Yes Medium 4	No Low 3
RRM 13.5 to 16.7	No Low 3	Yes High 4	Yes High 3	Yes Medium 4	Un Low 4	No Low 3
RRM 16.7 to 20.9	No Low 3	Yes[g] High[g] 4	Yes High 3	--	Un Low 4	No Low 3
RRM 20.9 to 24.0	No Low 3	Yes High 4	Yes High 3	--	Un Low 4	No Low 3
SFSR	No Low 3	Un Low 4	Yes High 3	No Low 4	No Low 4	No Low 3

Notes:
--, Not evaluated.
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
DRM, Dose rate model.
WOE Evaluation Elements (See Appendix G):
Presence of Potential Adverse Effects (Yes, Undetermined, No).
Potential for Effects (Low, Medium, High).
Relative Weight of ME (1, 2, 3, 4, 5).
a, Based on Table 6-17a and b.
b, Based on available data for three species (Table 6-18); where evaluations for more than one species is available for an Assessment Reach, the most conservative results are selected (see notes f, g, and h).
c, Based on AUF-Adjusted HQs for MeHg resulting from food web modeling (See Tables F-10, F-11, F-13, and F- for belted kingfisher, mallard duck, tree swallow, and river otter, respectively, in Appendix F).
d, Based on blood mercury evaluations in Table 6-21 (IHg for belted kingfisher and MeHg for tree swallow).
e, Based on Northern two-lined salamander; Evaluation for American toad indicates no potential effects and low magnitude of effects.
f, Based on Northern two-lined salamander; Evaluation for American toad indicates undetermined potential effects and low magnitude effects.
g, Based on Northern two-lined salamander; Evaluation for American toad indicates undetermined potential effects and low magnitude effects and evaluation for red-back salamander indicates no potential effects and low magnitude of effects.

Table 8-2b
Reach-Specific Weight of Evidence (WOE) Evaluation for Semi-Aquatic Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

RRM 0.0-0.8		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} C^{No} F^{No}	B^{No} D^{No} E^{no}	
	Medium					
	High					

RRM 0.8-1.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} C^{Un} F^{No}	E^{No}	
	Medium					
	High					

RRM 1.7-2.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	E^{No}	
	Medium			C^{Yes}	B^{Yes}	
	High					

RRM 2.7-4.4		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	D^{Un} E^{Un}	
	Medium					
	High			C^{Yes}		

RRM 4.4-5.2		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	D^{Un} E^{No}	
	Medium			C^{Yes}		
	High				B^{Yes}	

RRM 5.2-7.9		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	D^{Yes} E^{Un}	
	Medium					
	High			C^{Yes}	B^{Yes}	

RRM 7.9-9.2		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	D^{Un} E^{No}	
	Medium					
	High			C^{Yes}	B^{Yes}	

RRM 9.2-11.3		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{Yes} F^{No}	D^{Yes} E^{No}	
	Medium					
	High			C^{Yes}		

RRM 11.3-12.5		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	E^{No}	
	Medium				D^{Yes}	
	High			C^{Yes}	B^{Yes}	

RRM 12.5-13.5		ME_W				
		1	2	3	4	5
Magnitude of Effects	Low			A^{No} F^{No}		
	Medium				B^{Yes} E^{Yes}	
	High			C^{Yes}		

RRM 13.5-16.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	E^{Un}	
	Medium				D^{Yes}	
	High			C^{Yes}	B^{Yes}	

RRM 16.7-20.9		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{No}	E^{Un}	
	Medium					
	High			C^{Yes}	B^{Yes}	

RRM 20.9-24.0		ME_W				
		1 234512345				
Potential for Effects	Low			A^{No} F^{No}	E^{Un}	
	Medium					
	High			C^{Yes}	B^{yes}	

SFSR		ME_W				
Potential for Effects	Low			A^{No} F^{No}	D^{No} E^{Un}	
	Medium					
	High			C^{Yes}	B^{Un}	

Notes:

RRM, Relative river mile; $ME_{W,}$ Weight of the Measurement Endpoint; SFSR, South Fork Shenandoah River.

ME Designations:

A - Surface Water Chemistry - Amphibian; B - Tissue Chemistry - Amphibian (whole body) ; C - Dose Rate Modeling (DRM) - Belted kingfisher; D - Tissue Chemistry - Belted kingfisher (blood); E - DRM - Mallard duck; F - DRM - River Otter.

The values for ME_W, the Presence of Potential Adverse Effects (Yes/Undetermined/No) and the Potential for Effects (Low/Medium/High) are provided in Table 8-2a, which are based on the criteria developed for the WOE evaluation (see Appendix G).

Table 8-3a
Weight of Evidence (WOE) Evaluation for Terrestrial Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Measurement Endpoints (MEs)												
	Plants	Invertebrates	Eastern Screech Owl	Tree Swallow		American Robin		Short-Tailed Shrew		White-Tailed Deer	Big Brown Bat		
	Soil Chemistry[a]	Soil Chemistry[b]	DRM[c]	DRM[c]	Tissue Chemistry (Blood)[d]	DRM[c]	Tissue Chemistry (Blood)[d]	DRM[c]	Tissue Chemistry (Fur)[e]	DRM[c]	DRM[c]	Tissue Chemistry (Blood)[f]	Tissue Chemistry (Fur)[e]
RRM 0.0 to 0.8	No Low 3	Un Low 3	Un Low 3	No Low 3	--	Un Low 3	--	Un Low 3	--	No Low 3	No Low 3	--	--
RRM 0.8 to 1.7	Un Low 3	Yes Medium 3	Un Low 3	No Low 3	Un Low 4	Yes Medium 3	--	Un Low 3	--	No Low 3	No Low 3	--	--
RRM 1.7 to 2.7	No Low 3	Un Low 3	Un Low 3	No Low 3	Un Low 4	Yes Medium 3	Yes High 4	Un Low 3	--	No Low 3	No Low 3	Un Medium 4	Un Low 4
RRM 2.7 to 4.4	No Low 3	Un Low 3	Yes High 3	Yes High 3	Yes Medium 4	Yes Medium 3	--	Un Low 3	--	No Low 3	Un Low 3	--	--
RRM 4.4 to 5.2	No Low 3	Un Low 3	Un Low 3	Yes High 3	Yes Medium 4	Yes Medium 3	No Low 4	Un Low 3	--	No Low 3	No Low 3	--	--
RRM 5.2 to 7.9	No Low 3	Un Low 3	Yes High 3	Yes High 3	Yes Medium 4	Yes Medium 3	--	Un Low 3	--	No Low 3	Yes Medium 3	--	--
RRM 7.9 to 9.2	No Low 3	Un Low 3	Yes High 3	Yes High 3	Yes Medium 4	Yes Medium 3	--	Un Low 3	--	No Low 3	Un Low 3	--	--
RRM 9.2 to 11.3	No Low 3	Un Low 3	Yes Medium 3	Yes High 3	Yes Medium 4	Un Low 3	--	Un Low 3	--	No Low 3	Un Low 3	--	--
RRM 11.3 to 12.5	No Low 3	Yes Medium 3	Yes Medium 3	Yes Medium 3	Yes Medium 4	Un Low 3	--	No Low 3	--	No Low 3	No Low 3	Un High 4	Un Medium 4
RRM 12.5 to 13.5	No Low 3	No Low 3	Yes High 3	Yes High 3	--	Yes Medium 3	--	Un Low 3	--	No Low 3	No Low 3	--	--
RRM 13.5 to 16.7	No Low 3	No Low 3	Yes High 3	Yes High 3	Yes High 4	Yes Medium 3	--	Un Low 3	Un Medium 4	No Low 3	No Low 3	--	--
RRM 16.7 to 20.9	No Low 3	No Low 3	Yes High 3	Yes High 3	Yes High 4	Yes Medium 3	No Low 4	Un Low 3	Un Medium 4	No Low 3	No Low 3	--	--
RRM 20.9 to 24.0	No Low 3	No Low 3	Yes High 3	Yes High 3	Yes Medium 4	Un Low 3	No Low 4	No Low 3	--	No Low 3	No Low 3	--	--
SFSR	No Low 3	No Low 3	Yes High 3	Yes High 3	Un Low 4	Un Low 3	--	No Low 3	--	No Low 3	Yes[g] High[g] 3	--	--

Notes:
--, Not evaluated.
RRM, Relative river mile.
SFSR, South Fork Shenandoah River.
DRM, Dose rate model.
WOE Evaluation Elements (See Appendix G):
Presence of Potential Adverse Effects (Yes, Undetermined, No).
Potential for Effects (Low, Medium, High).
Relative Weight of ME (1, 2, 3, 4, 5).
a, Based on the most conservative results among the four floodplains (0.3, 2, 5, and 62 year) in Table 6-19.
b, Based on the most conservative results among the four floodplains (0.3, 2, 5, and 62 year) in Table 6-20.
c, Based on AUF-Adjusted HQs for MeHg resulting from food web modeling; See Appendix F, Table F-12 (Eastern screech owl), Table F-14 (American robin), Table F-16 (short-tailed shrew), Table F-17 (white-tailed deer), Table F-18 (big brown bat).
d, Based on available HQs for blood MeHg evaluations in Table 6-22.
e, Based on available HQs for fur THg evaluations in Table 6-24.
f, Based on available HQs for blood IHg evaluations in Table 6-23.
g, Highly uncertain because the dietary EPCs are assumed to be the same as those in RRM 20.9-24.0 and AUF = 1 is assumed.

Table 8-3b
Reach-Specific Weight of Evidence (WOE) Evaluation for Terrestrial Receptors
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

RRM 0.0-0.8		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{Un} C^{Un} D^{No} F^{Un} H^{Un} J^{No} K^{No}		
	Medium					
	High					

RRM 0.8-1.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} C^{Un} D^{No} H^{Un} J^{No} K^{No}	E^{Un}	
	Medium			B^{Yes} F^{Yes}		
	High					

RRM 1.7-2.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{Un} C^{Un} D^{No} H^{Un} J^{No} K^{No}	M^{Un} E^{Un}	
	Medium			F^{Yes}	L^{Un}	
	High				G^{Yes}	

RRM 2.7-4.4		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{Un} H^{Un} J^{No} K^{Un}		
	Medium			F^{Yes}	E^{Yes}	
	High			C^{Yes} D^{Yes}		

RRM 4.4-5.2		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{Un} C^{Un} H^{Un} J^{No} K^{No}	G^{No}	
	Medium			F^{Yes}	E^{Yes}	
	High			D^{Yes}		

RRM 5.2-7.9		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{Un} H^{Un} J^{No}		
	Medium			F^{Yes} K^{Yes}	E^{Yes}	
	High			C^{Yes} D^{Yes}		

RRM 7.9-9.2		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{Un} H^{Un} J^{No} K^{Un}		
	Medium			F^{Yes}	E^{Yes}	
	High			C^{Yes} D^{yes}		

RRM 9.2-11.3		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{Un} F^{Un} H^{Un} J^{No} K^{Un}		
	Medium			C^{Yes}	E^{Yes}	
	High			D^{Yes}		

RRM 11.3-12.5		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} F^{Un} H^{No} J^{No} K^{No}		
	Medium			B^{Yes} C^{Yes} D^{Yes}	M^{Un}	
	High				L^{Un}	

RRM 12.5-13.5		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{No} H^{Un} J^{No} K^{No}		
	Medium			F^{Yes}		
	High			C^{Yes} D^{Yes}		

RRM 13.5-16.7		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{No} H^{Un} J^{No} K^{No}		
	Medium			F^{Yes}	I^{Un}	
	High			C^{Yes} D^{Yes}	E^{Yes}	

RRM 16.7-20.9		ME_W				
		1	2	3	4	5
Potential for Effects	Low			A^{No} B^{No} H^{Un} J^{No} K^{No}	G^{No}	
	Medium			F^{Yes}	I^{Un}	
	High			C^{Yes} D^{Yes}	E^{Yes}	

RRM 20.9-24.0		ME_W				
		1 234512345				
Potential for Effects	Low			A^{No} B^{No} F^{Un} H^{Un} J^{No} K^{No}	G^{No}	
	Medium				E^{Yes}	
	High			C^{yes} D^{Yes}		

SFSR		ME_W				
Potential for Effects	Low			A^{No} B^{No} F^{Un} H^{Un} J^{No}		
	Medium				E^{un}	
	High			C^{Yes} D^{Yes} K^{Yes}		

Notes:

RRM, Relative river mile; ME_W, Weight of the Measurement Endpoint; SFSR, South Fork Shenandoah River.

ME Designations:
A - Soil Chemistry - Plants; B - Soil Chemistry - Invertebrates; C - Dose Rate Modeling (DRM) - Eastern screech owl; D - DRM - Tree swallow; E - Tissue Chemistry - Tree swallow (blood); F - DRM - American robin; G - Tissue Chemistry - American robin (blood); H - DRM - Short-tailed shrew; I - Tissue Chemistry - Short-tailed shrew (fur); J - DRM - White-tailed deer; K - DRM - Big brown bat; L - Tissue Chemistry - Big brown bat (blood); M - Tissue Chemistry - Big brown bat (fur).

The values for ME_W, the Presence of Potential Adverse Effects (Yes/Undetermined/No) and the Potential for Effects (Low/Medium/High) are provided in Table 8-3a which are based on the criteria developed for the WOE evaluation (see Appendix G).

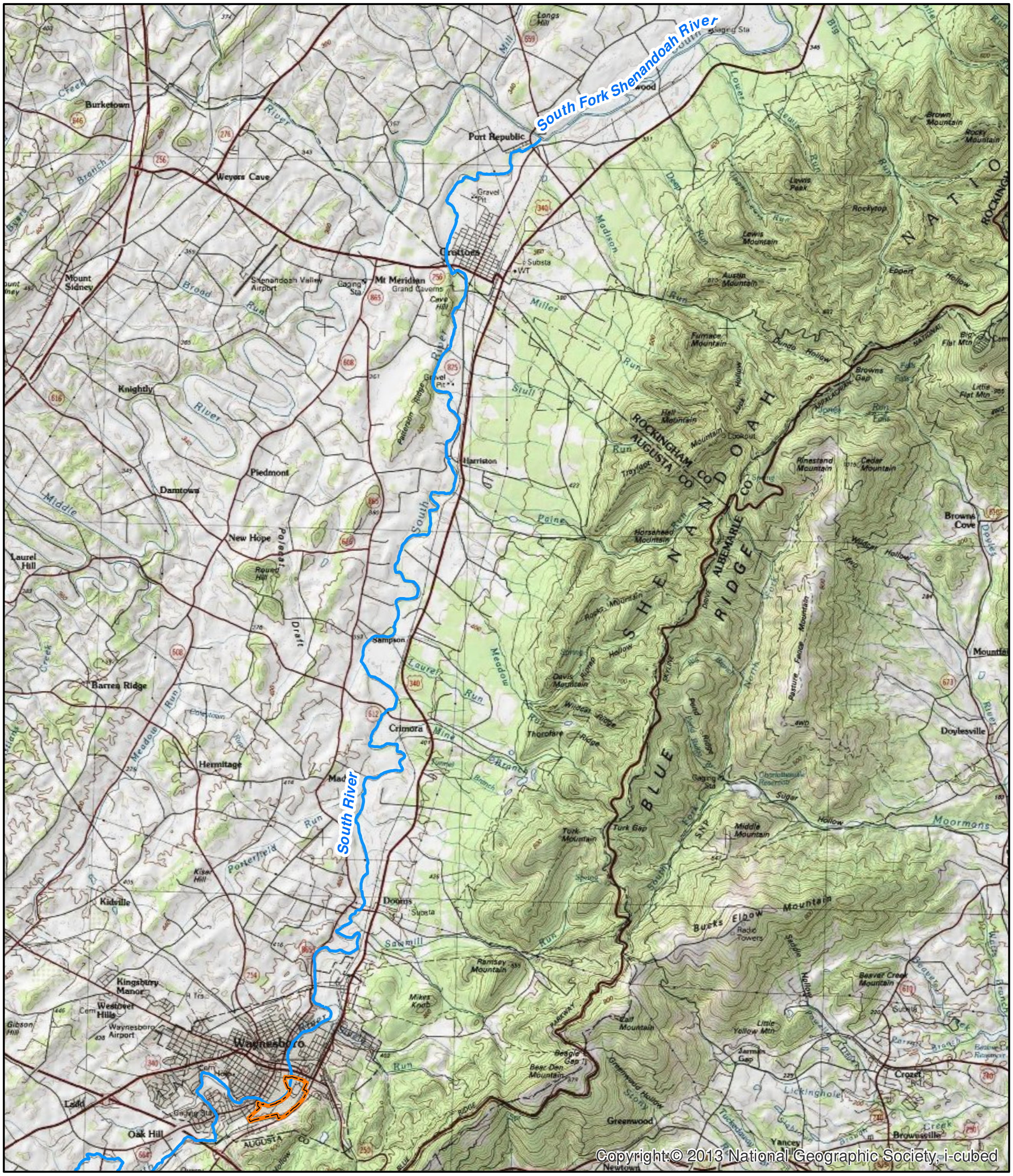
Table 9-1
Summary of Potential Ecological Risks[a]
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia

Assessment Reach	Receptors Potentially at Risk		
	Aquatic	Semi-Aquatic	Terrestrial
RRM 0.0 to 0.8	Invertebrates[b]	--	--
RRM 0.8 to 1.7	Invertebrates	--	--
RRM 1.7 to 2.7	Invertebrates Adult Fish	--	Ground insectivorous birds
RRM 2.7 to 4.4	YOY and Adult Fish Invertebrates	Piscivorous birds	Carnivorous birds Aerial insectivorous birds
RRM 4.4 to 5.2	Invertebrates[c] Adult fish	Amphibians	Aerial insectivorous birds
RRM 5.2 to 7.9	Invertebrates Adult fish	Piscivorous birds	Carnivorous birds Aerial insectivorous birds
RRM 7.9 to 9.2	Invertebrates	Amphibians Piscivorous birds	Carnivorous birds Aerial insectivorous birds
RRM 9.2 to 11.3	YOY and Adult Fish Invertebrates	Piscivorous birds	Aerial insectivorous birds
RRM 11.3 to 12.5	YOY and Adult Fish Invertebrates	Amphibians Piscivorous birds	Aerial insectivorous mammals
RRM 12.5 to 13.5	Invertebrates	Piscivorous birds	Carnivorous birds Aerial insectivorous birds
RRM 13.5 to 16.7	Adult Fish Invertebrates	Amphibians Piscivorous birds	Carnivorous birds Aerial insectivorous birds
RRM 16.7 to 20.9	YOY and Adult Fish Invertebrates	Amphibians Piscivorous birds	Carnivorous birds Aerial insectivorous birds
RRM 20.9 to 24.0	Adult Fish Invertebrates	Amphibians Piscivorous birds	Carnivorous birds Aerial insectivorous birds
SFSR	--	Piscivorous birds	Carnivorous birds Aerial insectivorous birds Aerial insectivorous mammals

Notes:
RRM, Relative river mile.
--, Potential risks not identified based on available evaluations.
SFSR, South Fork Shenandoah River.
YOY, Young of the year.
a, Based on information provided in the Tables 8-1 through 8-3.
b, Invertebrates include crayfish, larval invertebrates, and emergent invertebrates.
c, Based on sediment chemistry (with a Relative Weight = 3 for the Measurement Endpoint).

Figures

N



Legend

South River

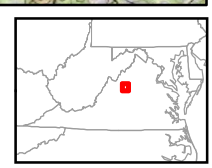
Approximate Site Boundary

0 1.25 2.5 5
Miles

1 inch = 2.5 miles

Reference:
USGS Topographic Basemap

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



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Prepared by: MAL

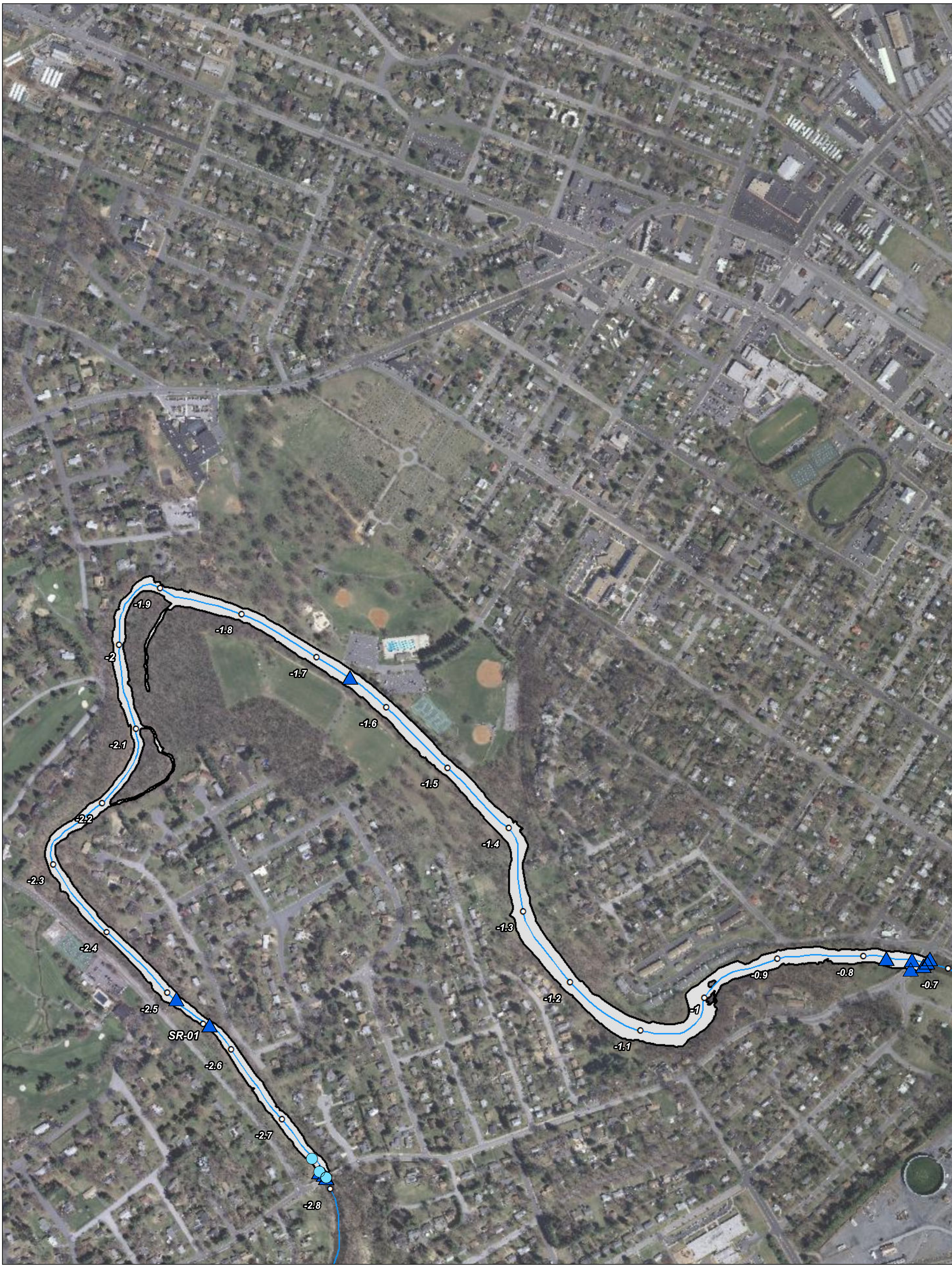
Checked by: JB/BR

Date: 8/15/2014

Figure 1-1
Site Location Map
AOC 4 Ecological Risk Assessment Report

Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\EcoRiskAssessmentReport\Figure 1-1 Waynesboro Site Location Map.mxd



Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 750 1,500 Feet

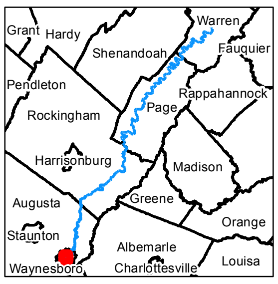
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Job: 18986307.01340	**Figure 3-1**
Prepared by: VP	**Panel 1 of 16**
Checked by: BR	**Surface Water Sample Reach RRM -2.7 to -0.7** **AOC 4 Ecological Risk Assessment Report**
Date: 8/14/2014	Former Dupont Waynesboro Plant Waynesboro, Virginia

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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 462.5 925 Feet

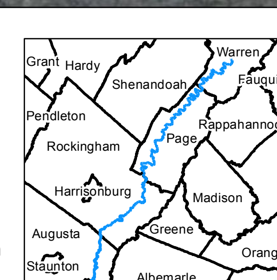
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Prepared by: VP

Checked by: BR

Date: 8/14/2014

Figure 3-1
Panel 2 of 16
Surface Water Sample Reach RRM -0.7 to 0.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 437.5 875 Feet

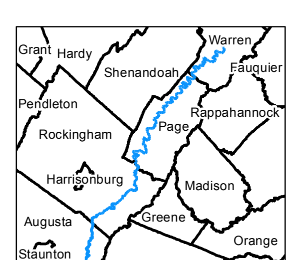
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Prepared by: VP	
Checked by: BR	
Date: 8/14/2014	

Figure 3-1
Panel 3 of 16
Surface Water Sample Reach RRM 0.0 to 0.8
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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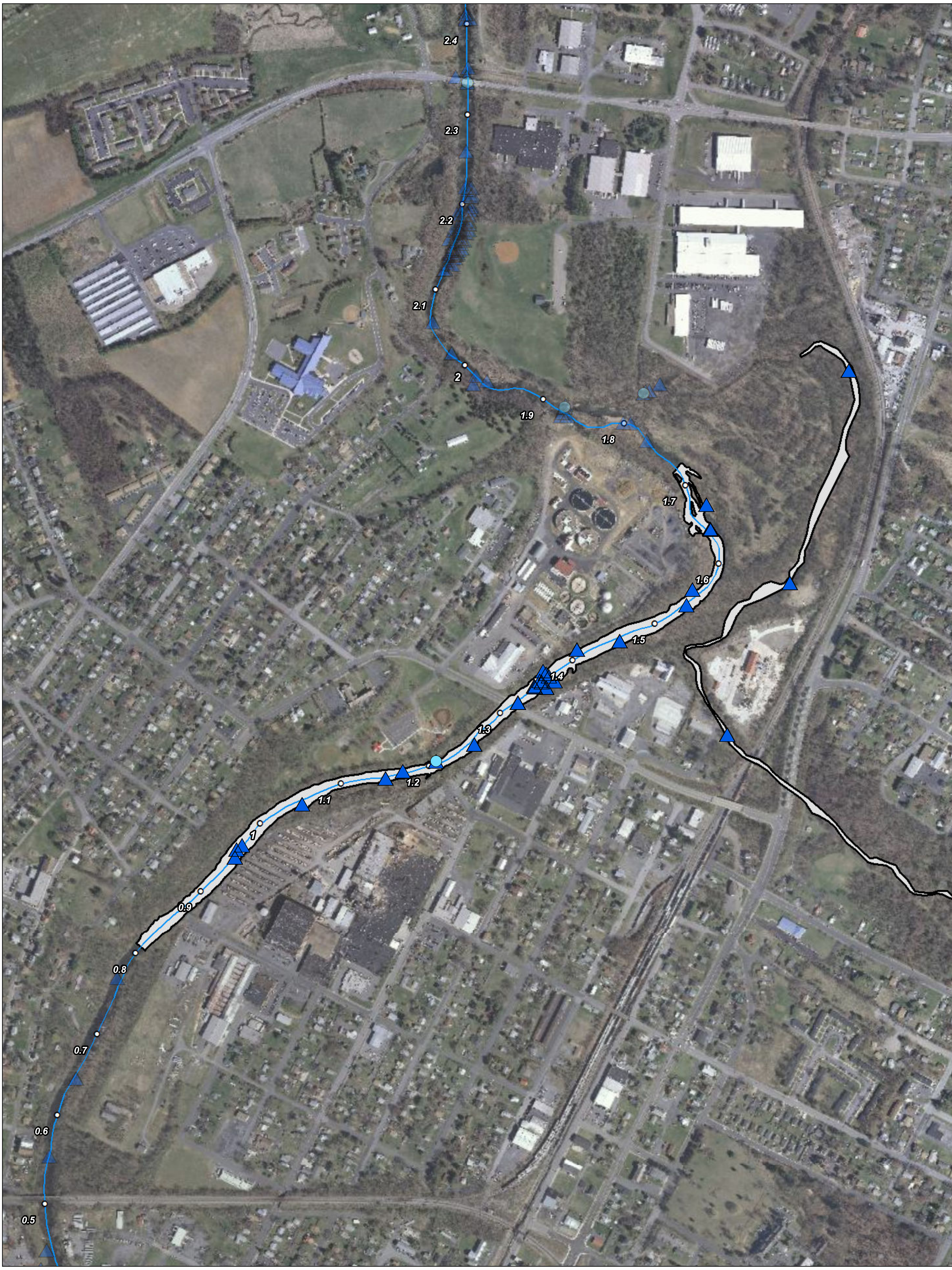

Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

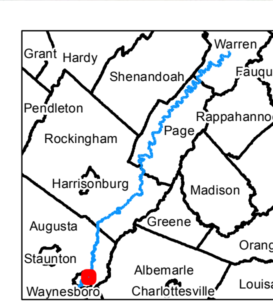

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Figure 3-1
Panel 4 of 16
Surface Water Sample Reach RRM 0.8 to 1.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 500 1,000 Feet

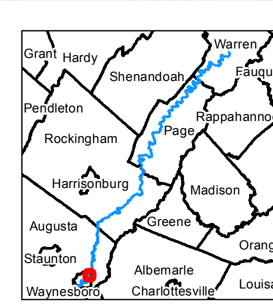
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Job: 18986307.01340	**Figure 3-1** **Panel 5 of 16** **Surface Water Sample Reach RRM 1.7 to 2.7** **AOC 4 Ecological Risk Assessment Report** Former Dupont Waynesboro Plant Waynesboro, Virginia
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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 700 1,400 Feet

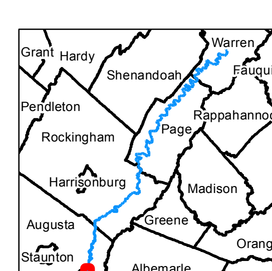
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Job: 18986307.01340	**Figure 3-1**
Prepared by: VP	**Panel 6 of 16**
Checked by: BR	**Surface Water Sample Reach RRM 2.7 to 4.4** **AOC 4 Ecological Risk Assessment Report**
Date: 8/14/2014	Former Dupont Waynesboro Plant Waynesboro, Virginia

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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 550 1,100 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

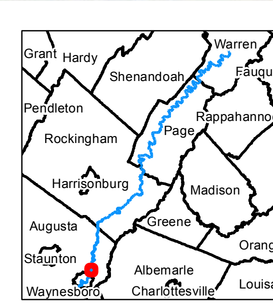

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Figure 3-1
Panel 7 of 16
Surface Water Sample Reach RRM 4.4 to 5.2
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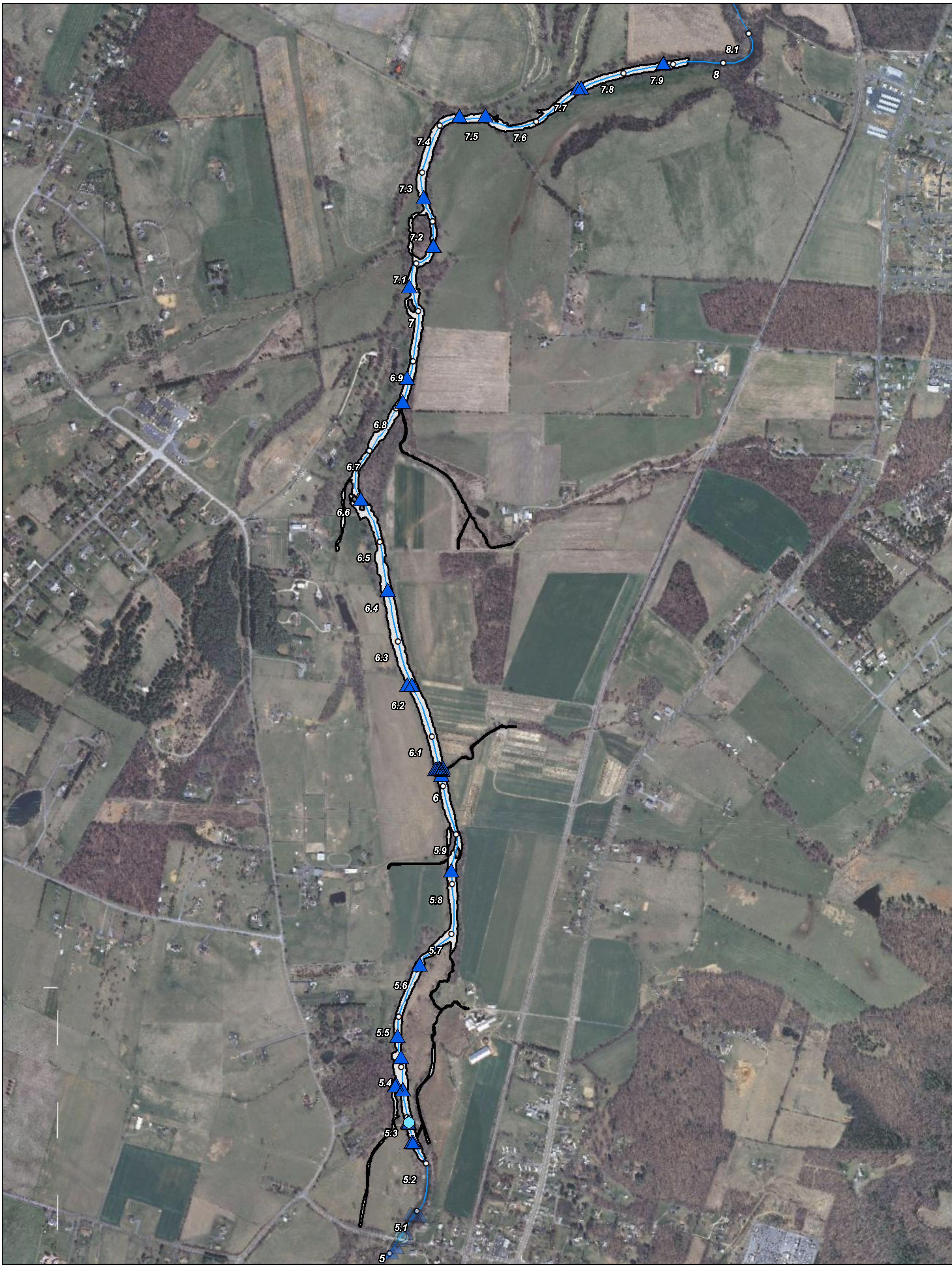

Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 1,300 2,600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

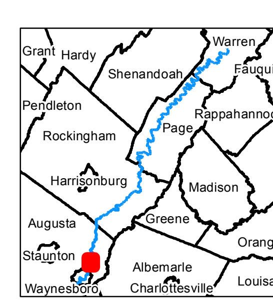

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Figure 3-1
Panel 8 of 16
Surface Water Sample Reach RRM 5.2 to 7.9
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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

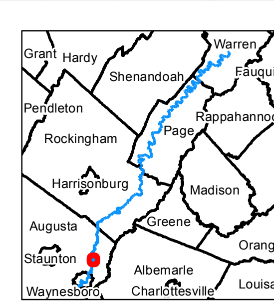

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Figure 3-1
Panel 9 of 16
Surface Water Sample Reach RRM 7.9 to 9.2
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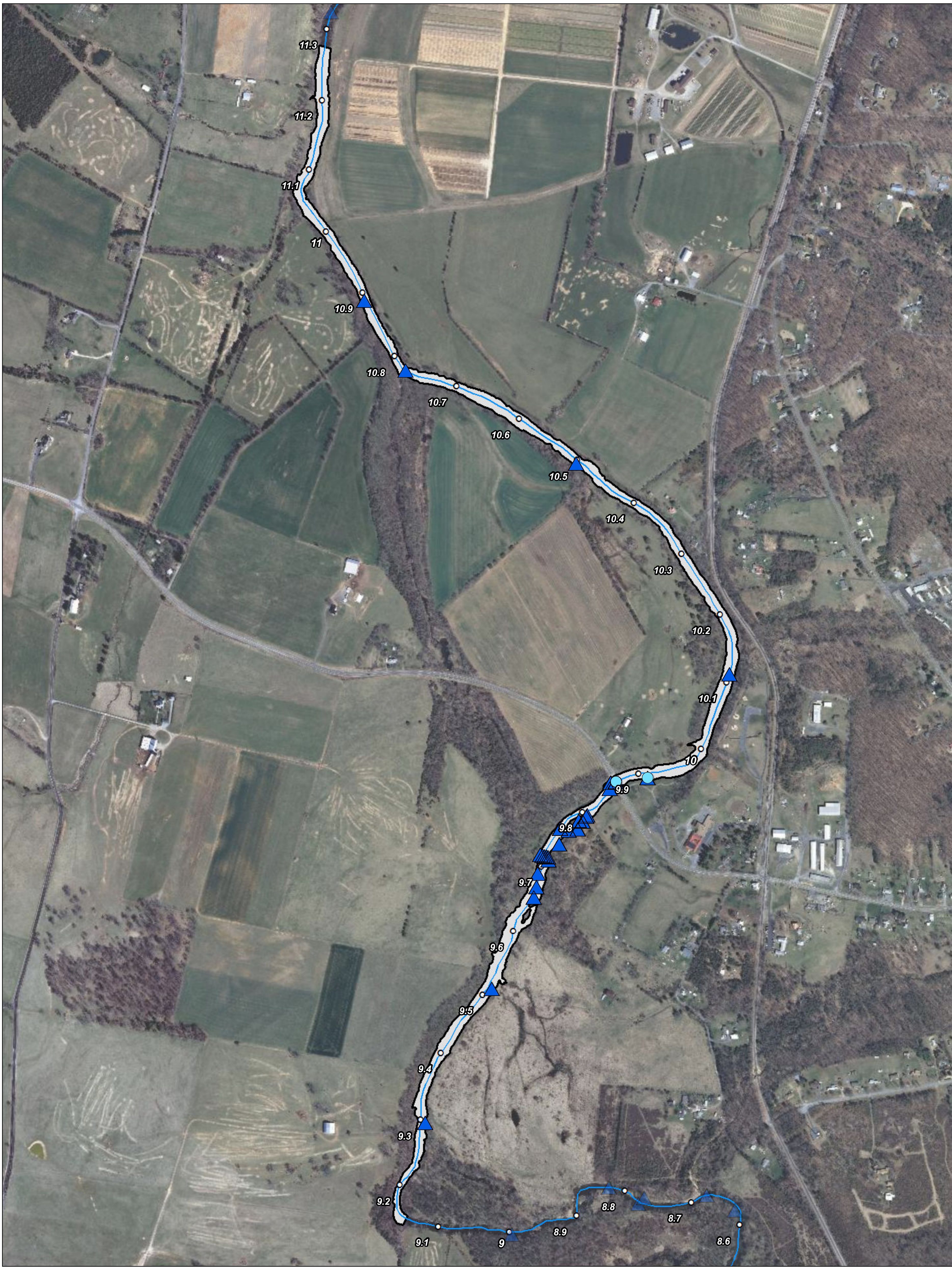
Waynesboro, Virginia



Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 900 1,800 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

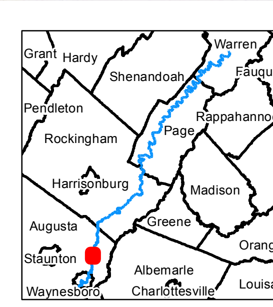


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Figure 3-1
Panel 10 of 16
Surface Water Sample Reach RRM 9.2 to 11.3
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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

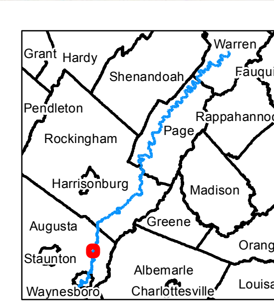

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Figure 3-1
Panel 11 of 16
Surface Water Sample Reach RRM 11.3 to 12.5
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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

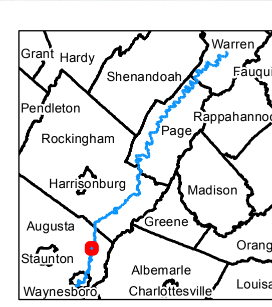

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Figure 3-1
Panel 12 of 16
Surface Water Sample Reach RRM 12.5 to 13.5
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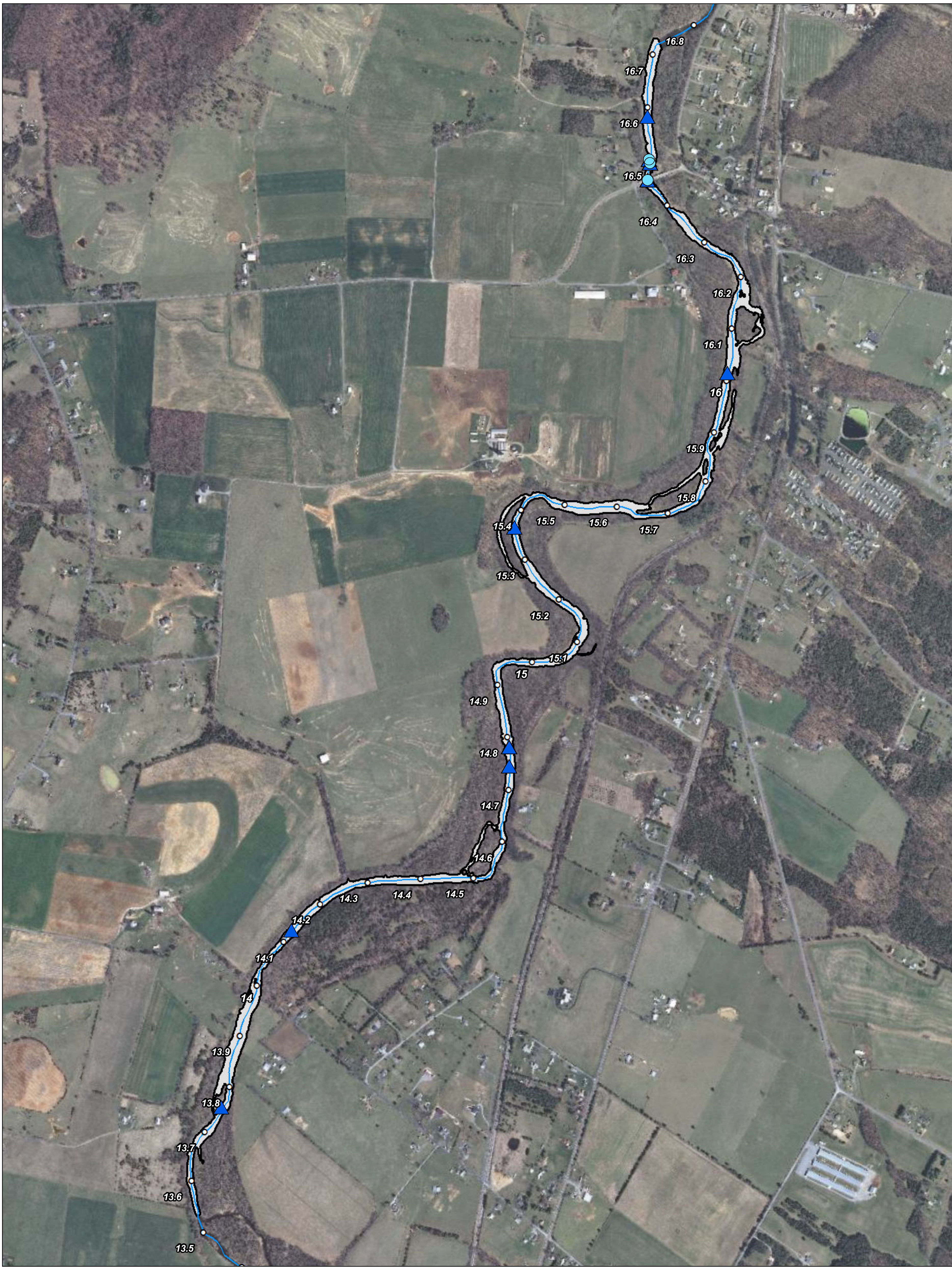


Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 1,250 2,500 Feet

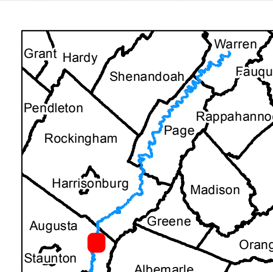
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Job: 18986307.01340	**Figure 3-1**
Prepared by: VP	**Panel 13 of 16**
Checked by: BR	**Surface Water Sample Reach RRM 13.5 to 16.7** **AOC 4 Ecological Risk Assessment Report**
Date: 8/14/2014	Former Dupont Waynesboro Plant Waynesboro, Virginia

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Legend

Storm Flow
RRM Intervals (Mile)
LiDAR Reach
Baseline Flow
Stream

0 1,850 3,700 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
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Projection: Transverse Mercator
Linear Unit: Foot US

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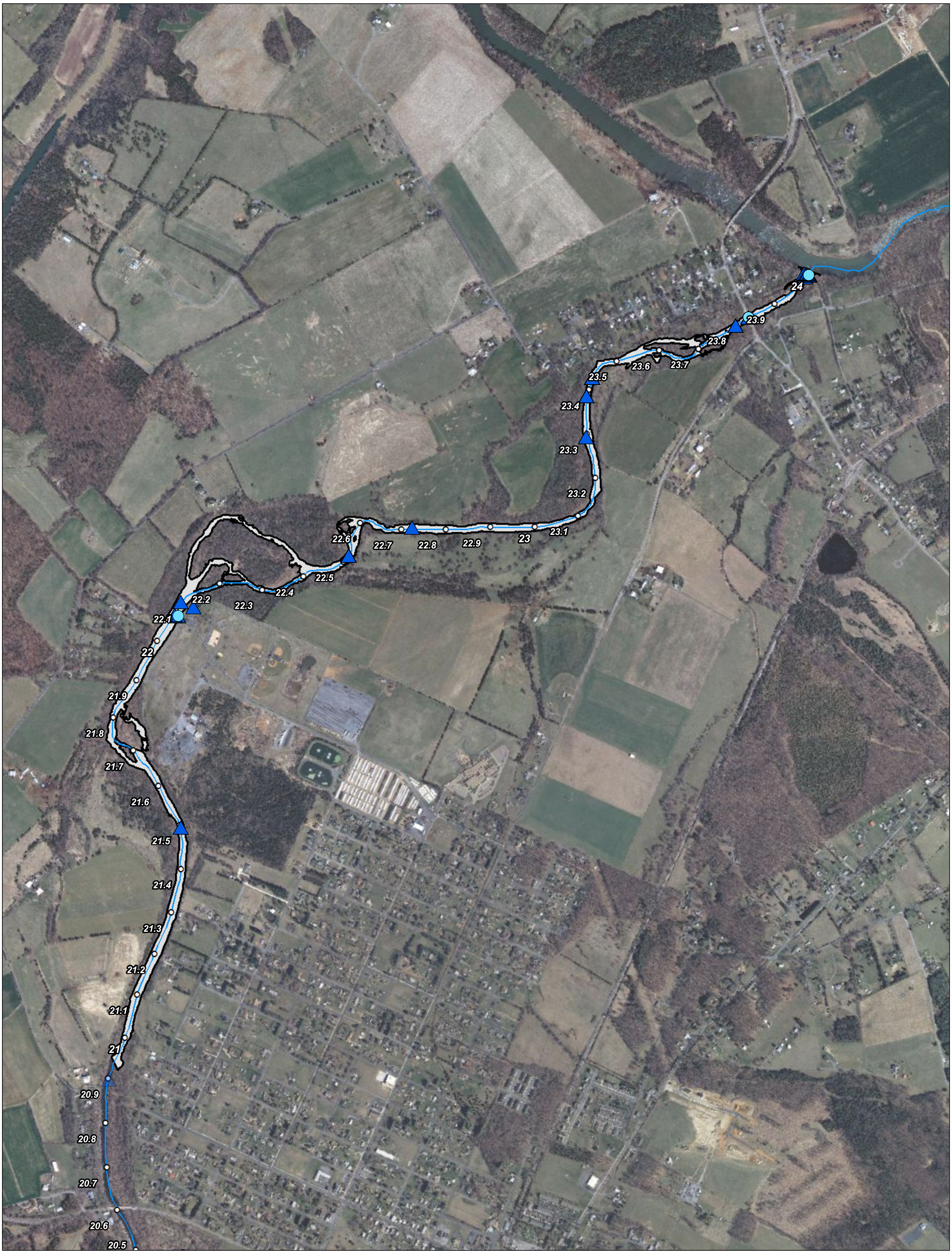
Job: 18986307.01340	**Figure 3-1**
Prepared by: VP	**Panel 14 of 16**
Checked by: BR	**Surface Water Sample Reach RRM 16.7 to 20.9**
Date: 8/14/2014	**AOC 4 Ecological Risk Assessment Report** Former Dupont Waynesboro Plant Waynesboro, Virginia



Legend

Storm Flow
Baseline Flow
RRM Intervals (Mile)
Stream
LiDAR Reach

0 1,450 2,900 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

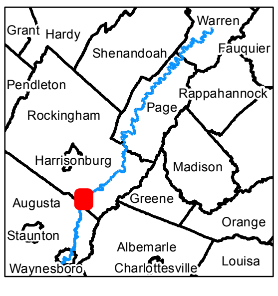


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Figure 3-1
Panel 15 of 16
Surface Water Sample Reach RRM 20.9 to 24.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
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Legend

- Storm Flow
- Baseline Flow
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 2,000 4,000 8,000 12,000 16,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

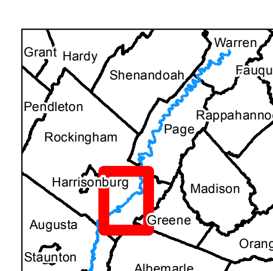

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Figure 3-1
Panel 16 of 16
Surface Water Sample Reach SFSR
AOC 4 Ecological Risk Assessment Report
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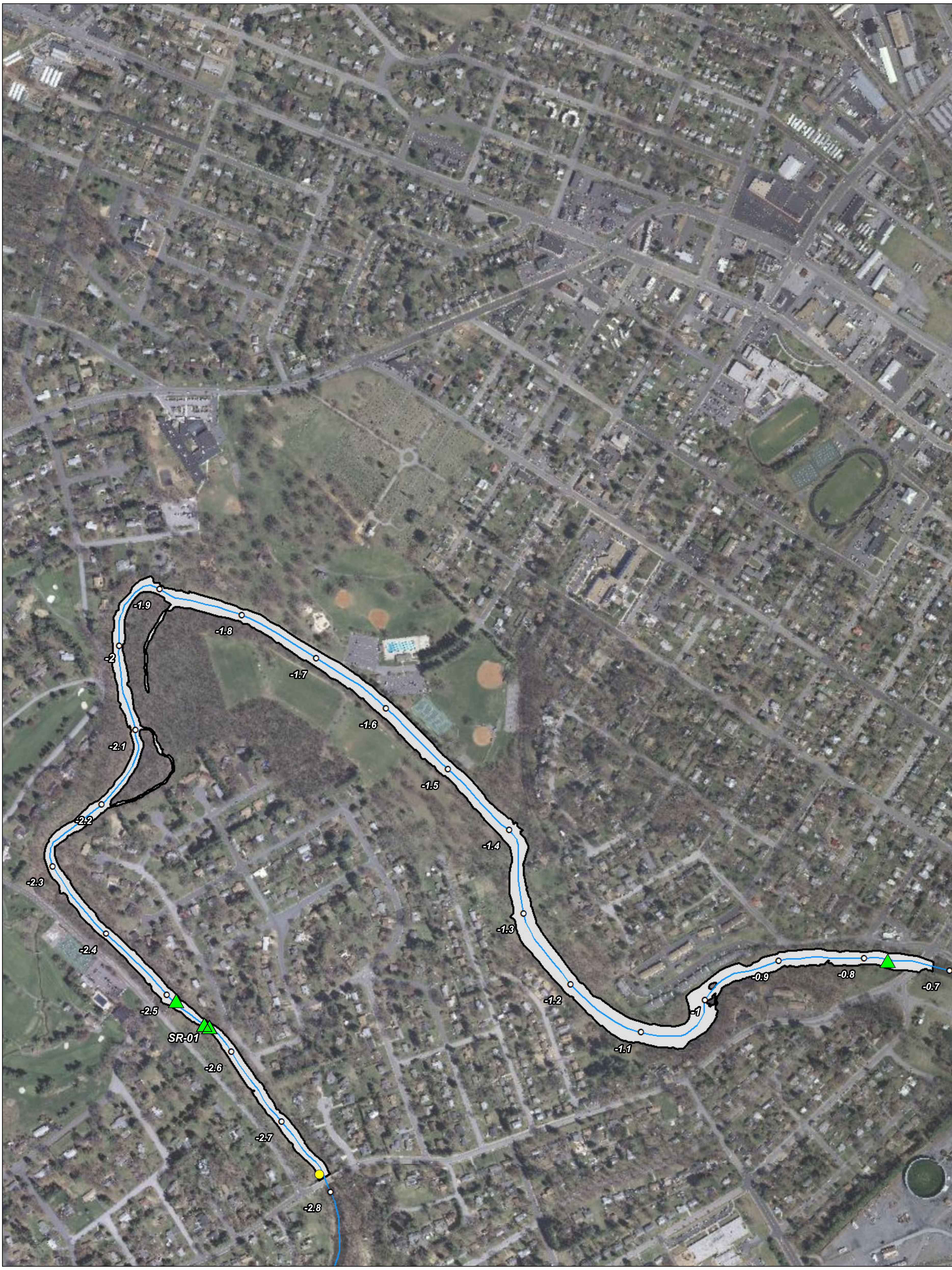

Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 750 1,500 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

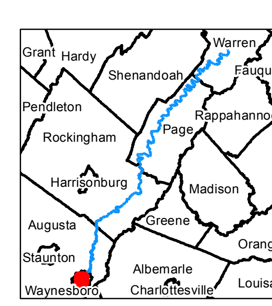

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Figure 3-2
Panel 1 of 16
Sediment Sample Reach RRM -2.7 to -0.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

Legend

- Bulk Sediment
- RRM Intervals (Mile)
- LiDAR Reach
- Interstitial Sediment
- Stream

0 462.5 925 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

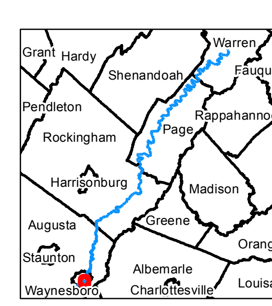

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Figure 3-2
Panel 2 of 16
Sediment Sample Reach RRM -0.7 to 0.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
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Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 435 870 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

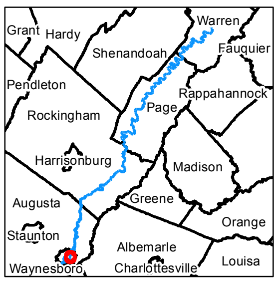

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Figure 3-2
Panel 3 of 16
Sediment Sample Reach RRM 0.0 to 0.8
AOC 4 Ecological Risk Assessment Report
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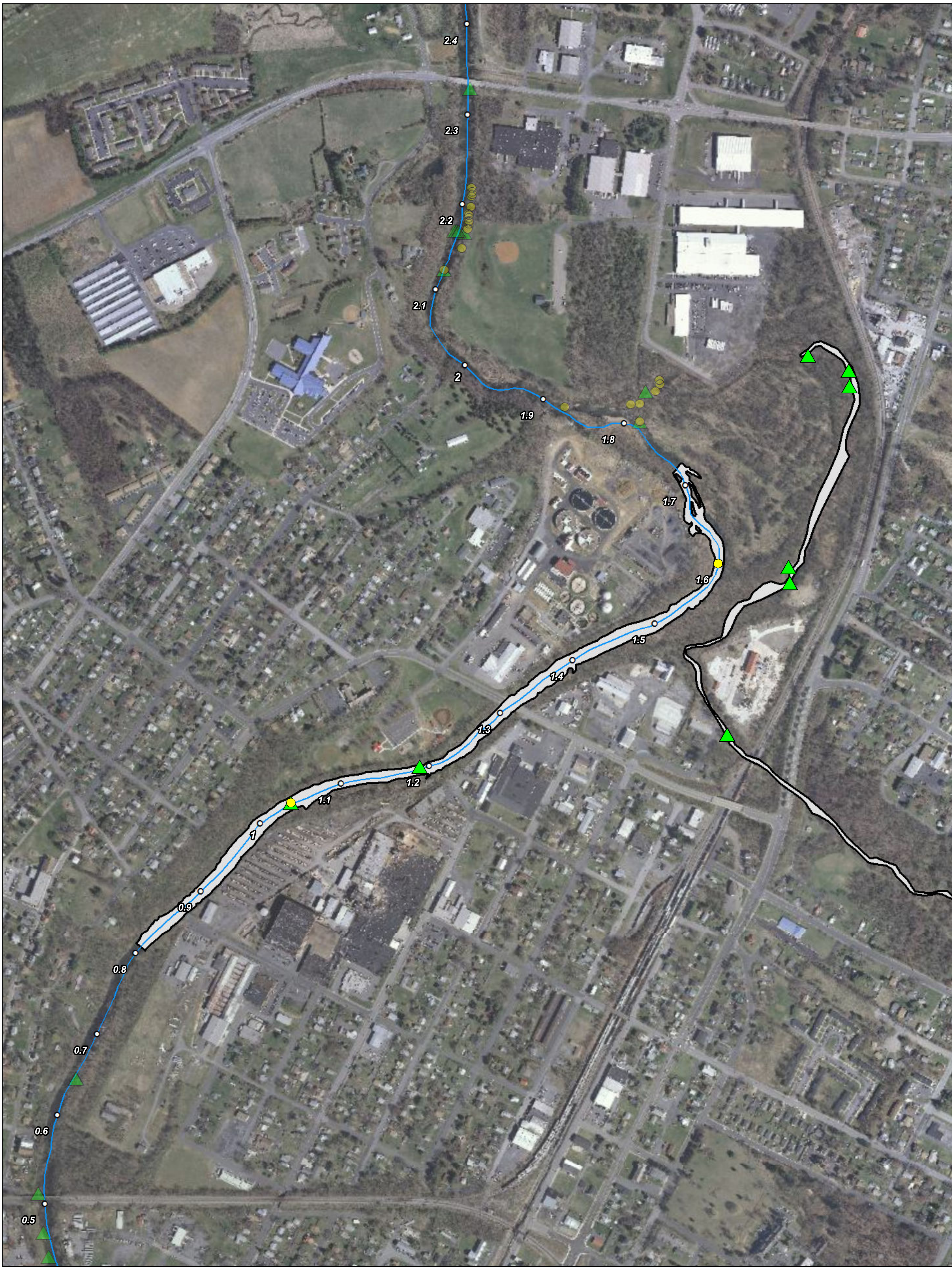

Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

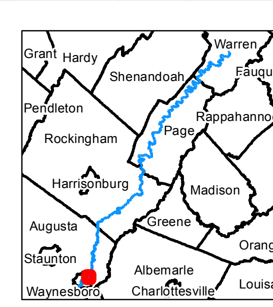

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Figure 3-2
Panel 4 of 16
Sediment Sample Reach RRM 0.8 to 1.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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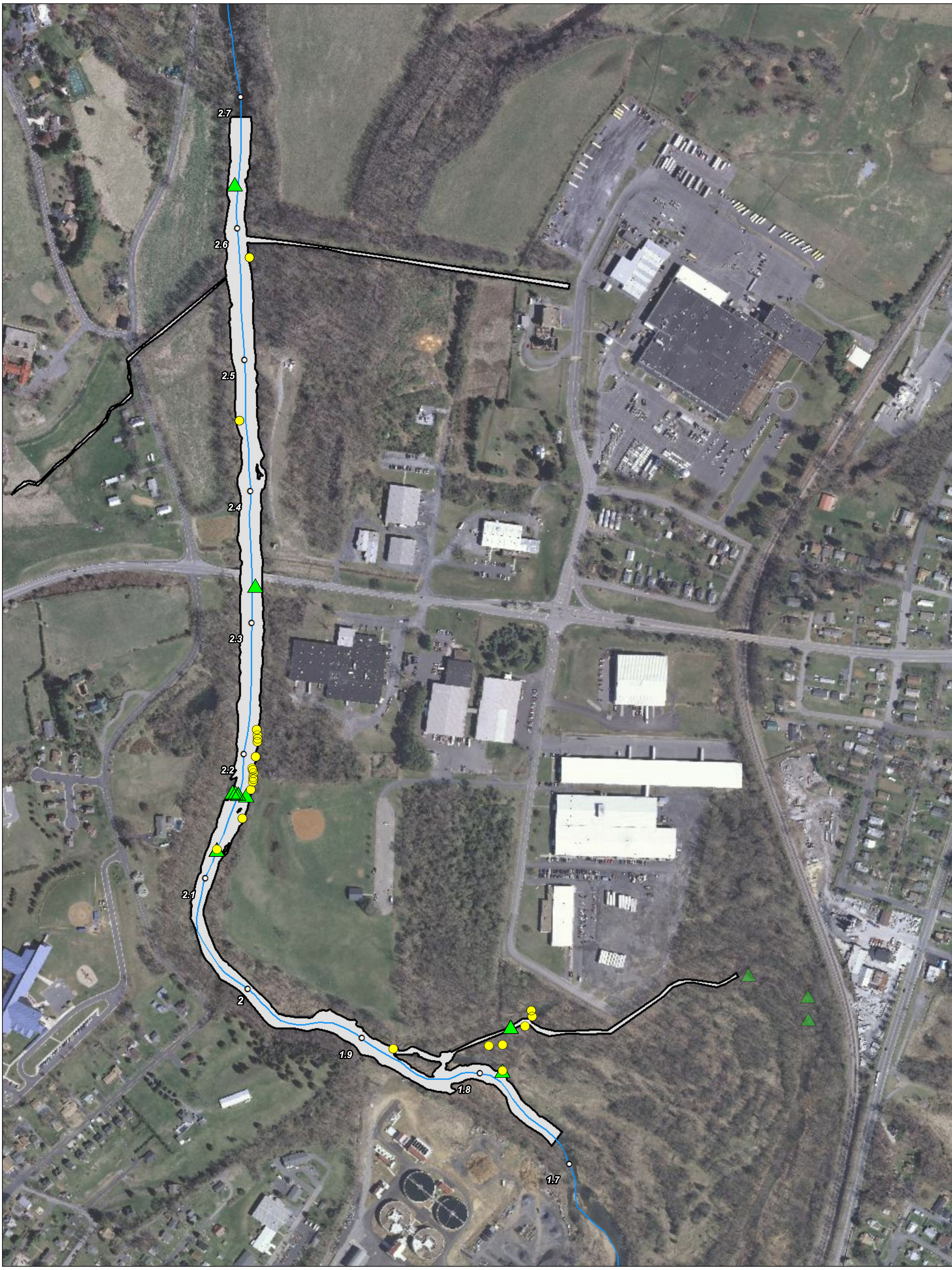

Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

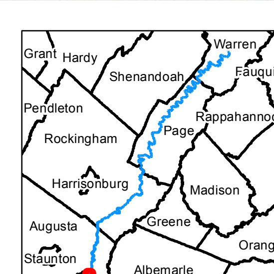

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Figure 3-2
Panel 5 of 16
Sediment Sample Reach RRM 1.7 to 2.7
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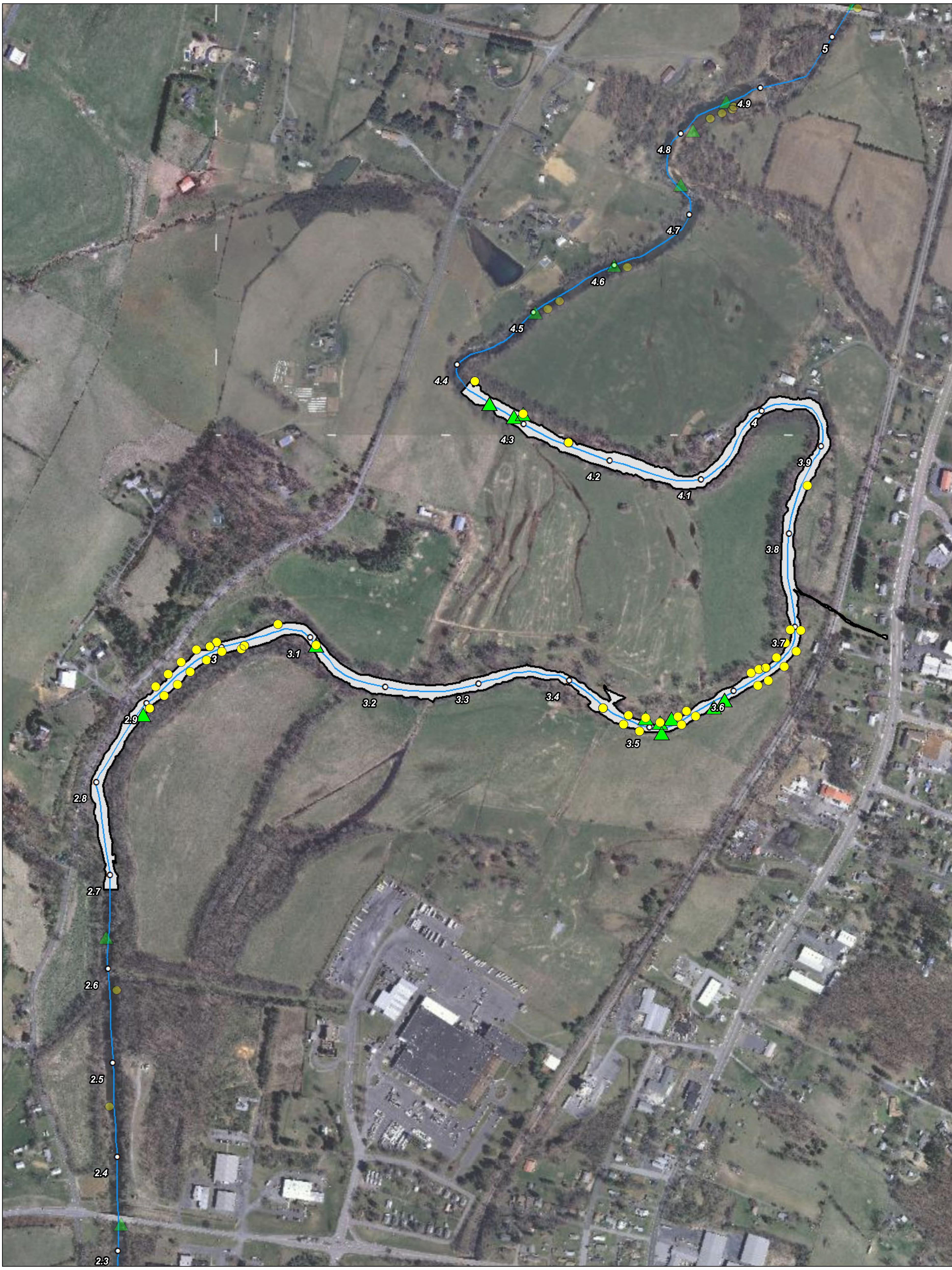

Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

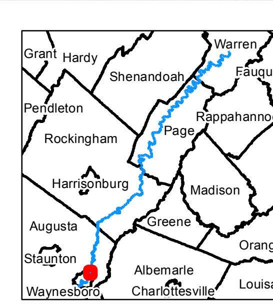

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Figure 3-2
Panel 6 of 16
Sediment Sample Reach RRM 2.7 to 4.4
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Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 550 1,100 Feet

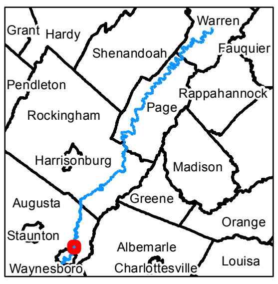
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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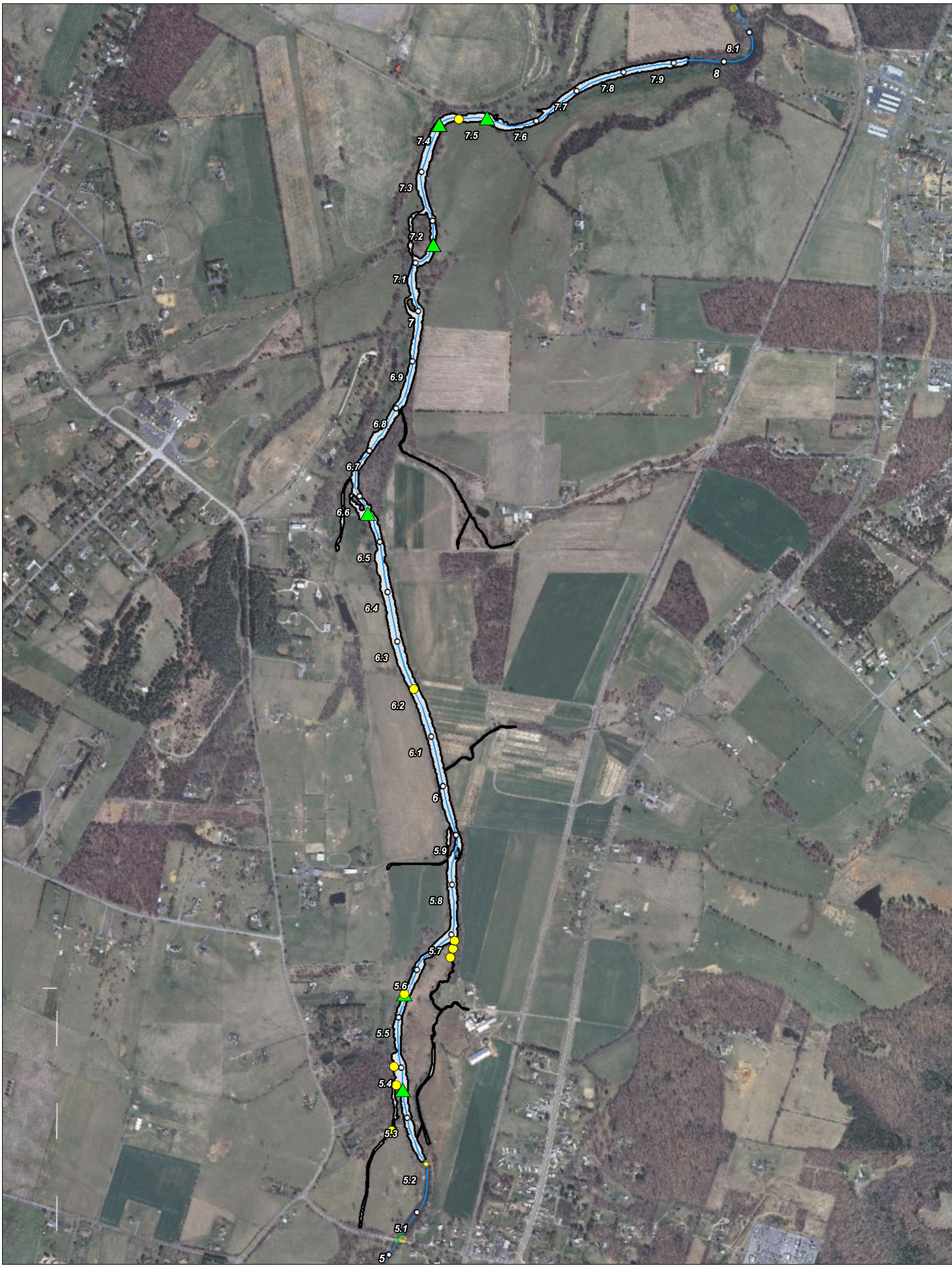
Job: 18986307.01340	**Figure 3-2**
Prepared by: VP	**Panel 7 of 16**
Checked by: BR	**Sediment Sample Reach RRM 4.4 to 5.2**
Date: 8/14/2014	**AOC 4 Ecological Risk Assessment Report**

Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\EcoRiskAssessmentReport\LiDAR Breaks DDP Maps Sediment.mxd



Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 1,300 2,600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

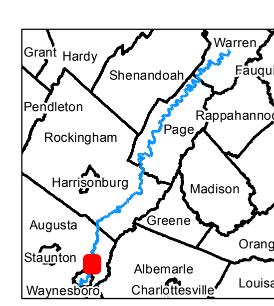


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Figure 3-2
Panel 8 of 16
Sediment Sample Reach RRM 5.2 to 7.9
AOC 4 Ecological Risk Assessment Report
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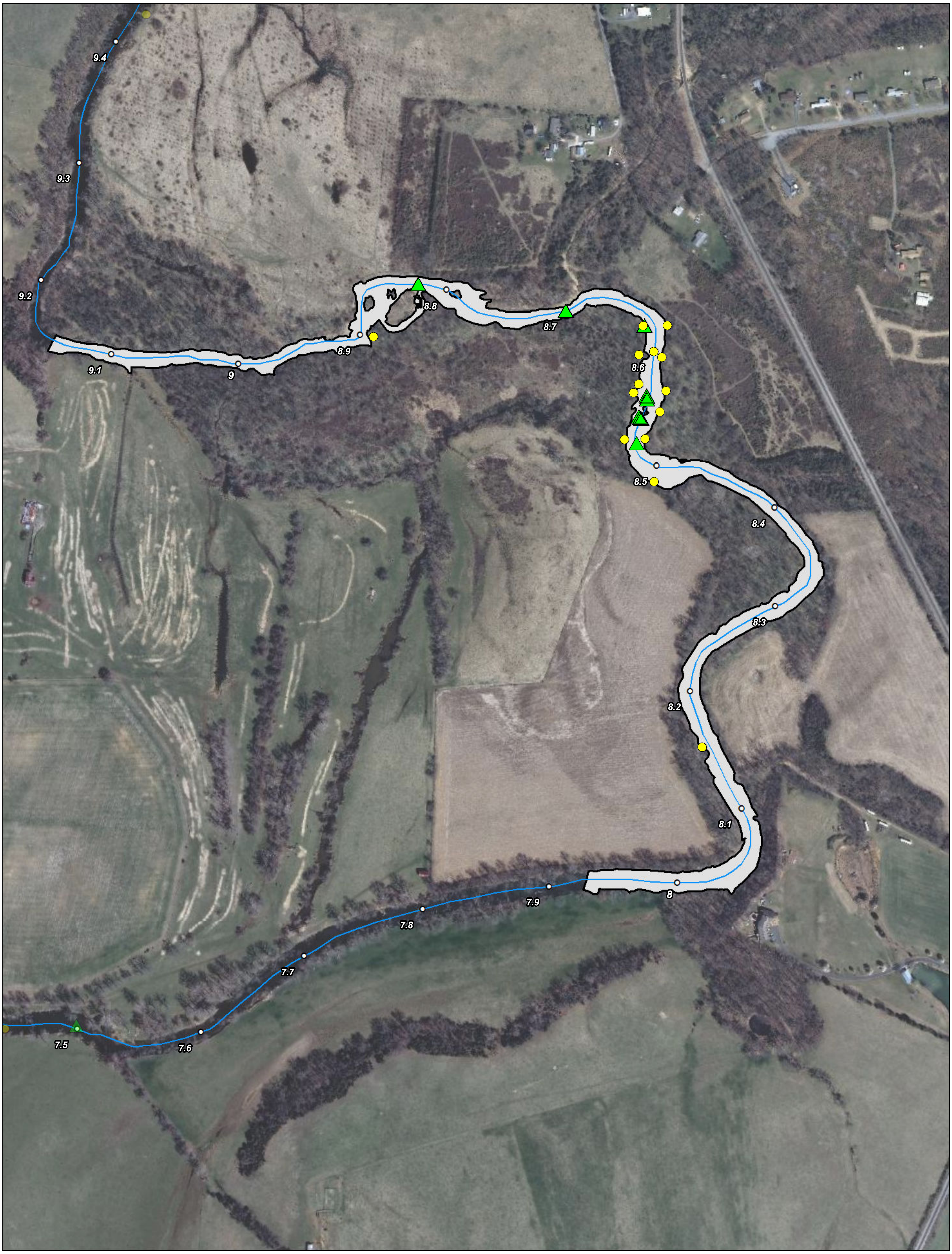
Waynesboro, Virginia



Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

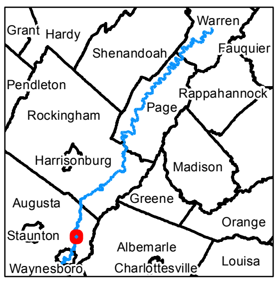


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Figure 3-2
Panel 9 of 16
Sediment Sample Reach RRM 7.9 to 9.2
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Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 900 1,800 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

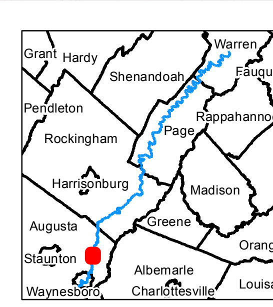

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Figure 3-2
Panel 10 of 16
Sediment Sample Reach RRM 9.2 to 11.3
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Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

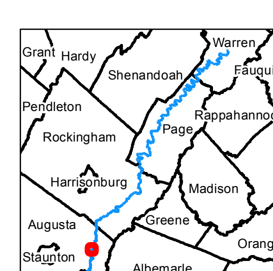

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Figure 3-2
Panel 11 of 16
Sediment Sample Reach RRM 11.3 to 12.5
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Legend

- Bulk Sediment
- RRM Intervals (Mile)
- LiDAR Reach
- Interstitial Sediment
- Stream

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

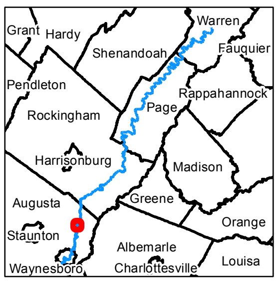

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Figure 3-2
Panel 12 of 16
Sediment Sample Reach RRM 12.5 to 13.5
AOC 4 Ecological Risk Assessment Report
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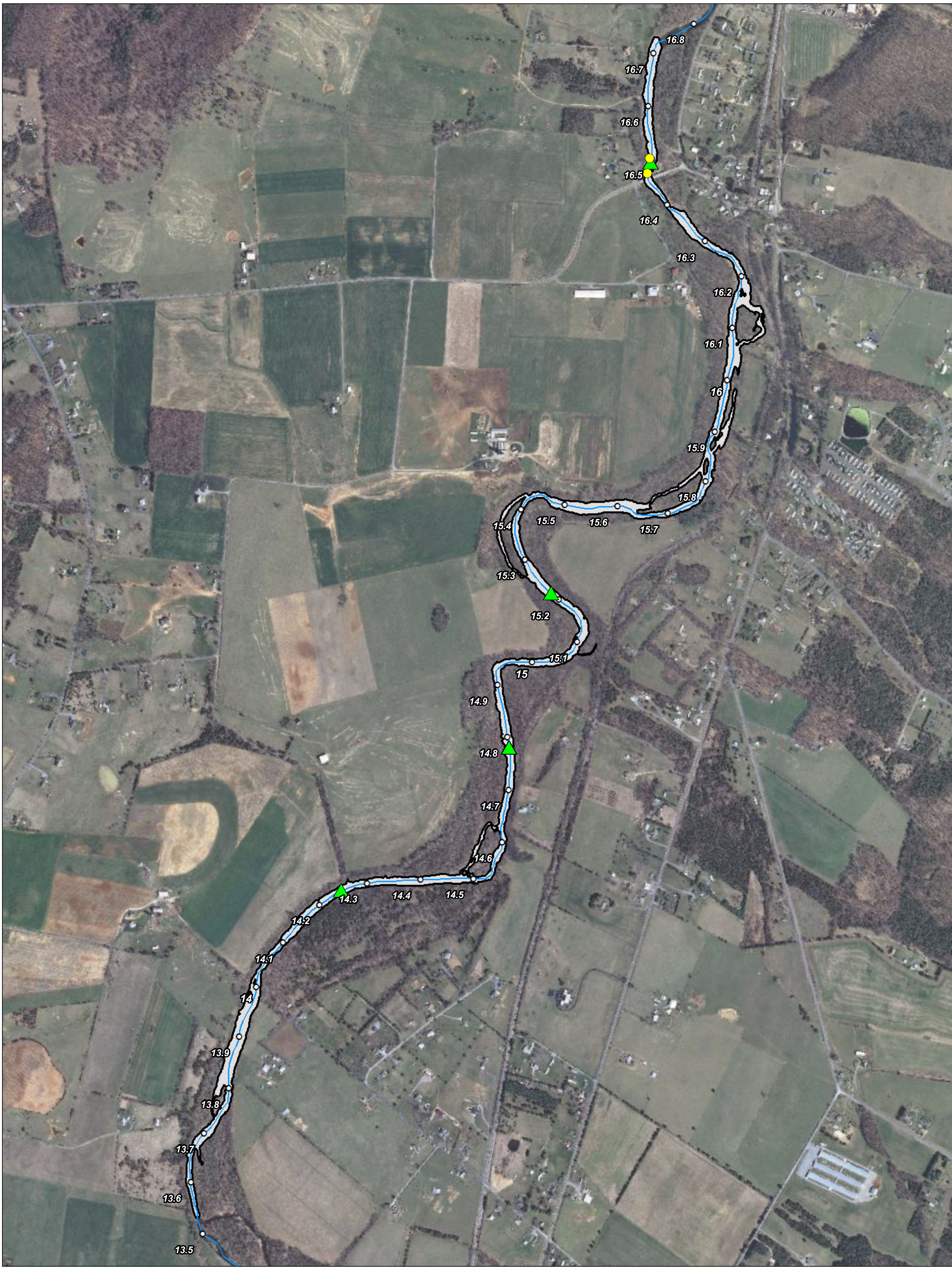

Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 1,250 2,500 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

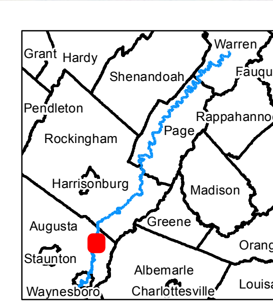

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Figure 3-2
Panel 13 of 16
Sediment Sample Reach RRM 13.5 to 16.7
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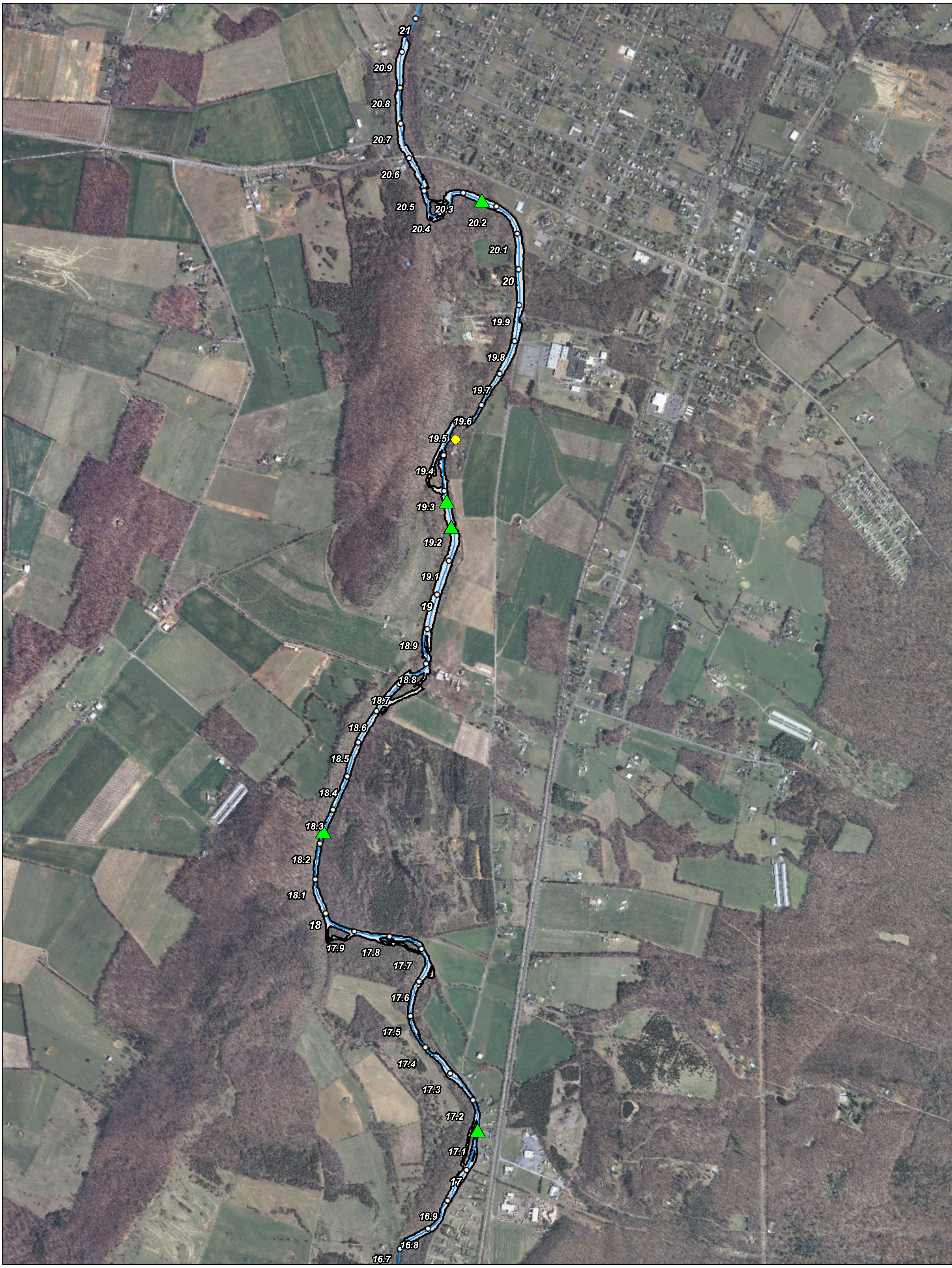


Legend

- Bulk Sediment
- RRM Intervals (Mile)
- LiDAR Reach
- Interstitial Sediment
- Stream

0 1,850 3,700 Feet

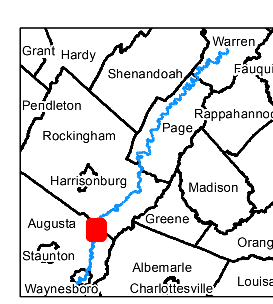
Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

N



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Date: 8/14/2014

Figure 3-2
Panel 14 of 16
Sediment Sample Reach RRM 16.7 to 20.9
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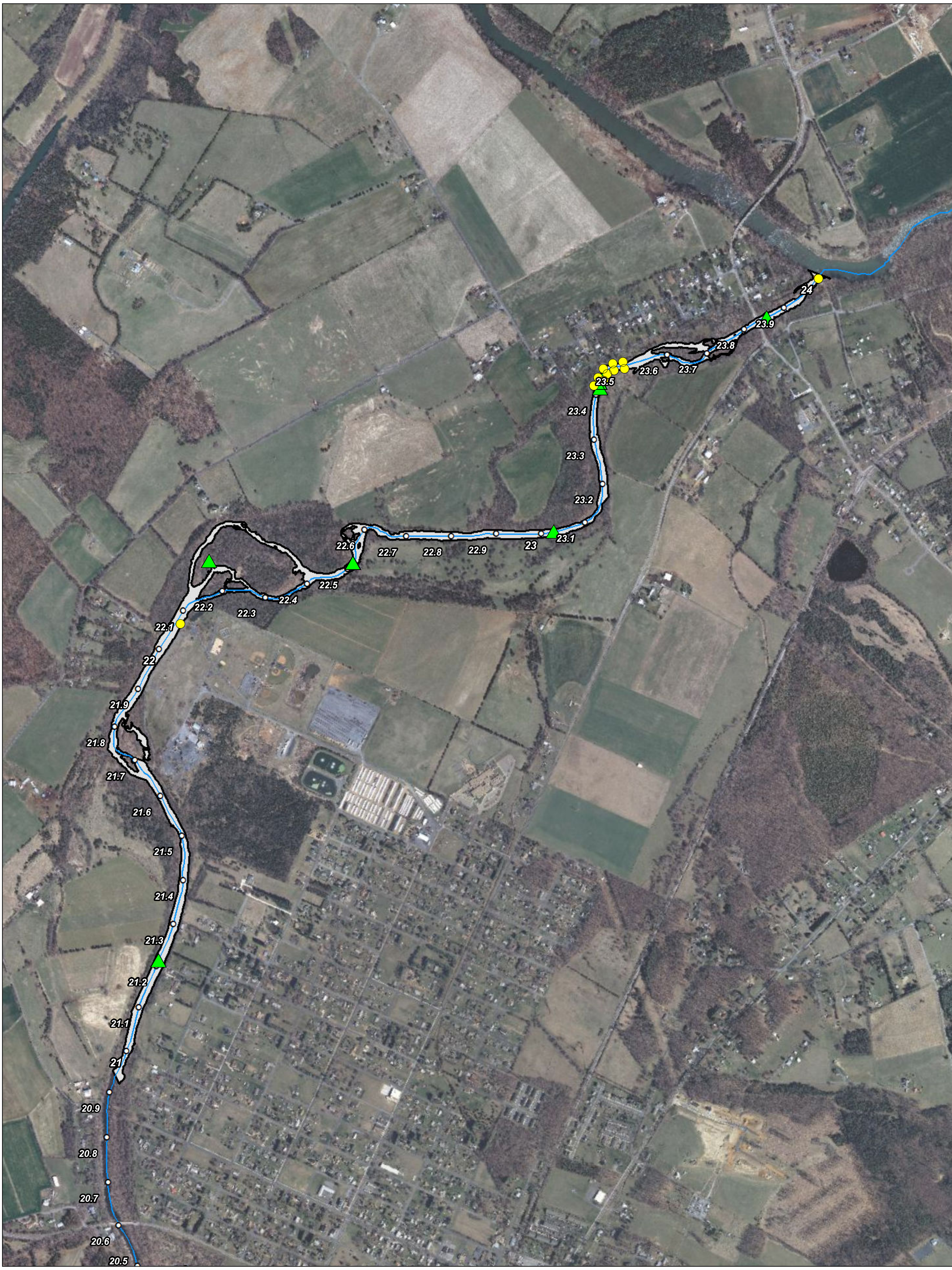

Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 1,450 2,900 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

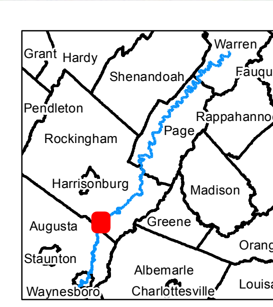

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Figure 3-2
Panel 15 of 16
Sediment Sample Reach RRM 20.9 to 24.0
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Legend

- Bulk Sediment
- Interstitial Sediment
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 2,000 4,000 8,000 12,000 16,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

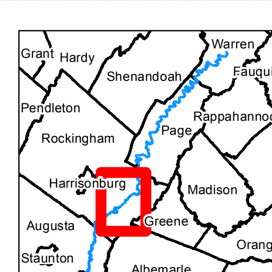

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Figure 3-2
Panel 16 of 16
Sediment Sample Reach SFSR
AOC 4 Ecological Risk Assessment Report
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Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 750 1,500 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

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Figure 3-3
Panel 1 of 16
Soil Sample Reach RRM -2.7 to -0.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 462.5 925 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

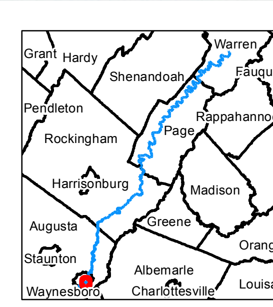

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Figure 3-3
Panel 2 of 16
Soil Sample Reach RRM -0.7 to 0.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
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Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 435 870 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

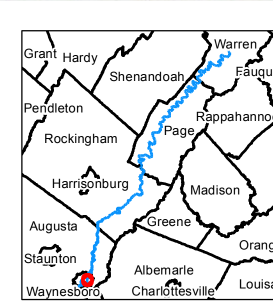

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Figure 3-3
Panel 3 of 16
Soil Sample Reach RRM 0.0 to 0.8
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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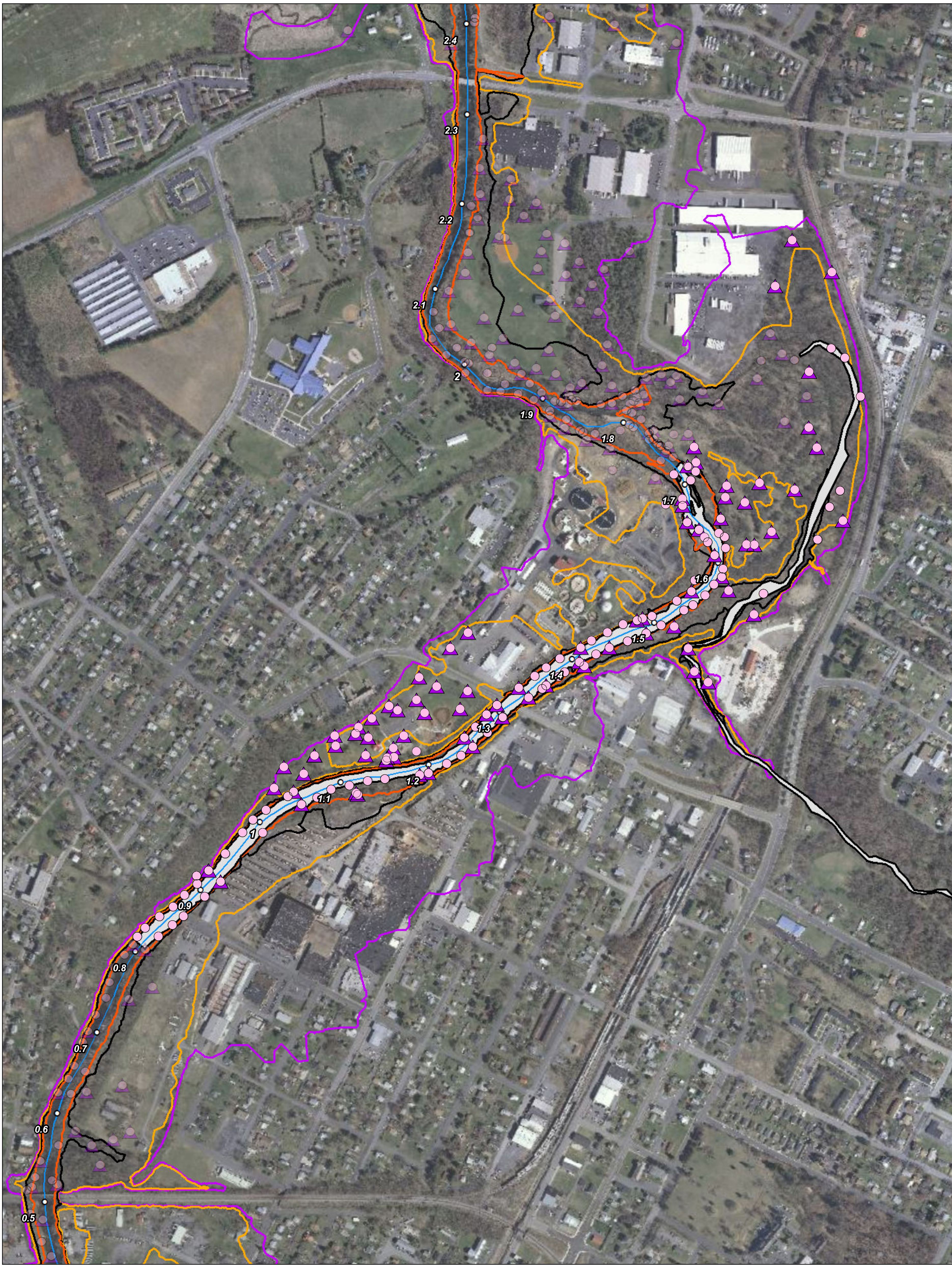

Legend

Surface Soil (0.0'- 0.5')	Stream	5-Year Floodplain
Subsurface Soil (0.5'- 2.0')	0.3 Year Floodplain	62-Year Floodplain
RRM Intervals (Mile)	2-Year Floodplain	LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

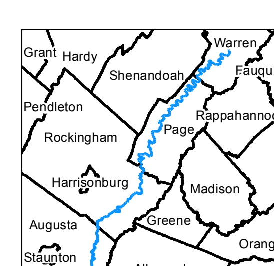

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Figure 3-3
Panel 4 of 16
Soil Sample Reach RRM 0.8 to 1.7
AOC 4 Ecological Risk Assessment Report
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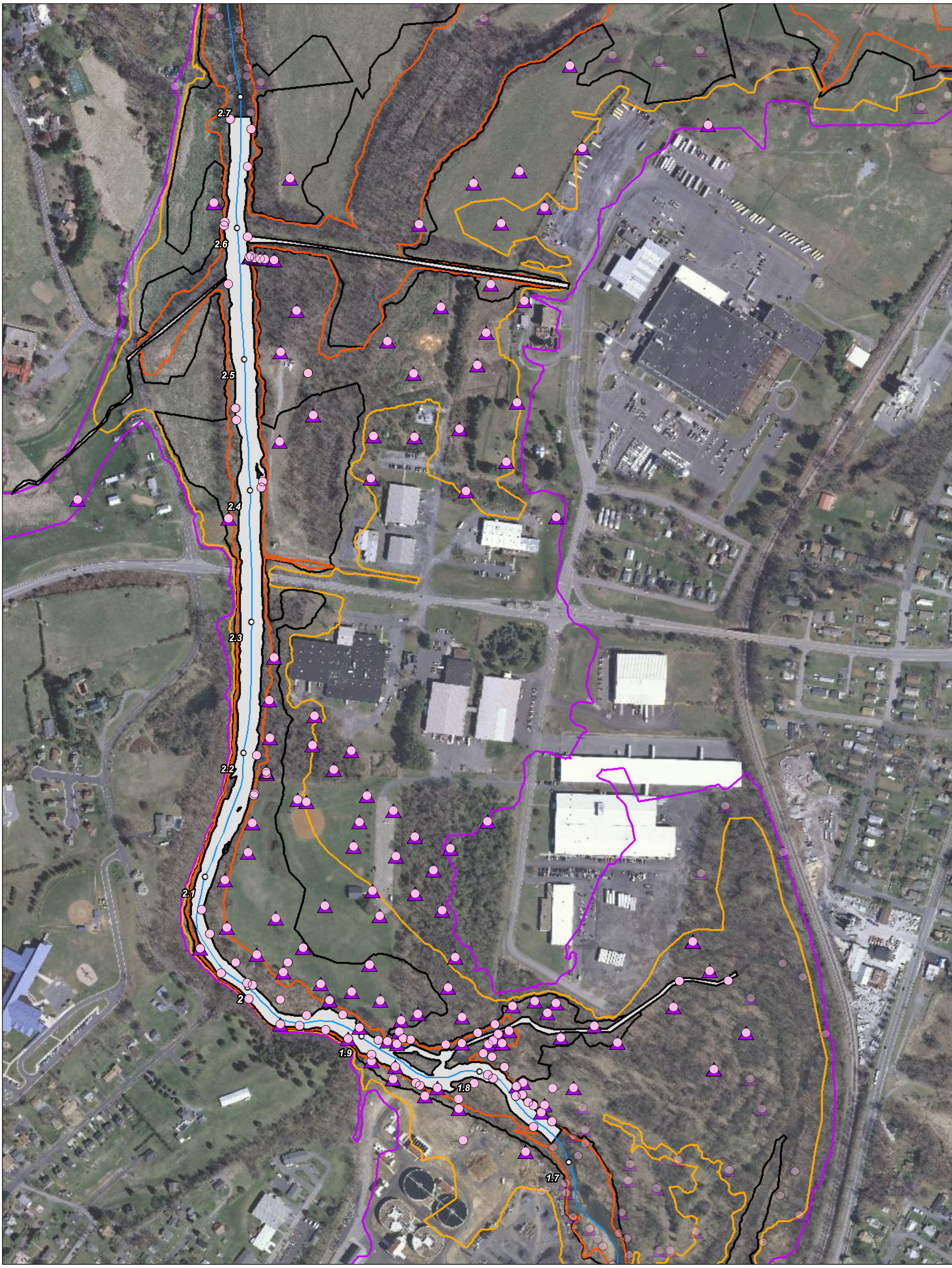

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

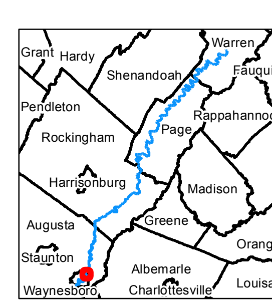

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Figure 3-3
Panel 5 of 16
Soil Sample Reach RRM 1.7 to 2.7
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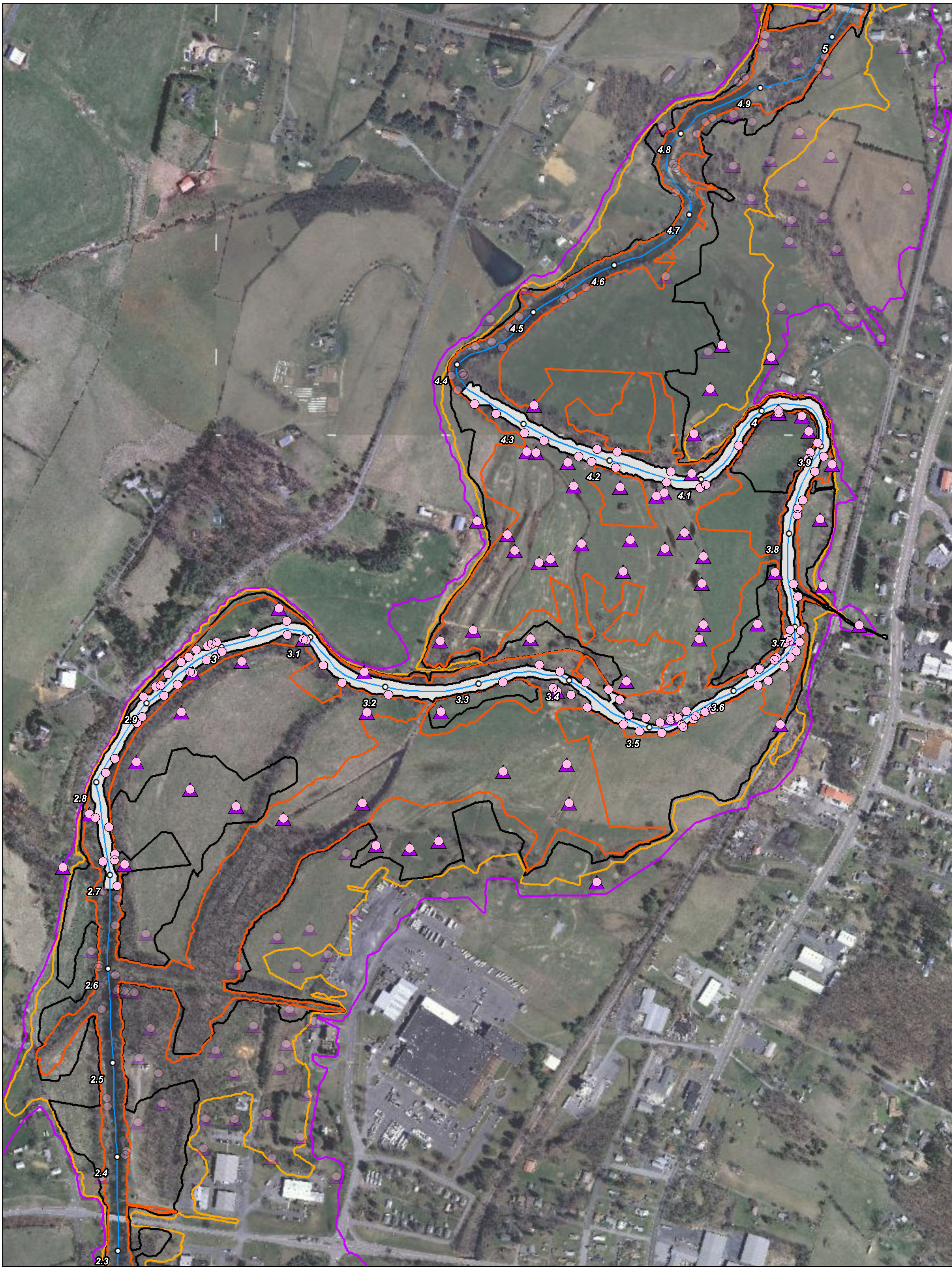

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

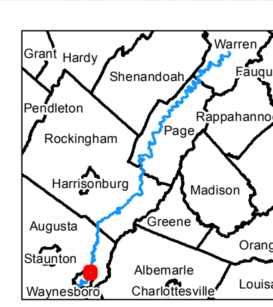

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Figure 3-3
Panel 6 of 16
Soil Sample Reach RRM 2.7 to 4.4
AOC 4 Ecological Risk Assessment Report
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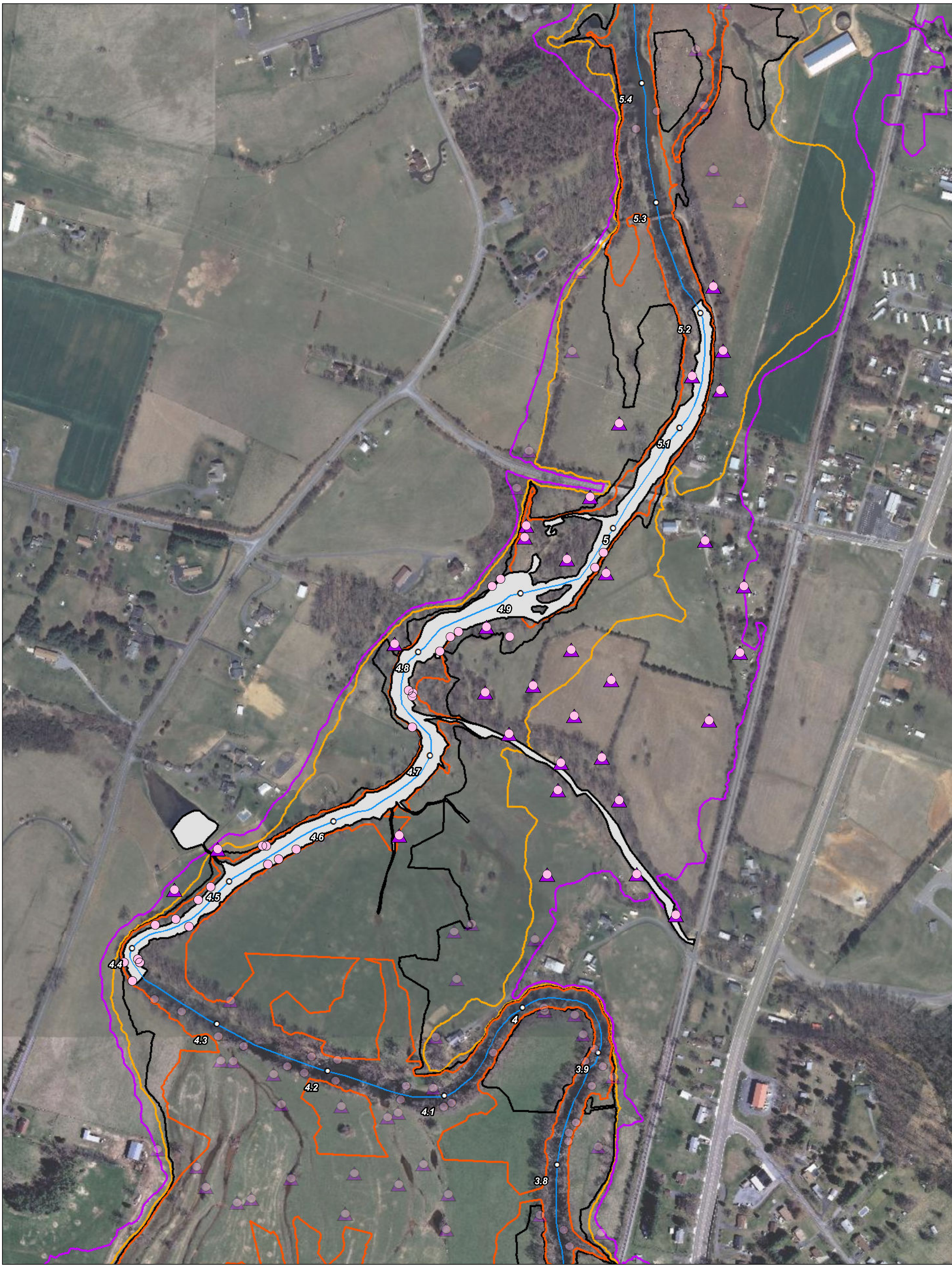

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 550 1,100 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

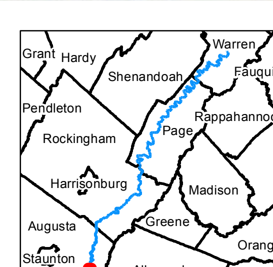

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Figure 3-3
Panel 7 of 16
Soil Sample Reach RRM 4.4 to 5.2
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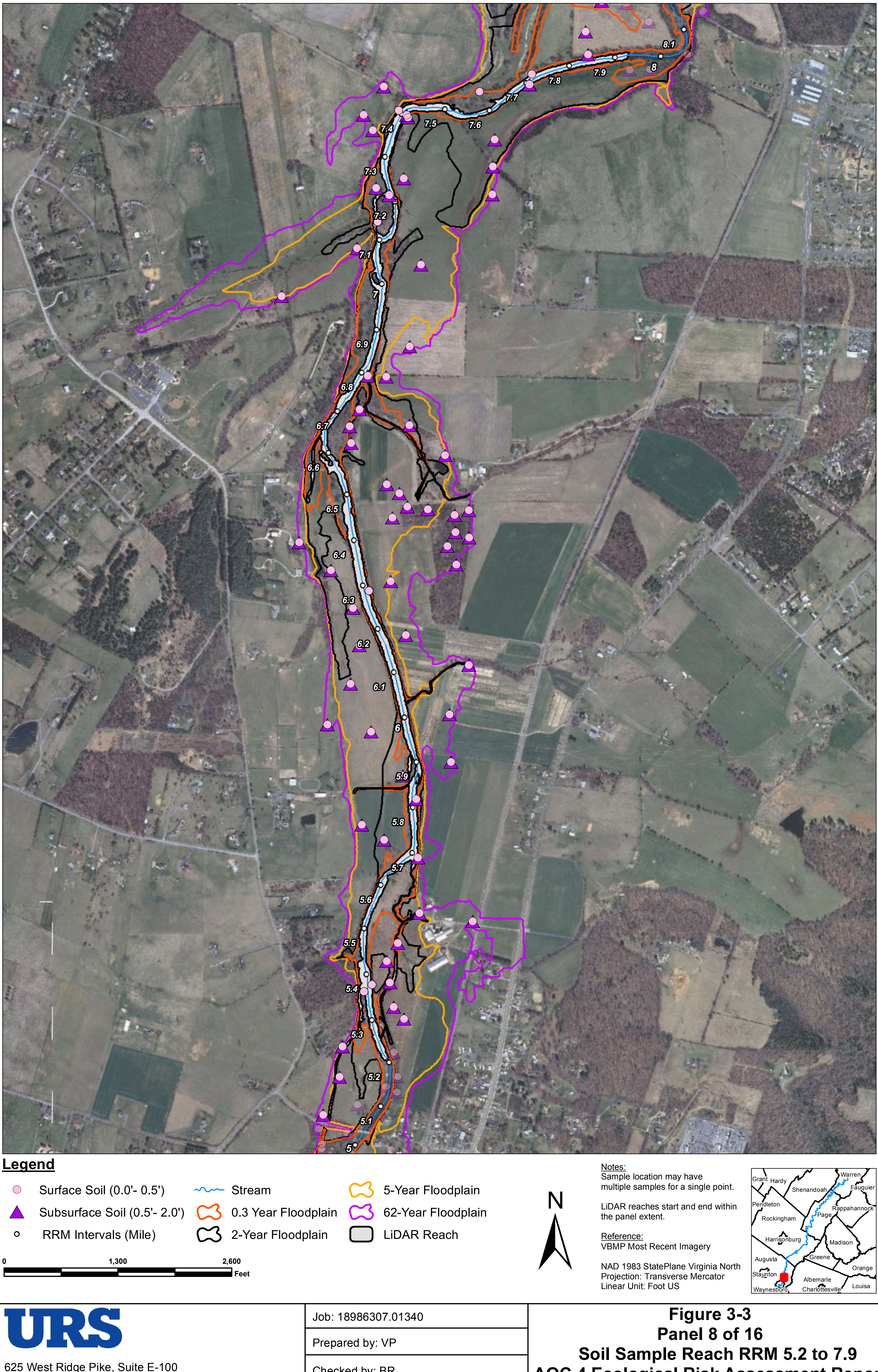

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

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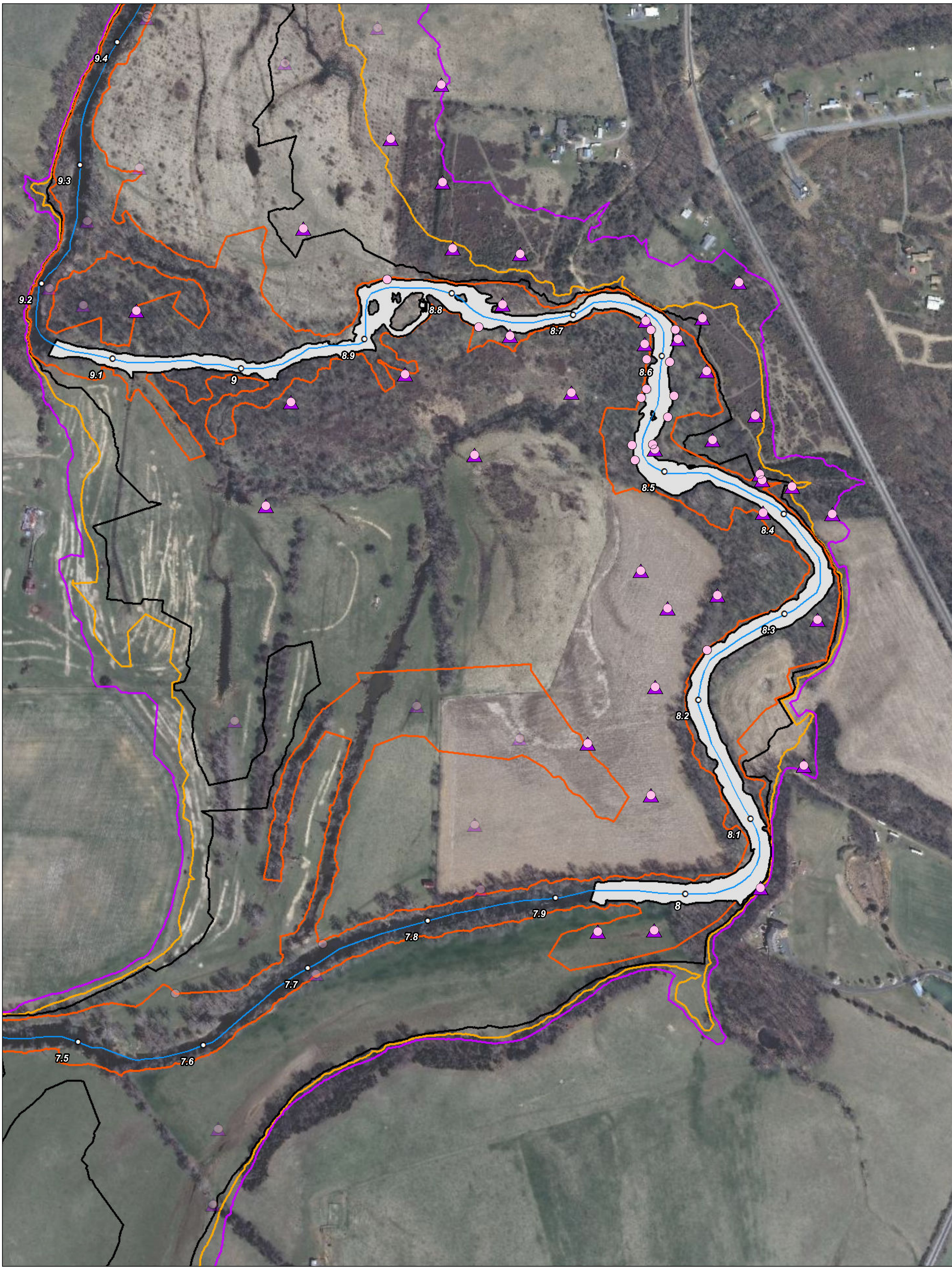
Prepared by: VP

Checked by: BR

Date: 8/14/2014

Figure 3-3
Panel 8 of 16
Soil Sample Reach RRM 5.2 to 7.9
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

S:\Projects\IMS\DUPONT\STHRIVER\Projects\EcoRiskAssessmentReport\LiDAR Breaks DDP Maps Soil.mxd



Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

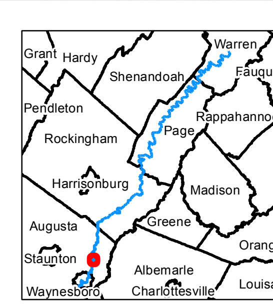


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Figure 3-3
Panel 9 of 16
Soil Sample Reach RRM 7.9 to 9.2
AOC 4 Ecological Risk Assessment Report
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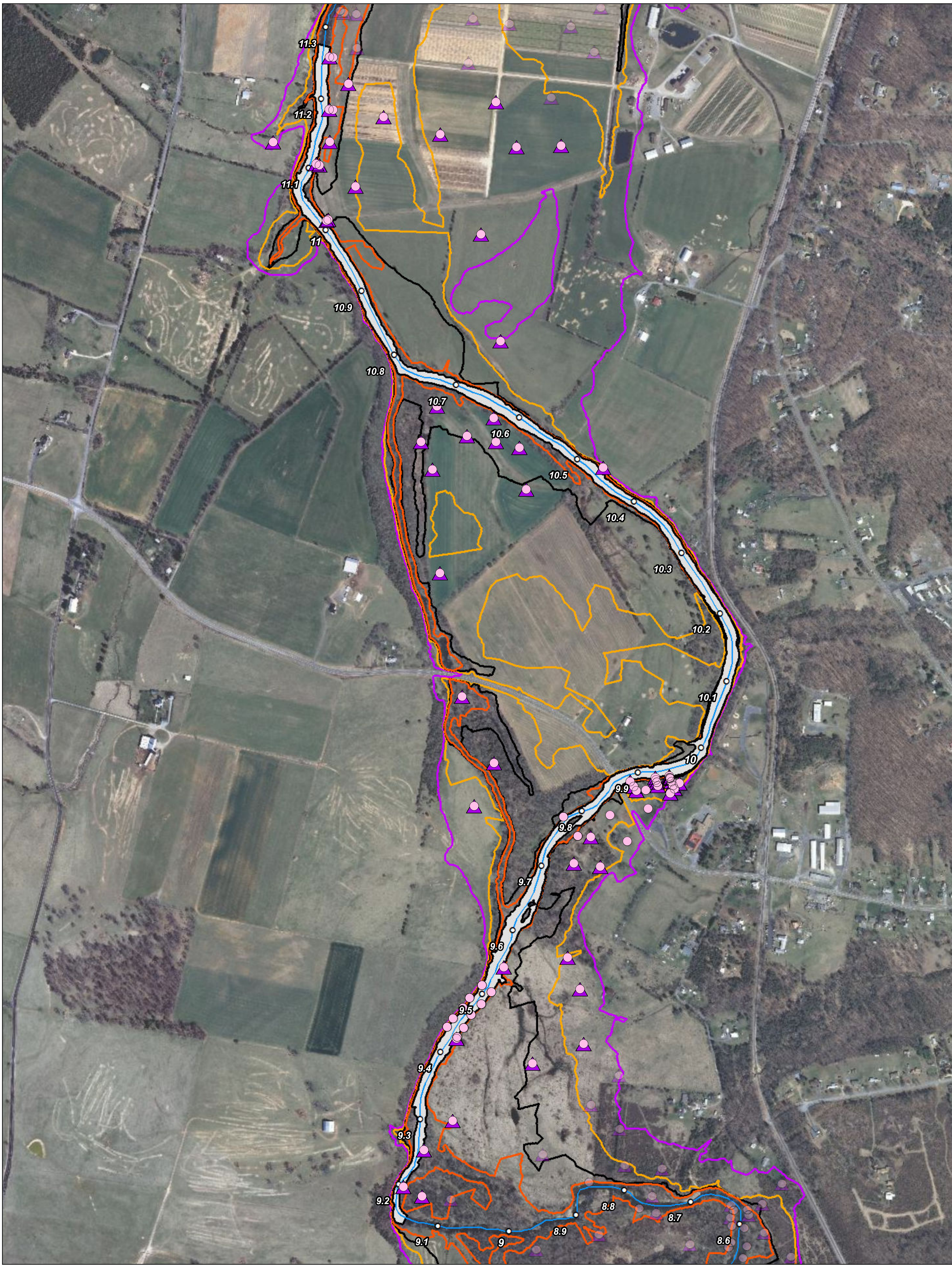

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 900 1,800 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

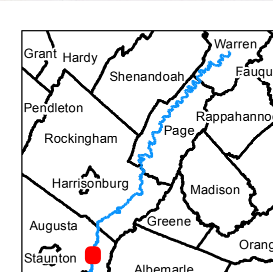

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Figure 3-3
Panel 10 of 16
Soil Sample Reach RRM 9.2 to 11.3
AOC 4 Ecological Risk Assessment Report
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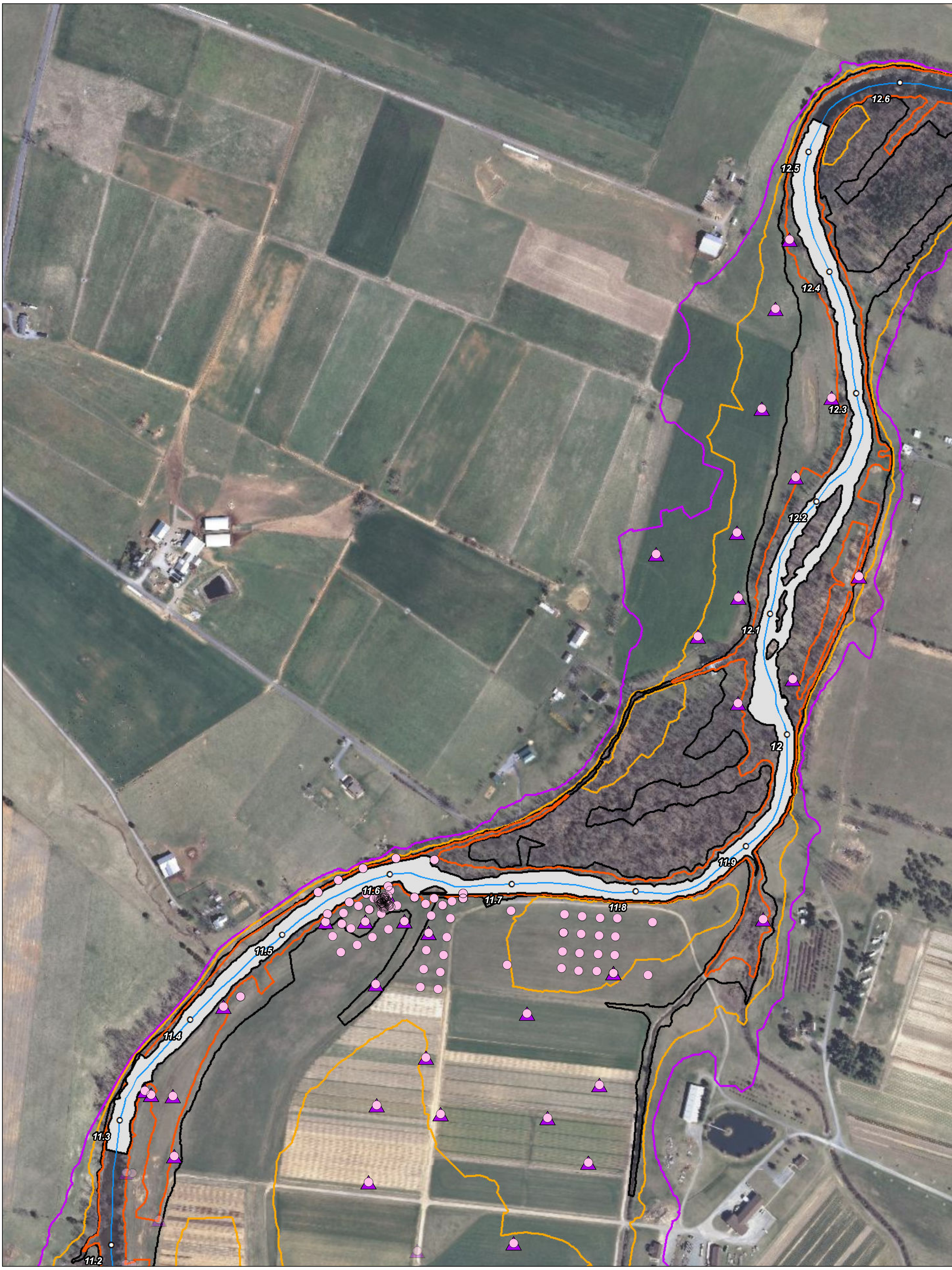

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

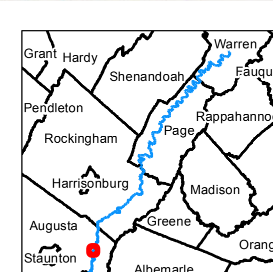

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Figure 3-3
Panel 11 of 16
Soil Sample Reach RRM 11.3 to 12.5
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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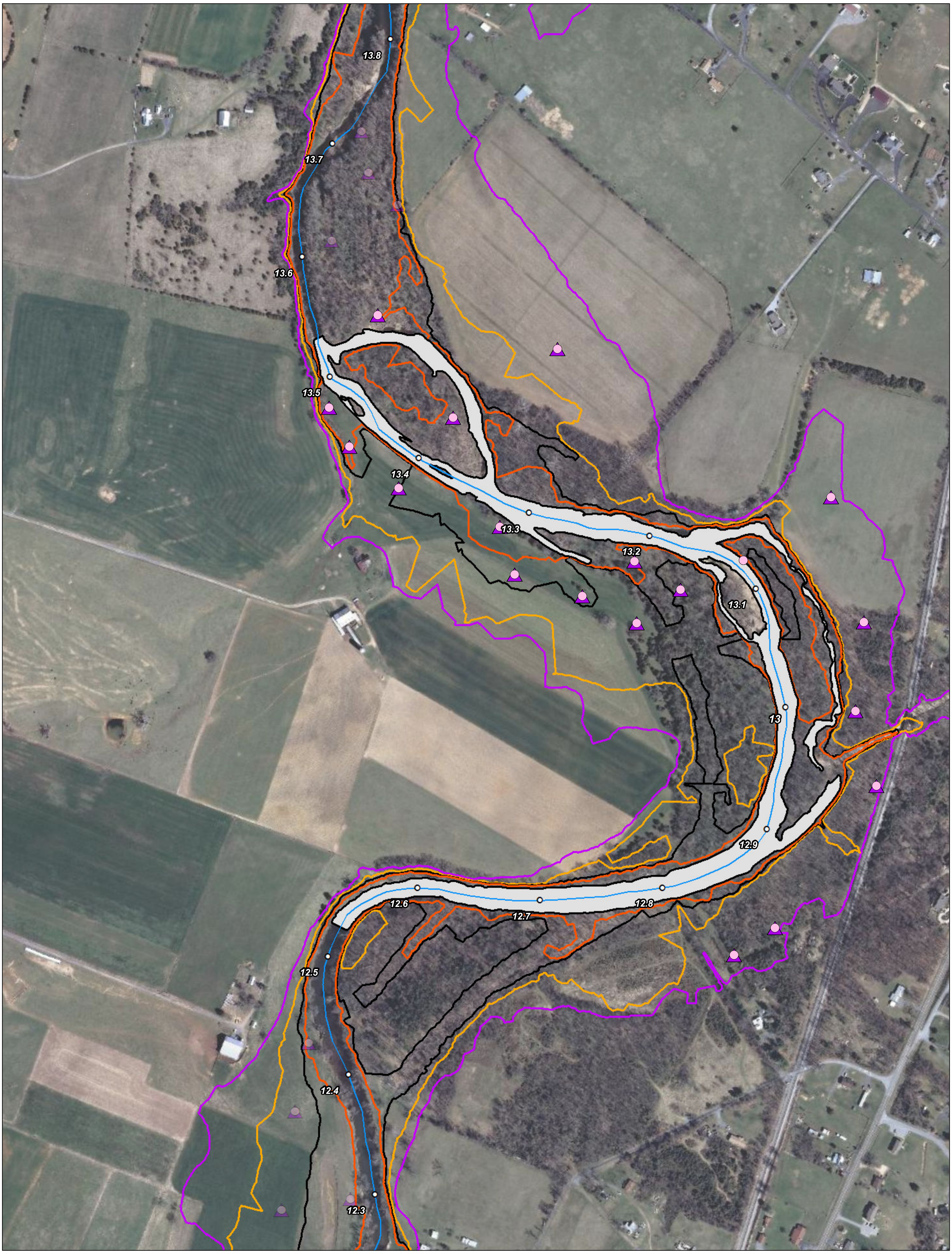

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

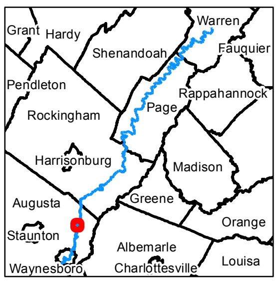

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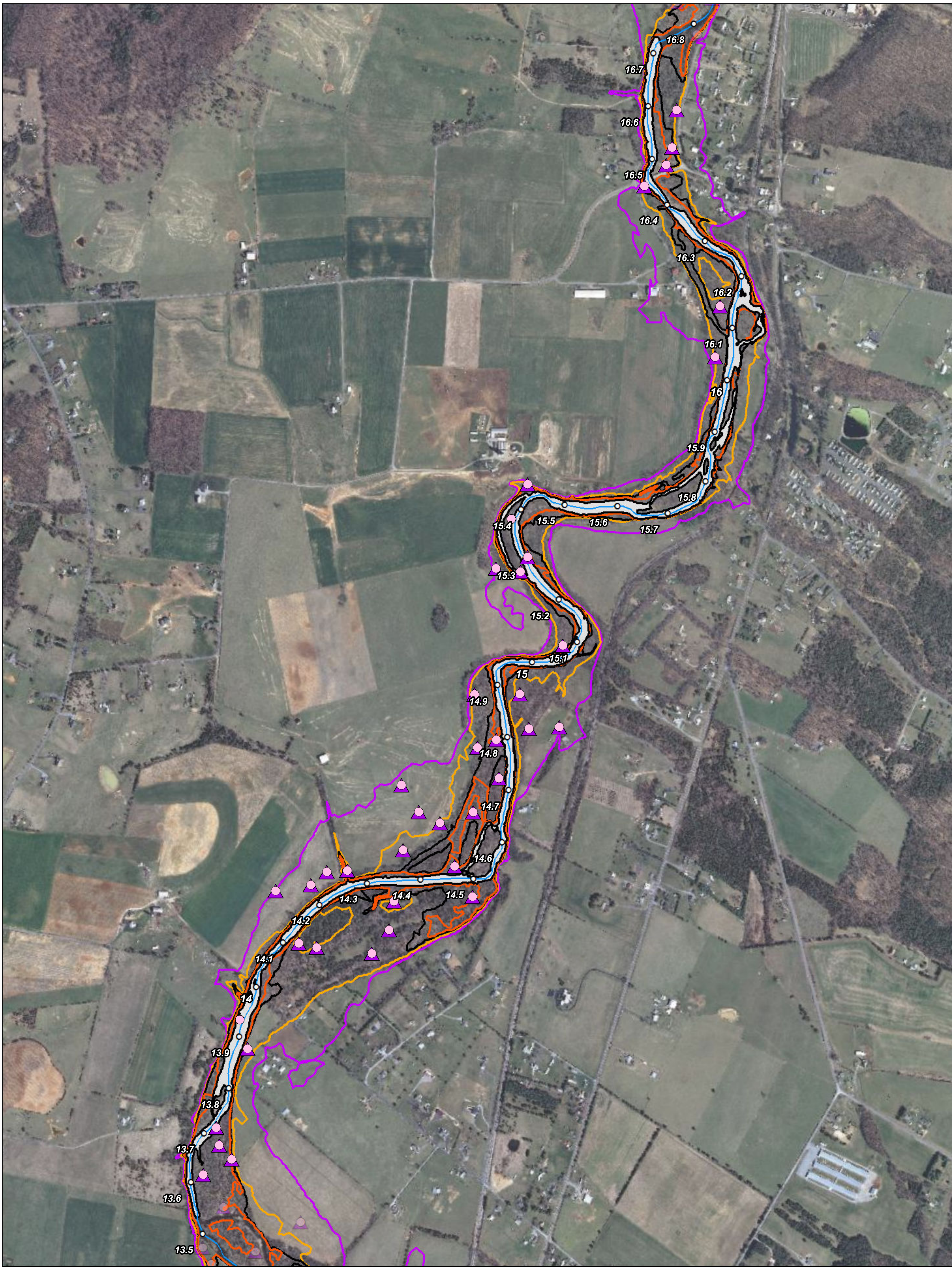
Figure 3-3
Panel 12 of 16
Soil Sample Reach RRM 12.5 to 13.5
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia



Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 1,250 2,500 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

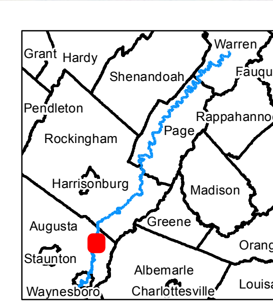


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Figure 3-3
Panel 13 of 16
Soil Sample Reach RRM 13.5 to 16.7
AOC 4 Ecological Risk Assessment Report
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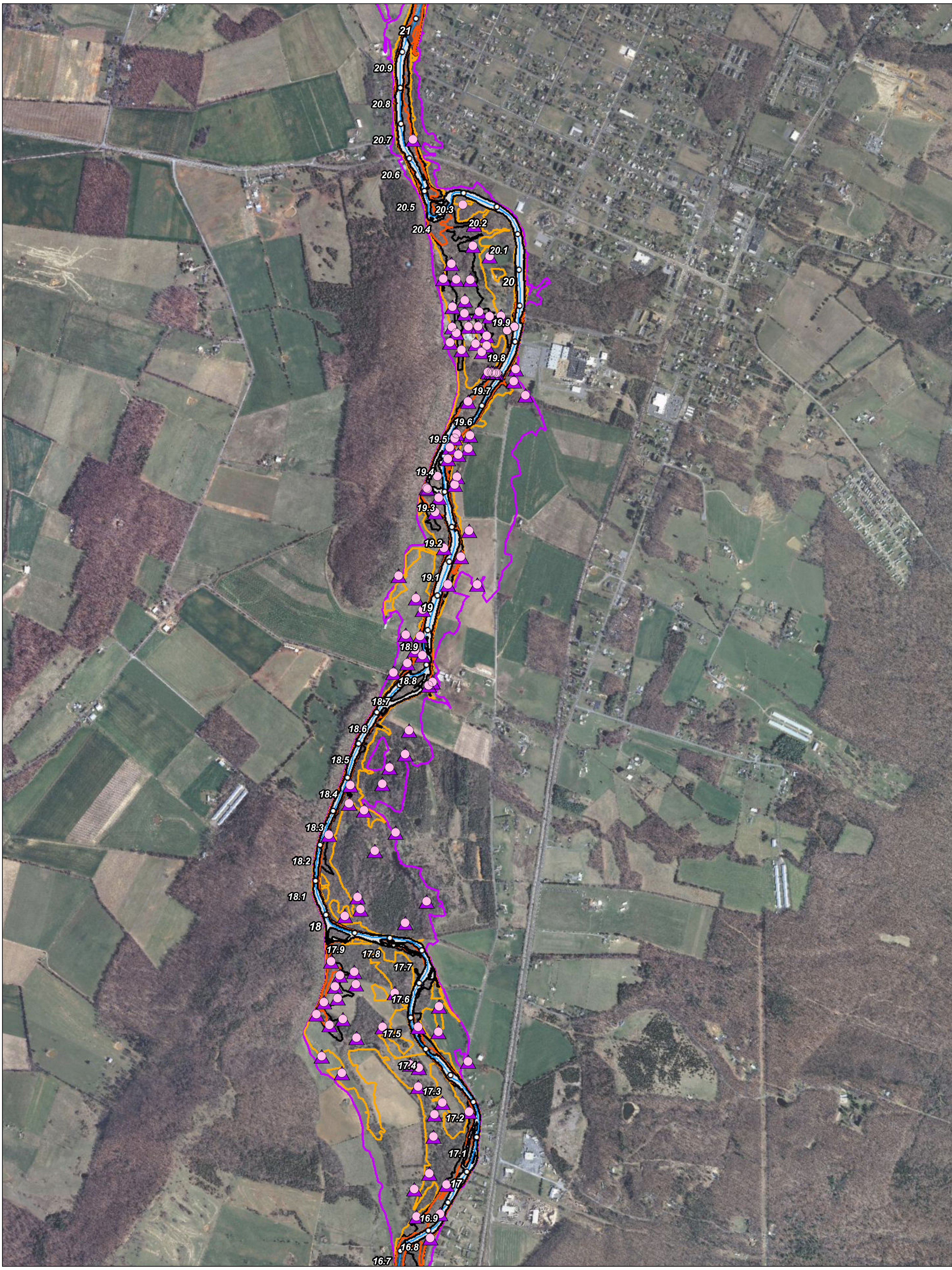

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 1,850 3,700 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

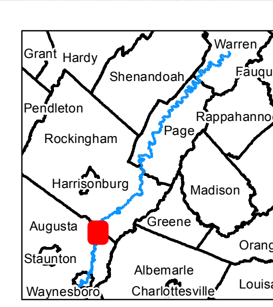

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Figure 3-3
Panel 14 of 16
Soil Sample Reach RRM 16.7 to 20.9
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Waynesboro, Virginia

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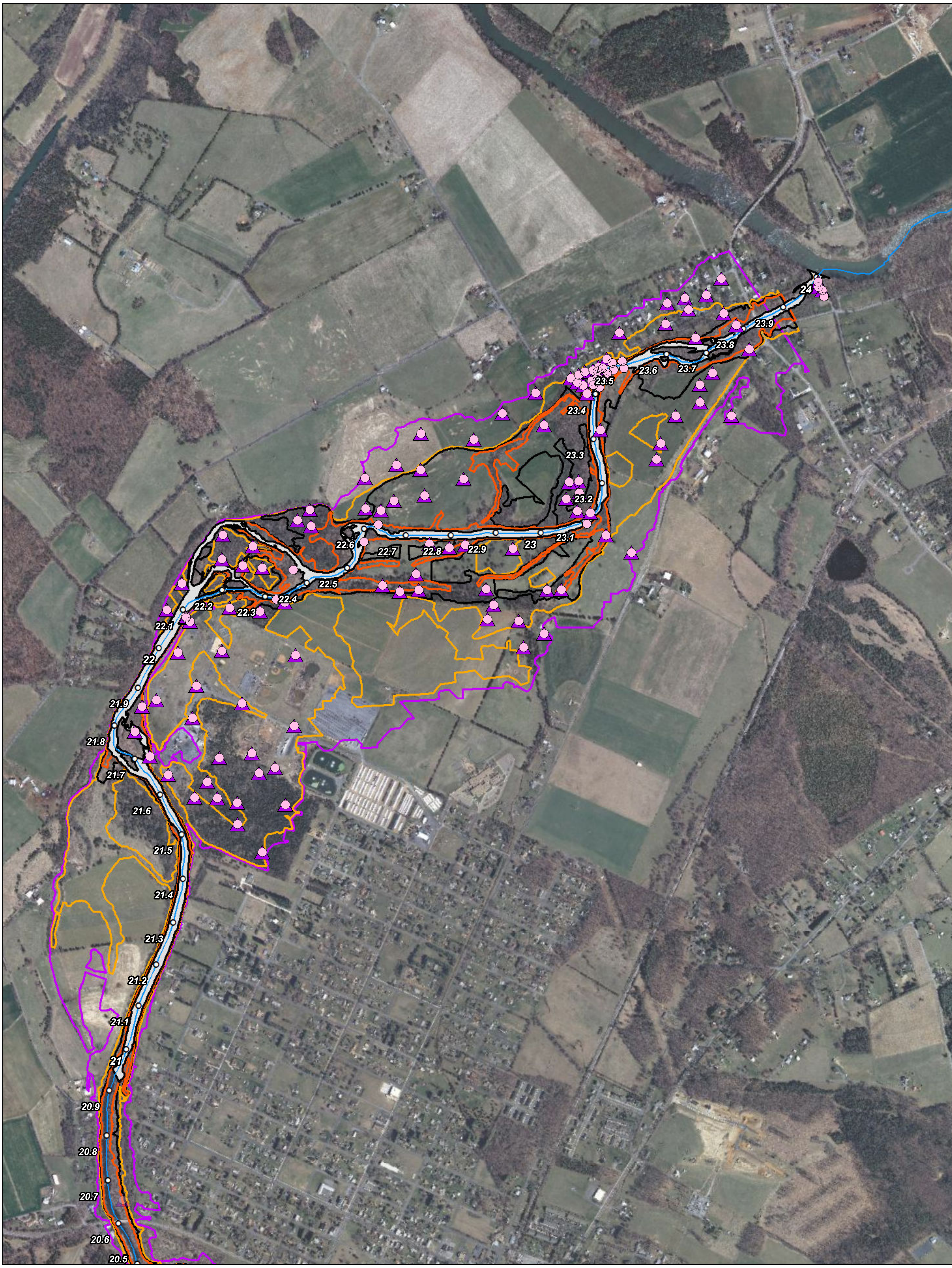

Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 1,450 2,900 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

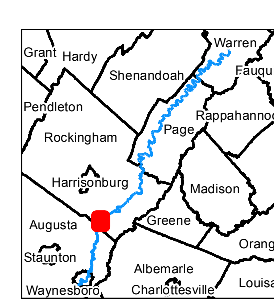

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Figure 3-3
Panel 15 of 16
Soil Sample Reach RRM 20.9 to 24.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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Legend

- Surface Soil (0.0'- 0.5')
- Subsurface Soil (0.5'- 2.0')
- RRM Intervals (Mile)
- Stream
- 0.3 Year Floodplain
- 2-Year Floodplain
- 5-Year Floodplain
- 62-Year Floodplain
- LiDAR Reach

0 2,000 4,000 8,000 12,000 16,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

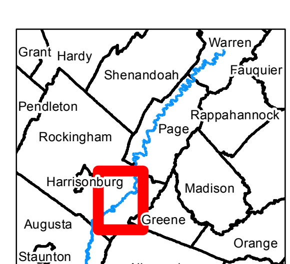

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Figure 3-3
Panel 16 of 16
Soil Sample Reach SFSR
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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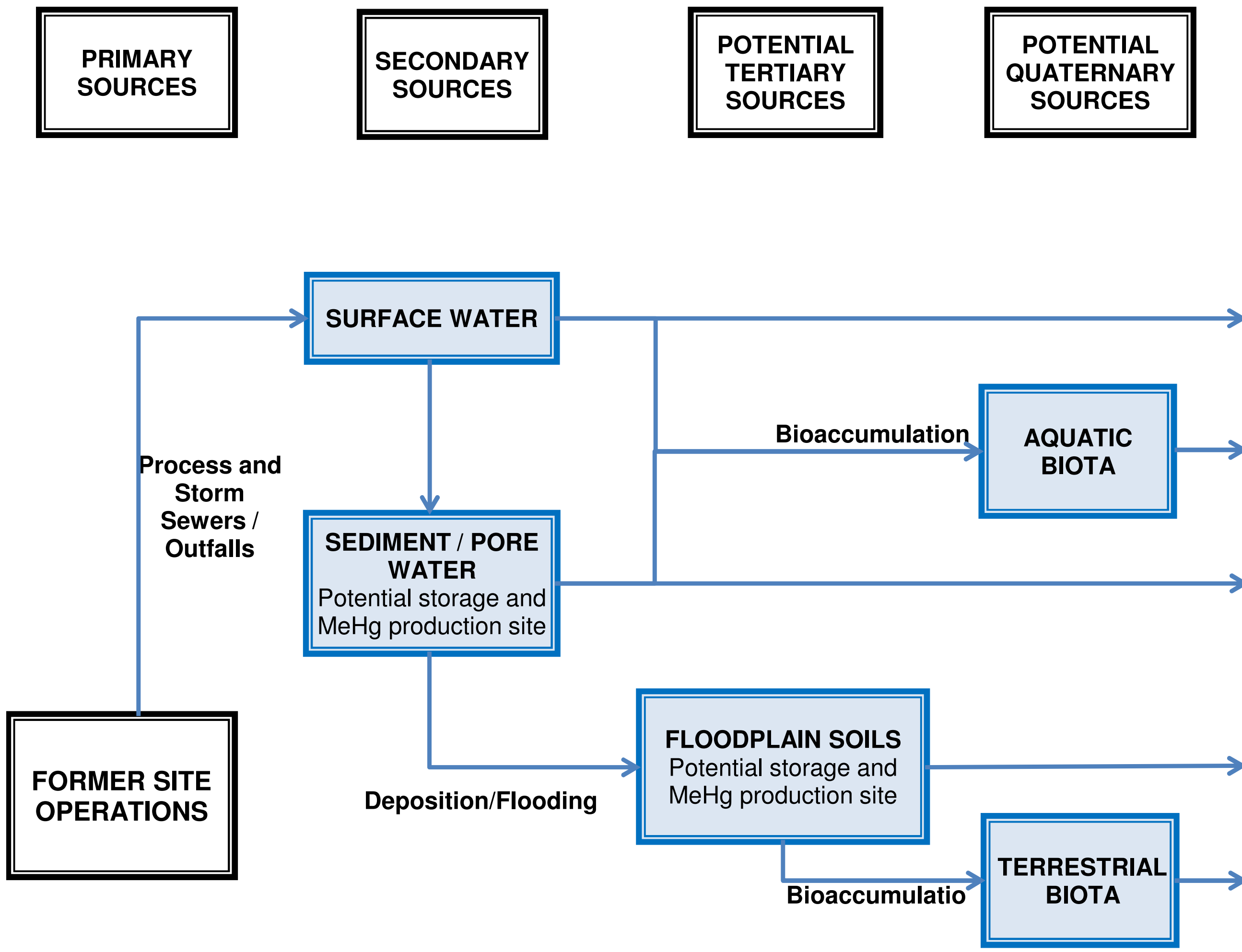
Figure 3-4
Ecological Conceptual Site Model (ECSM)
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia



		Potential Receptors															
		Aquatic			Semi-Aquatic					Terrestrial							
Source	Exposure Pathway	Benthic Macroinvertebrates	Fishes	Submerged Aquatic Vegetation	Amphibians	Reptiles	Piscivorous Birds	Omnivorous Birds	Piscivorous Mammals	Terrestrial Vegetation	Soil Invertebrates	Insectivorous Birds (Aerial)	Insectivorous Birds (Terrestrial)	Carnivorous birds	Aerial Insectivorous Mammals	Invertivorous Mammals	Herbivorous Mammals
Surface Water	Direct Contact/Absorption	●	●	●	●	●	--	--	--			--	--	--	--		
	Incidental Ingestion	○	○		○	○	●	●	●			--	--	--	--	--	--
	Direct Ingestion	--	--				●	●	●			●	●	●	●	●	●
Aquatic Biota	Direct Ingestion	○	●		●	●	●	●	●			●		●	●		
Sediment / Pore Water	Direct Contact/Absorption	●	○	●	●	●	--	--	--					--			
	Incidental Ingestion	○	○		○	○	●	●	●					●			
	Direct Ingestion																
Floodplain Soils	Direct Contact/Absorption				○	○	--	--	--	●	●	--		--		--	--
	Incidental Ingestion				○	○	●	●	●		○	--		●		●	●
Terrestrial Biota	Direct Ingestion		○		●	●	--	●	●		○	●		●	●	●	●

Notes:

→ CONTAMINANT MIGRATION PATHWAY

● POTENTIALLY COMPLETE EXPOSURE PATHWAY

○ SECONDARY EXPOSURE PATHWAY; NOT DIRECTLY QUANTIFIED

-- EXPOSURE PATHWAY IS POTENTIALLY COMPLETE BUT INSIGNIFICANT

BLANK = INCOMPLETE EXPOSURE PATHWAY

INCIDENTAL INGESTION OF SURFACE WATER DURING FEEDING IS NOT AN APPLICABLE PATHWAY

Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 750 1,500 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

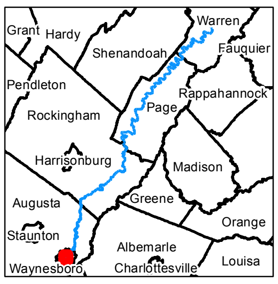


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Figure 5-1
Panel 1 of 16
Pore Water Sample Reach RRM -2.7 to -0.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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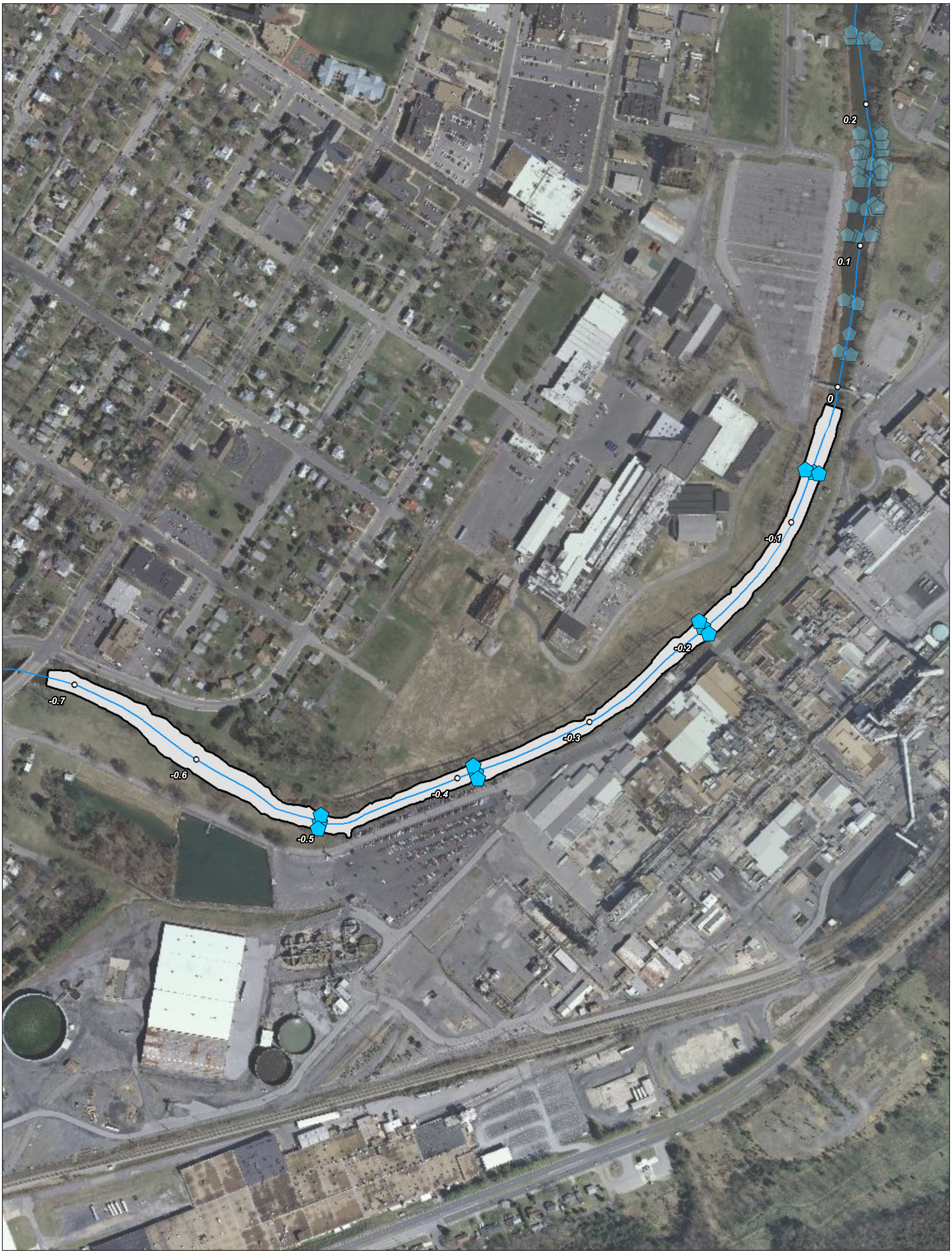

Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 | 462.5 | 925 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

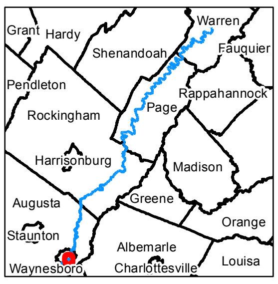

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Figure 5-1
Panel 2 of 16
Pore Water Sample Reach RRM -0.7 to 0.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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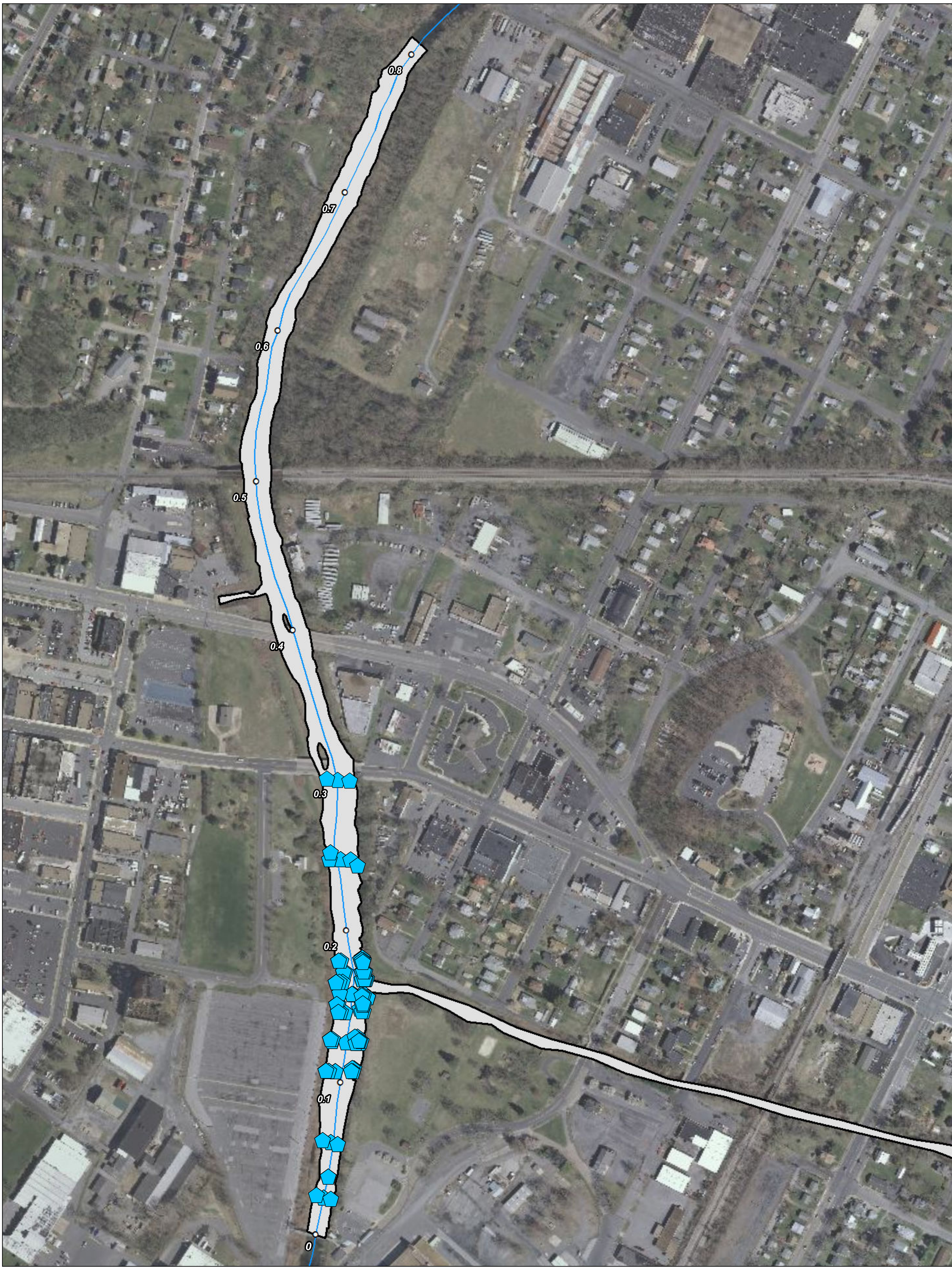

Legend

- Pore Water
- RRM Intervals (Mile)
- Stream
- LiDAR Reach

0 435 870 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

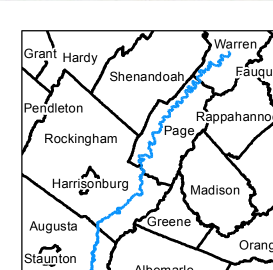

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Figure 5-1
Panel 3 of 16
Pore Water Sample Reach RRM 0.0 to 0.8
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

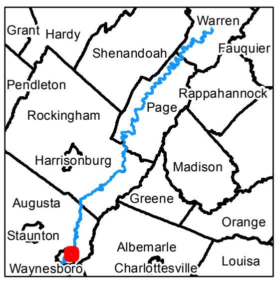

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Figure 5-1
Panel 4 of 16
Pore Water Sample Reach RRM 0.8 to 1.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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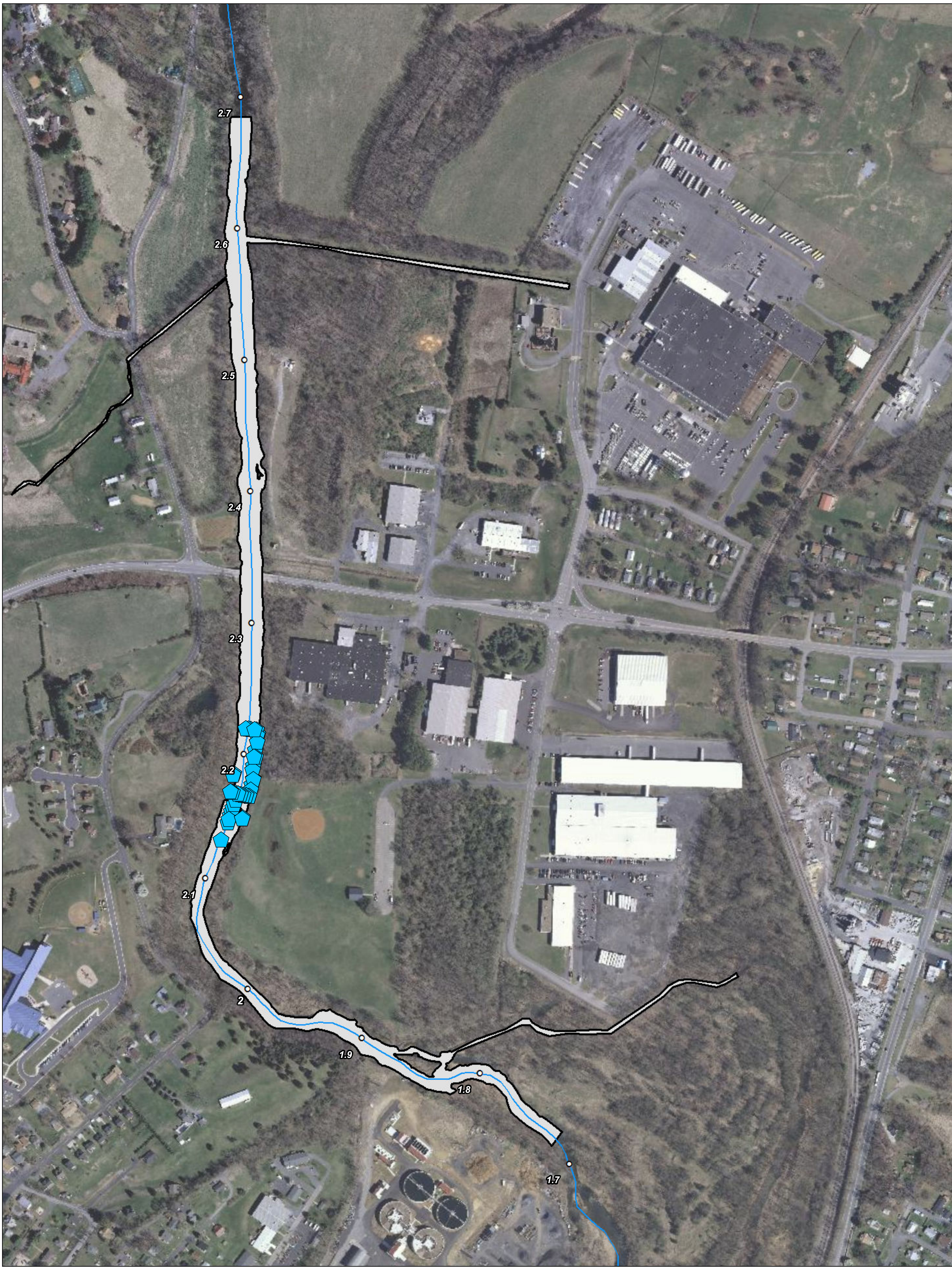

Legend

Pore Water · RRM Intervals (Mile) · Stream · LiDAR Reach

0 · 500 · 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

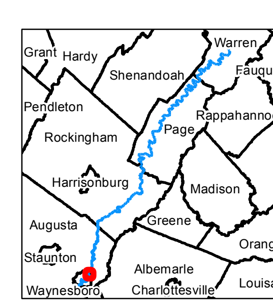

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Figure 5-1
Panel 5 of 16
Pore Water Sample Reach RRM 1.7 to 2.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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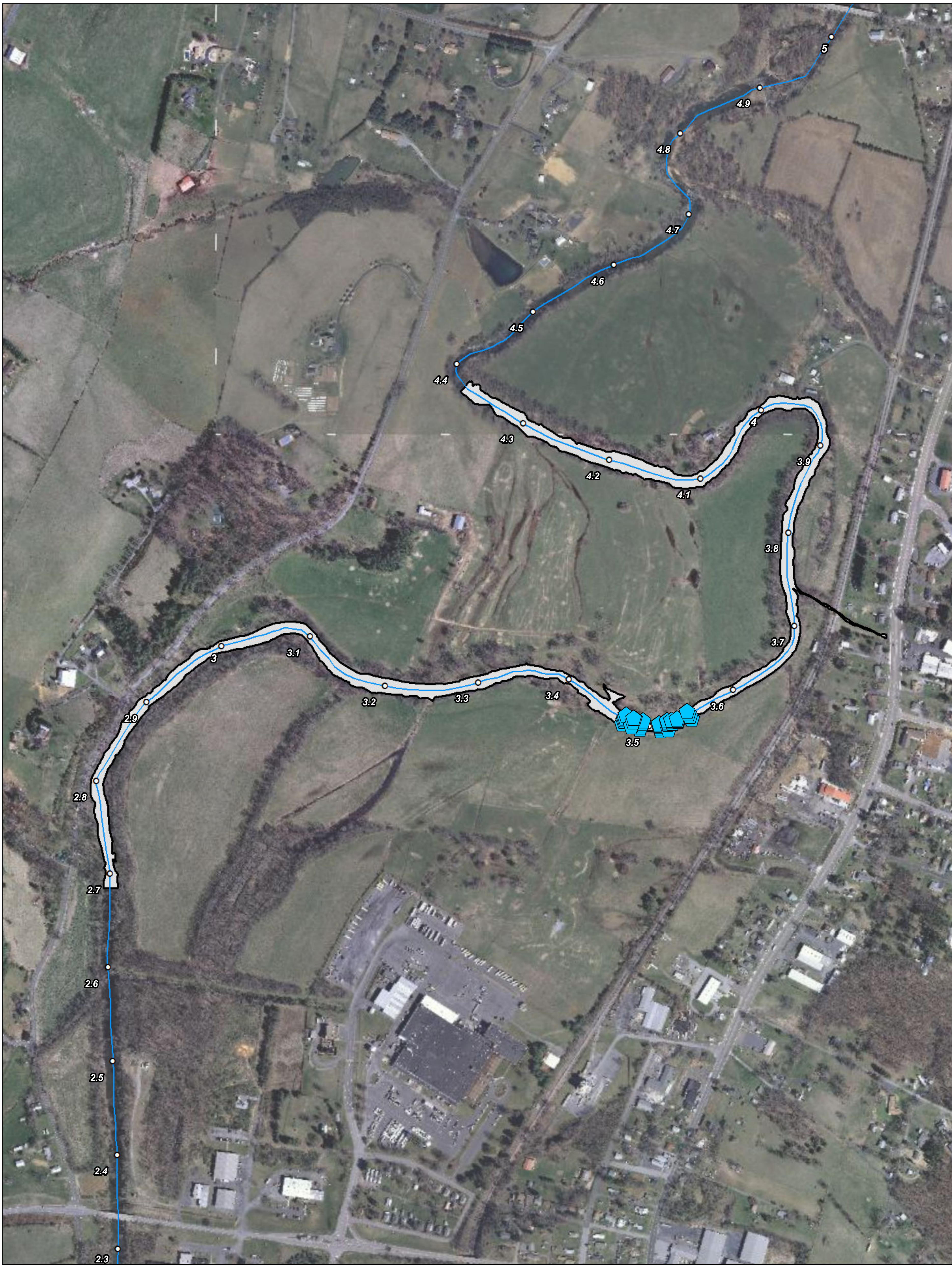


Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 700 1,400 Feet

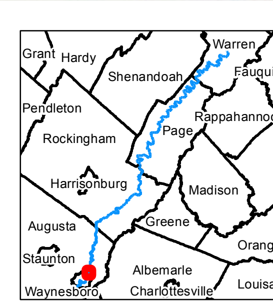
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Job: 18986307.01340	**Figure 5-1** **Panel 6 of 16** **Pore Water Sample Reach RRM 2.7 to 4.4** **AOC 4 Ecological Risk Assessment Report** Former Dupont Waynesboro Plant Waynesboro, Virginia
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Checked by: BR	
Date: 8/14/2014	

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Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 550 1,100 Feet

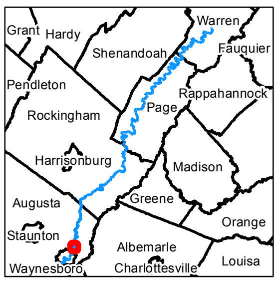
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Date: 8/14/2014

Figure 5-1
Panel 7 of 16
Pore Water Sample Reach RRM 4.4 to 5.2
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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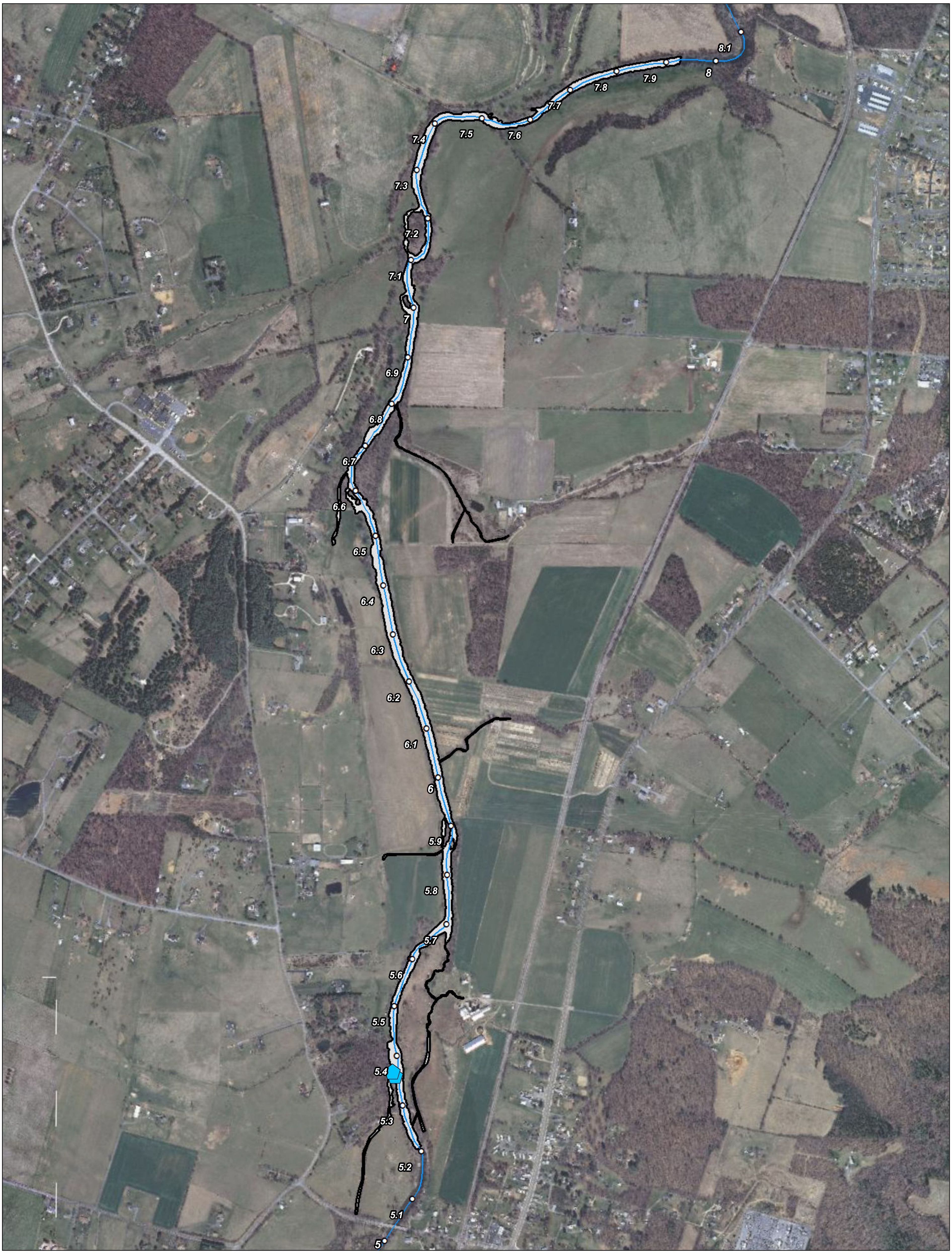

Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 1,300 2,600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

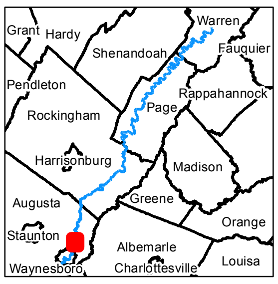

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Figure 5-1
Panel 8 of 16
Pore Water Sample Reach RRM 5.2 to 7.9
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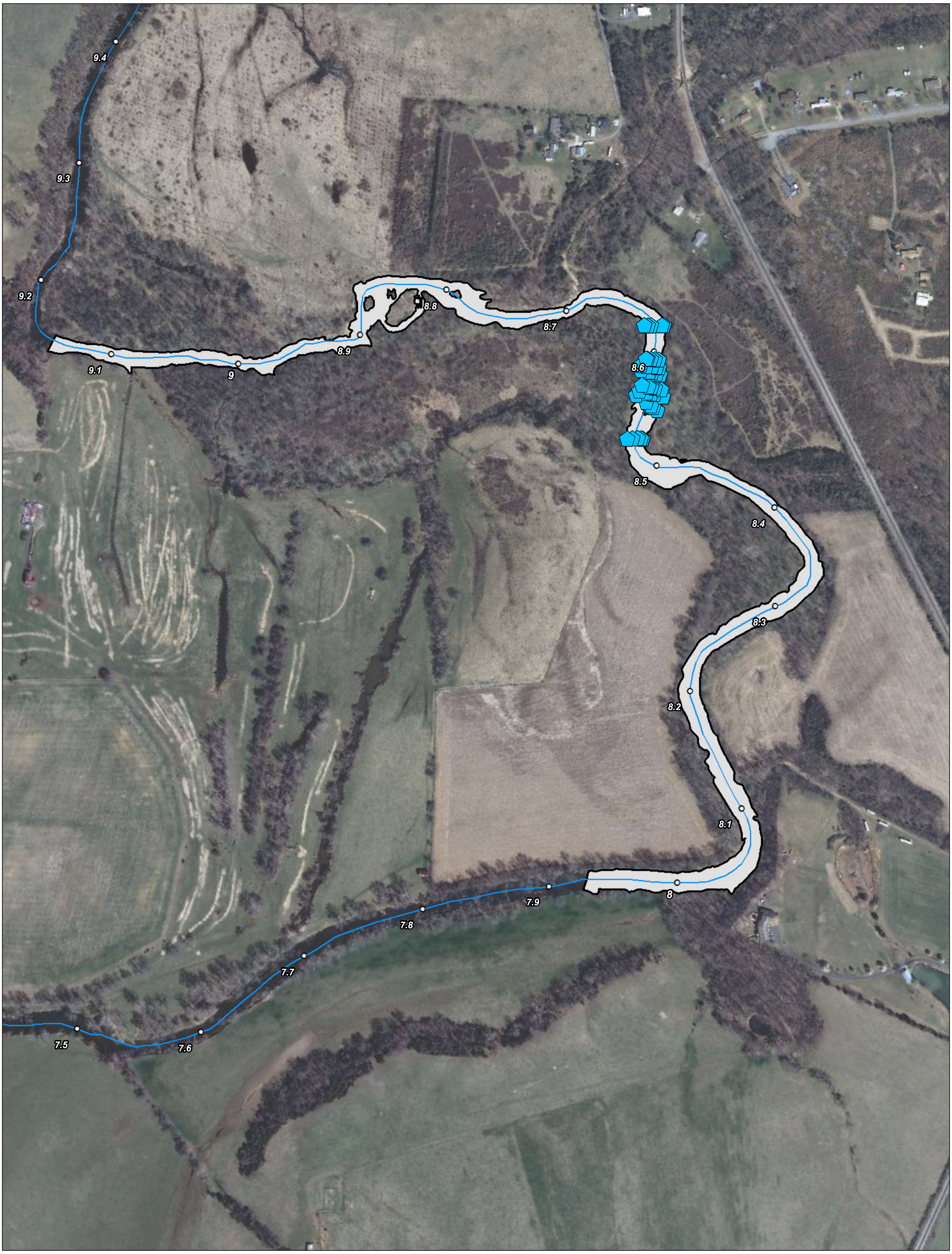
Waynesboro, Virginia



Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

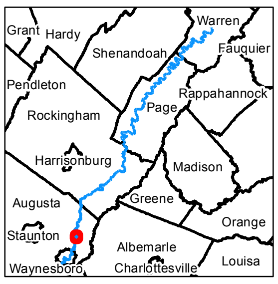


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Figure 5-1
Panel 9 of 16
Pore Water Sample Reach RRM 7.9 to 9.2
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Former Dupont Waynesboro Plant
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Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 900 1,800 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

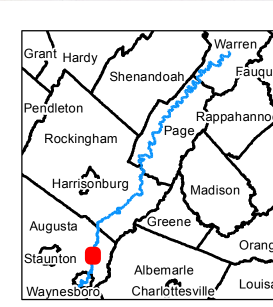

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Figure 5-1
Panel 10 of 16
Pore Water Sample Reach RRM 9.2 to 11.3
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

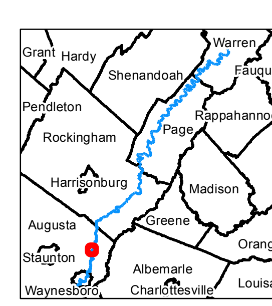

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Figure 5-1
Panel 11 of 16
Pore Water Sample Reach RRM 11.3 to 12.5
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Legend

Pore Water   RRM Intervals (Mile)   Stream   LiDAR Reach

0   500   1,000 Feet

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

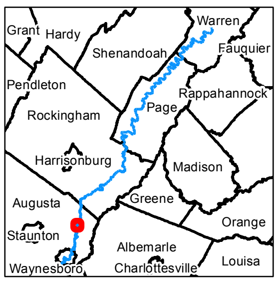

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Figure 5-1
Panel 12 of 16
Pore Water Sample Reach RRM 12.5 to 13.5
AOC 4 Ecological Risk Assessment Report
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Waynesboro, Virginia

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Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 | 1,250 | 2,500 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

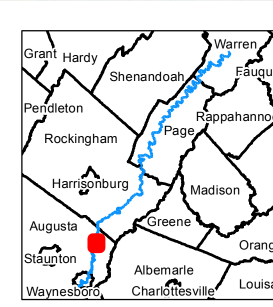

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Figure 5-1
Panel 13 of 16
Pore Water Sample Reach RRM 13.5 to 16.7
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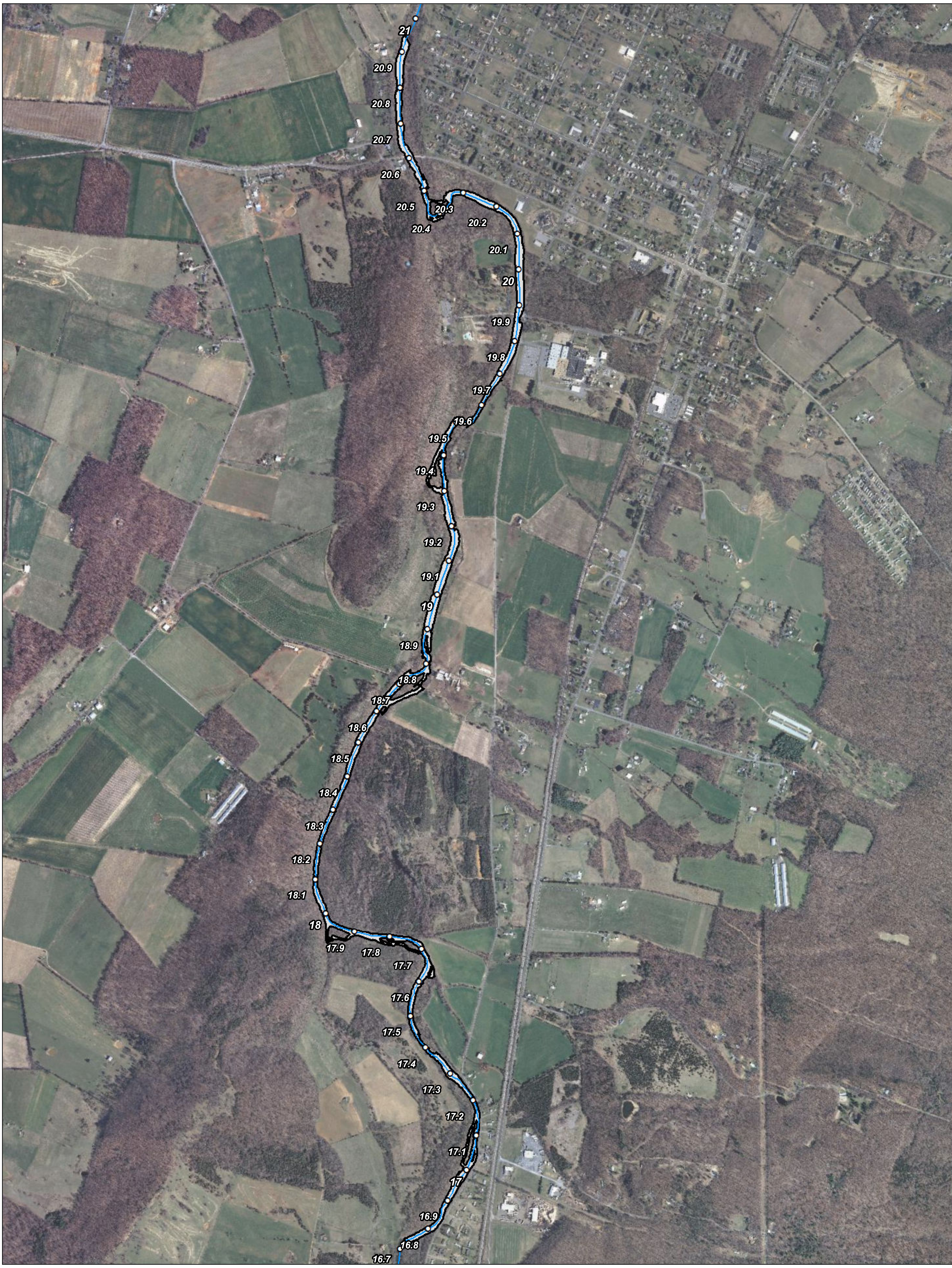

Legend

Pore Water · RRM Intervals (Mile) · Stream · LiDAR Reach

0 · 1,850 · 3,700 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

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Figure 5-1
Panel 14 of 16
Pore Water Sample Reach RRM 16.7 to 20.9
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
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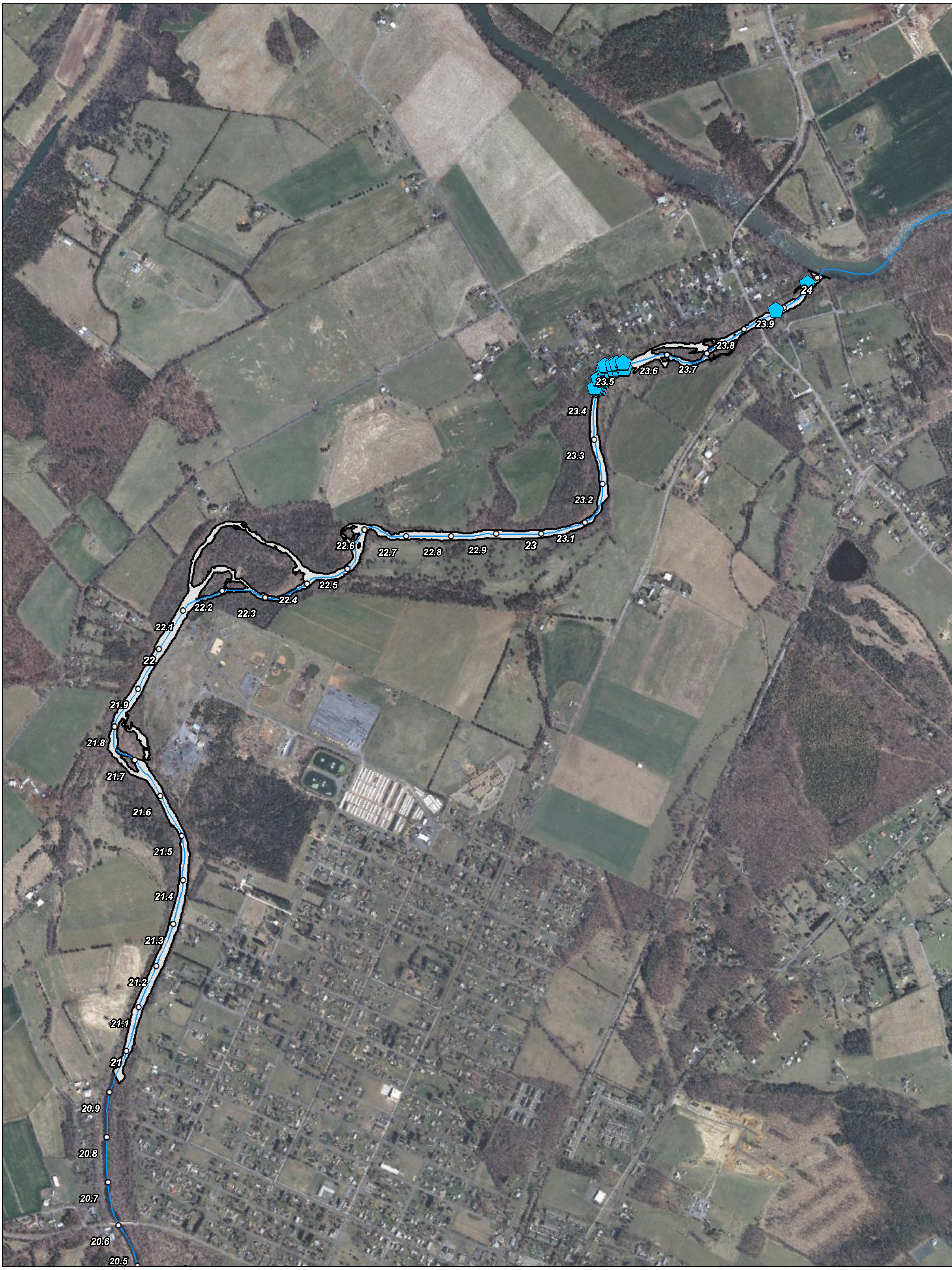

Legend

Pore Water | RRM Intervals (Mile) | Stream | LiDAR Reach

0 | 1,450 | 2,900 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

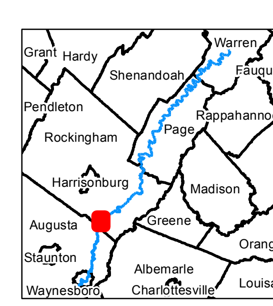

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Figure 5-1
Panel 15 of 16
Pore Water Sample Reach RRM 20.9 to 24.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
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Legend

Pore Water
RRM Intervals (Mile)
Stream
LiDAR Reach

0 2,000 4,000 8,000 12,000 16,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

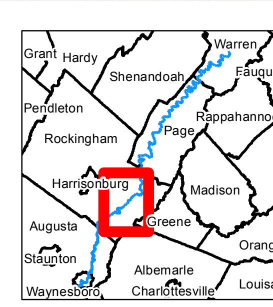

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Figure 5-1
Panel 16 of 16
Pore Water Sample Reach SFSR
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 750 1,500 Feet

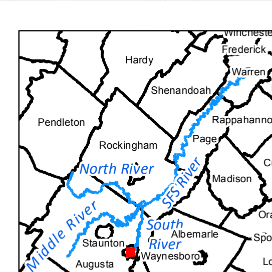
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Prepared by: VP

Checked by: BR

Date: 2/19/2015

Figure 5-2
Panel 1 of 20: Biological Sample Reach
RRM -2.7 to -0.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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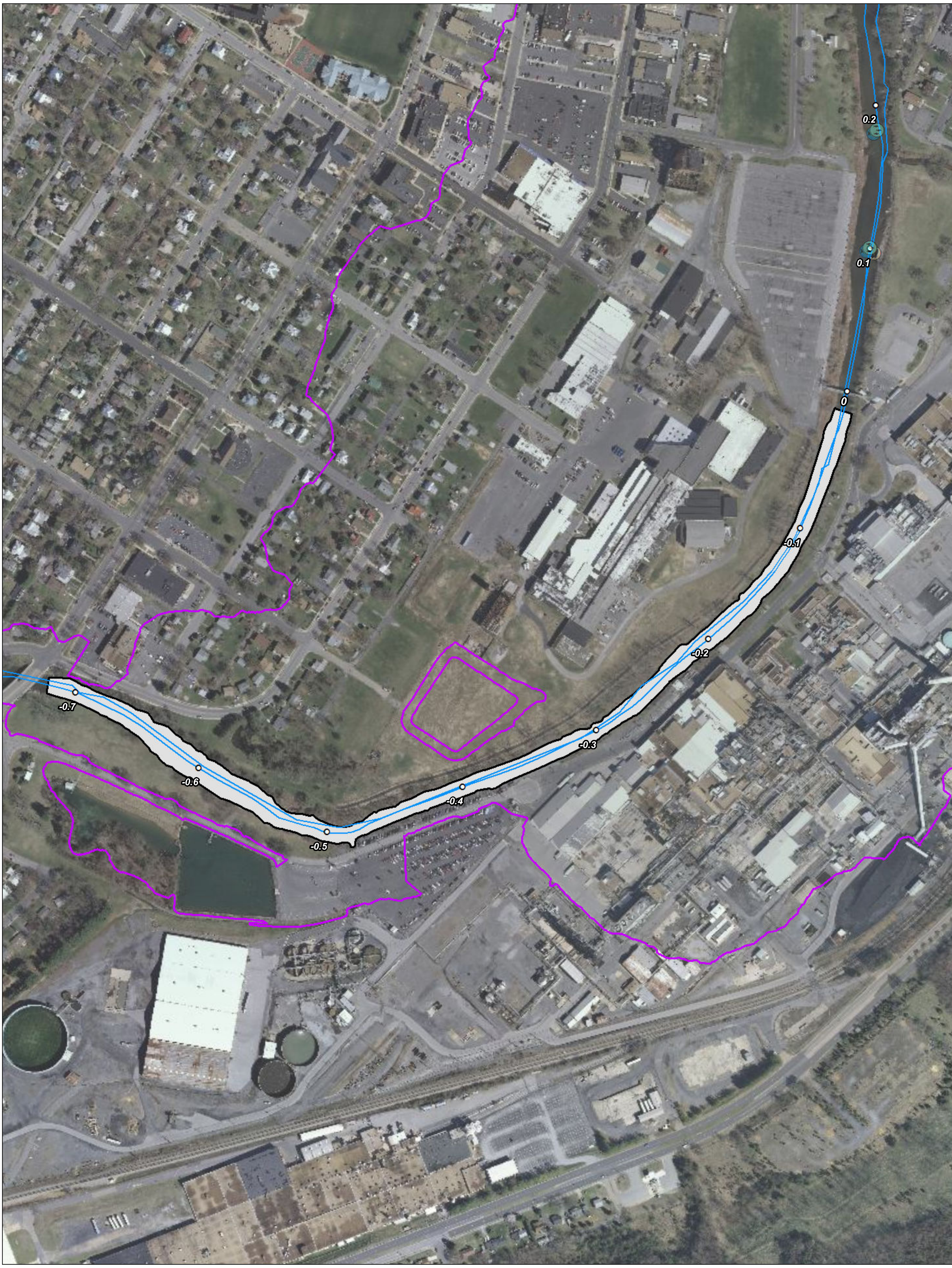


Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 462.5 925 Feet

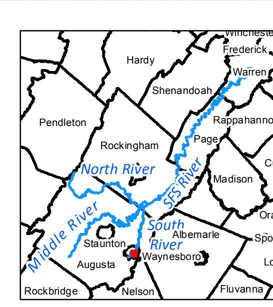
N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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



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Date: 2/19/2015

Figure 5-2
Panel 2 of 20: Biological Sample Reach
RRM -0.7 to 0.0
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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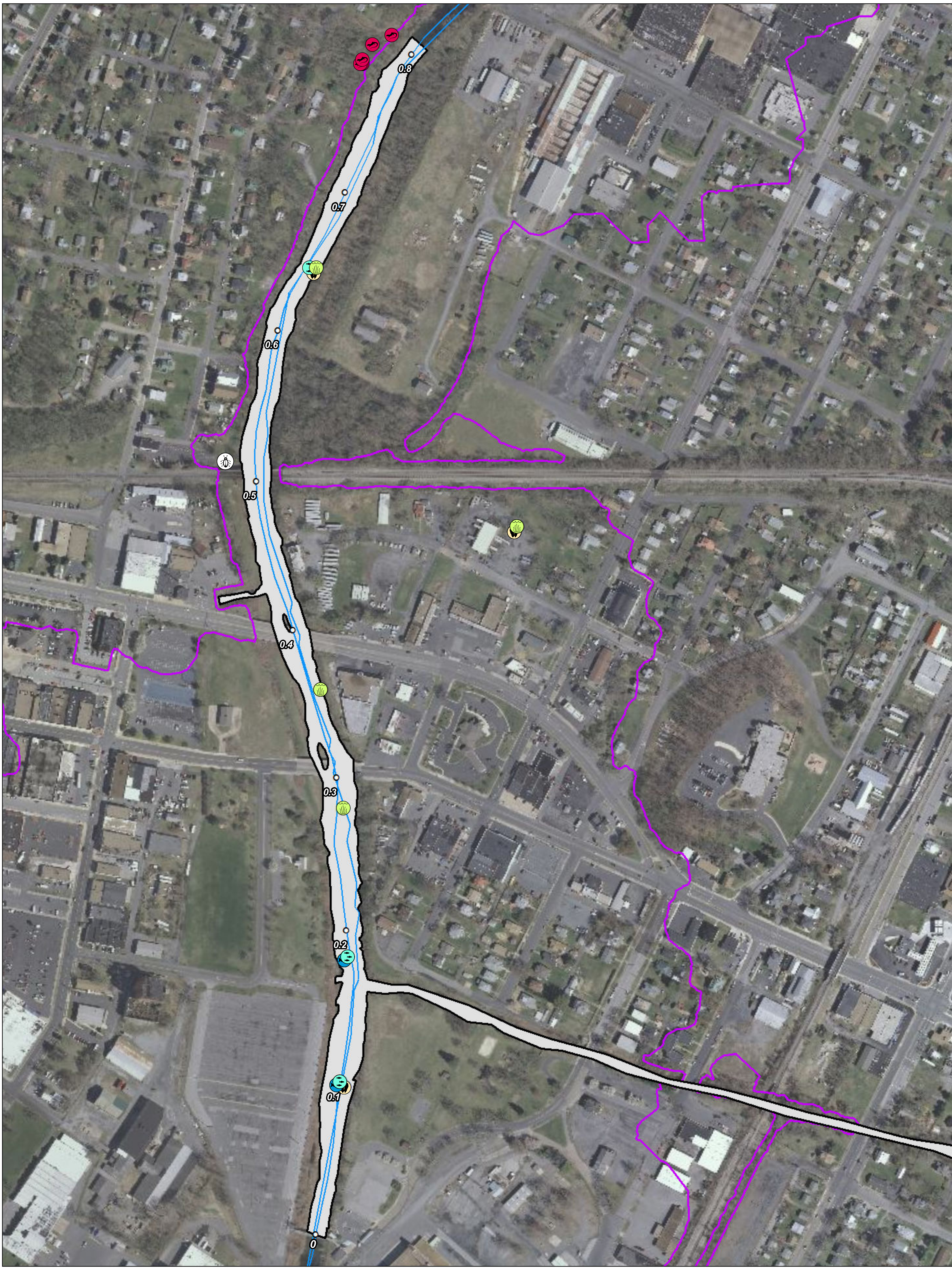

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 435 870 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

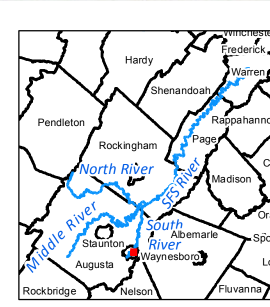

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Figure 5-2
Panel 3 of 20: Biological Sample Reach
RRM 0.0 to 0.8
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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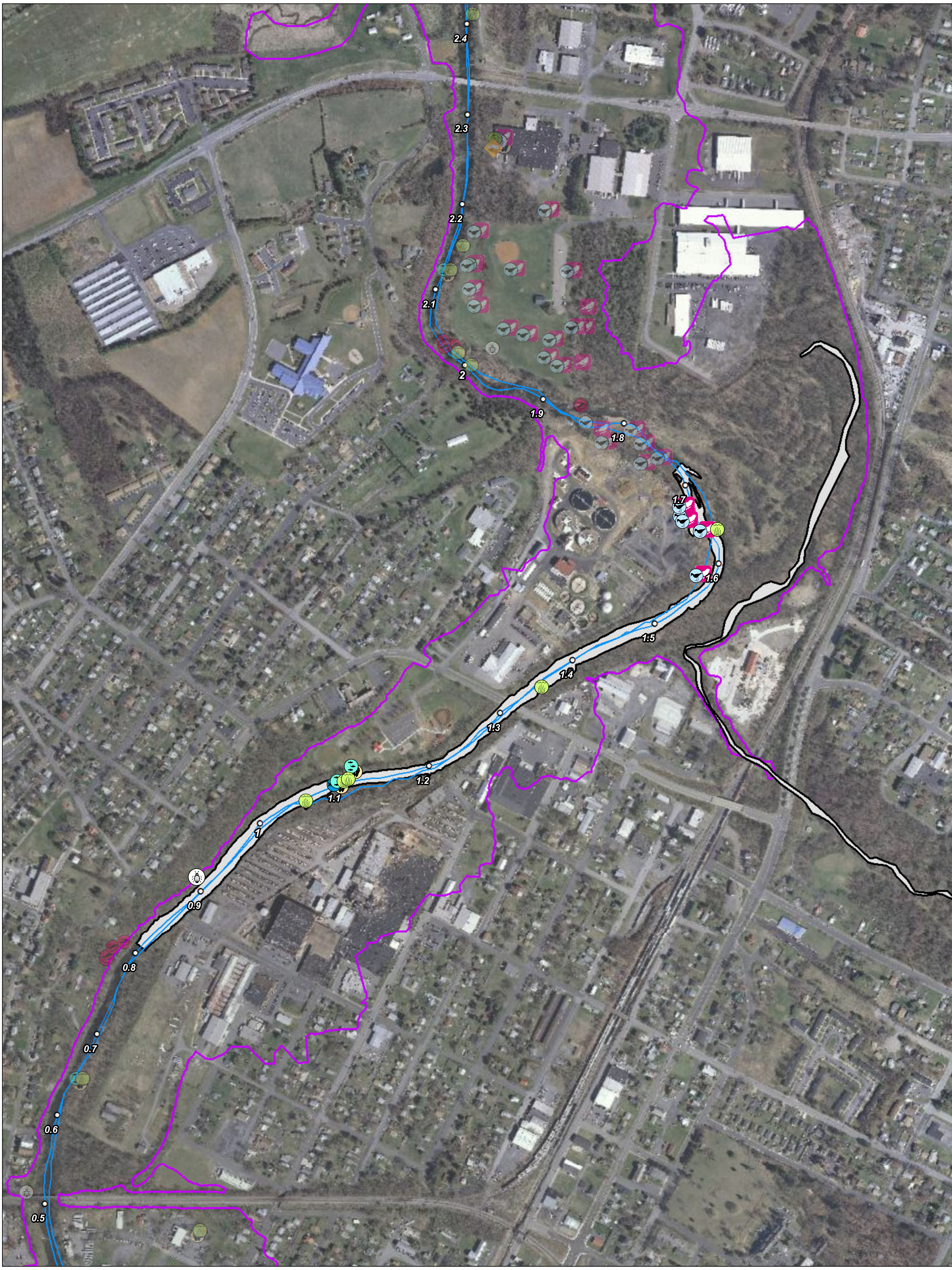

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

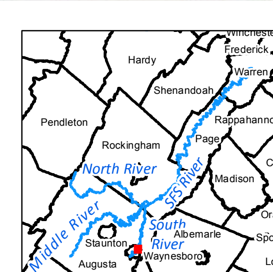

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Figure 5-2
Panel 4 of 20: Biological Sample Reach
RRM 0.8 to 1.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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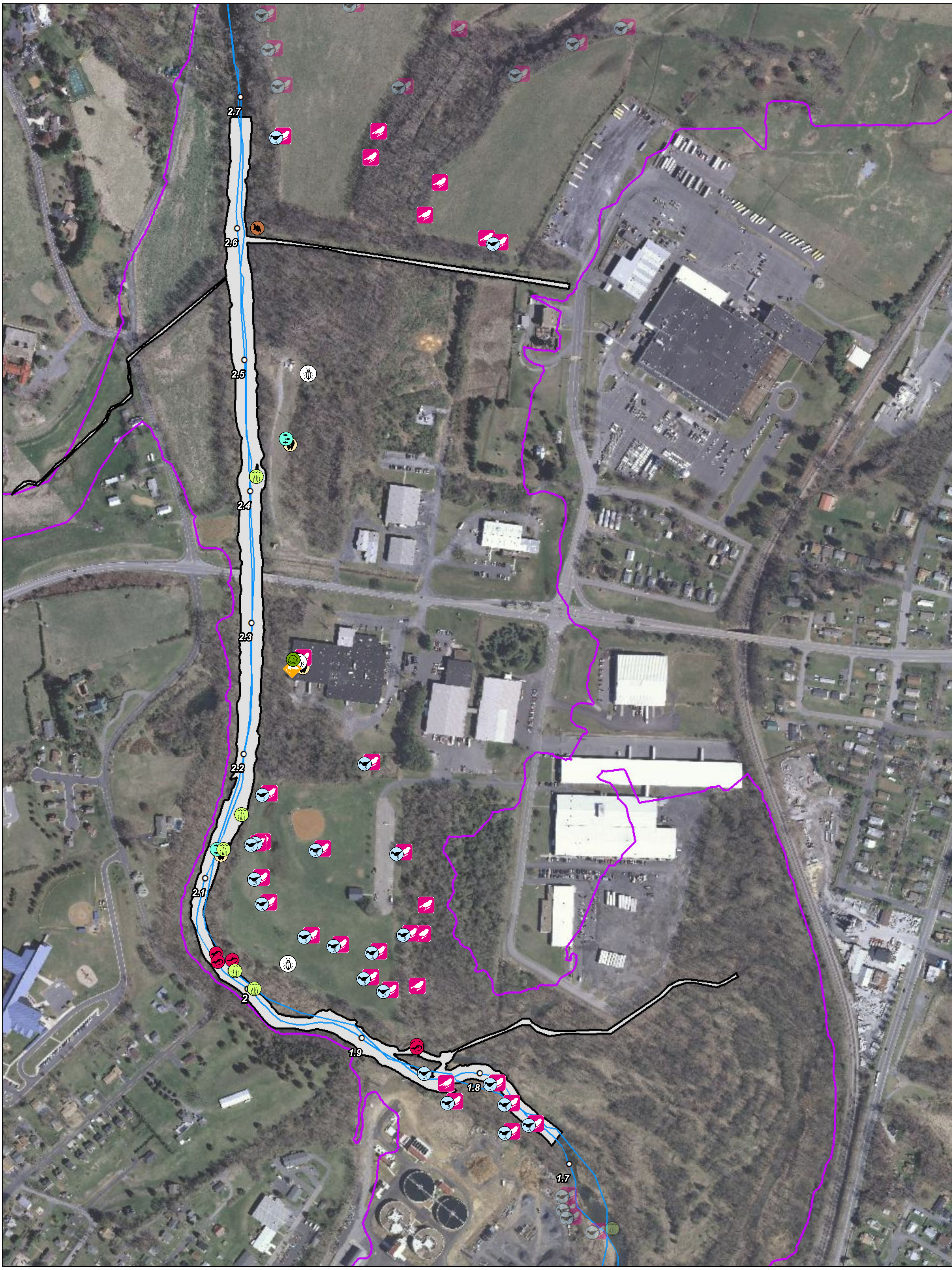

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

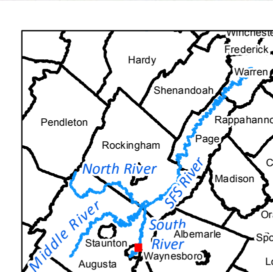

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Figure 5-2
Panel 5 of 20: Biological Sample Reach
RRM 1.7 to 2.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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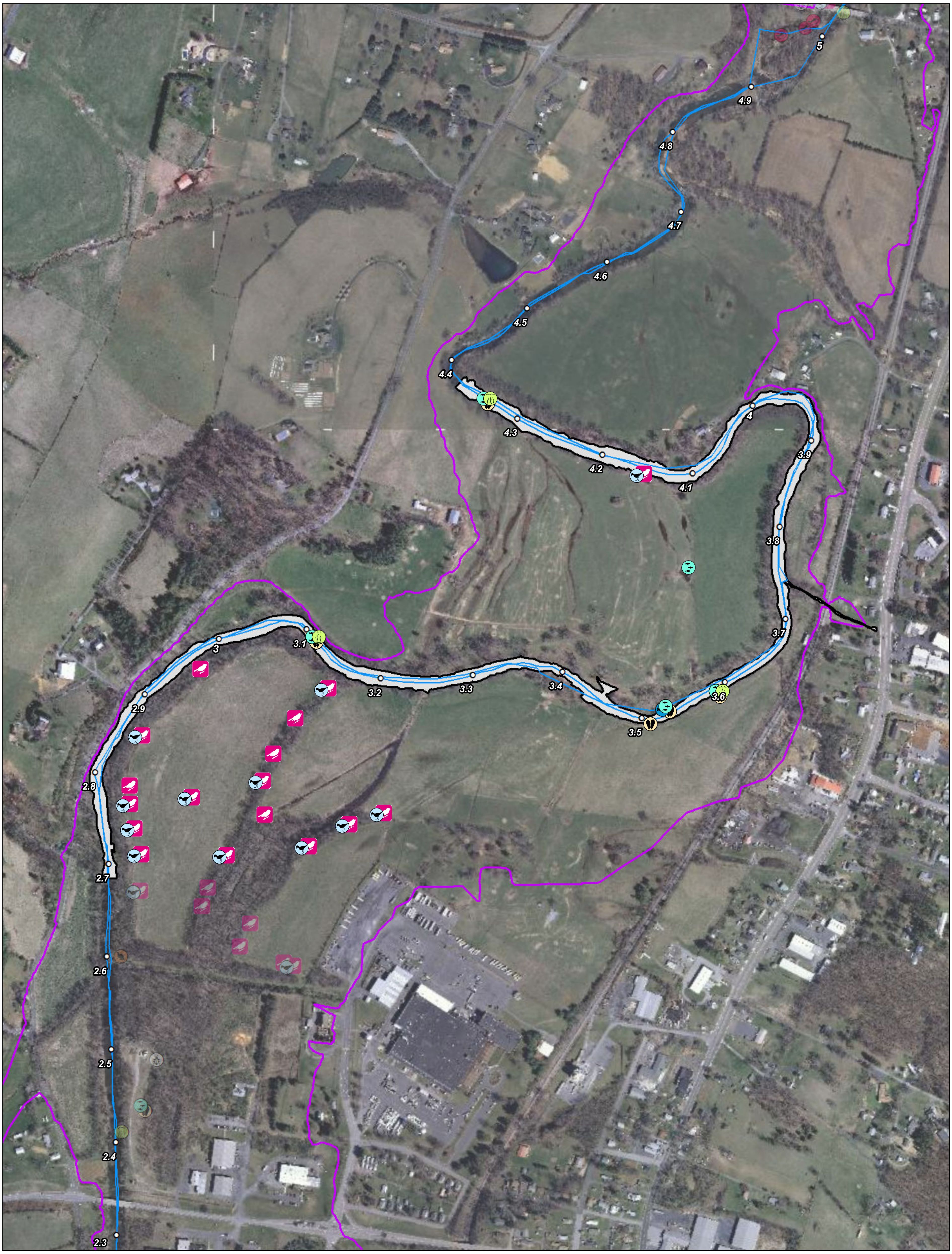

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 700 1,400 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

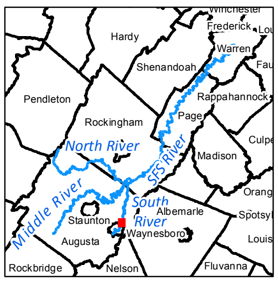

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Figure 5-2
Panel 6 of 20: Biological Sample Reach
RRM 2.7 to 4.4
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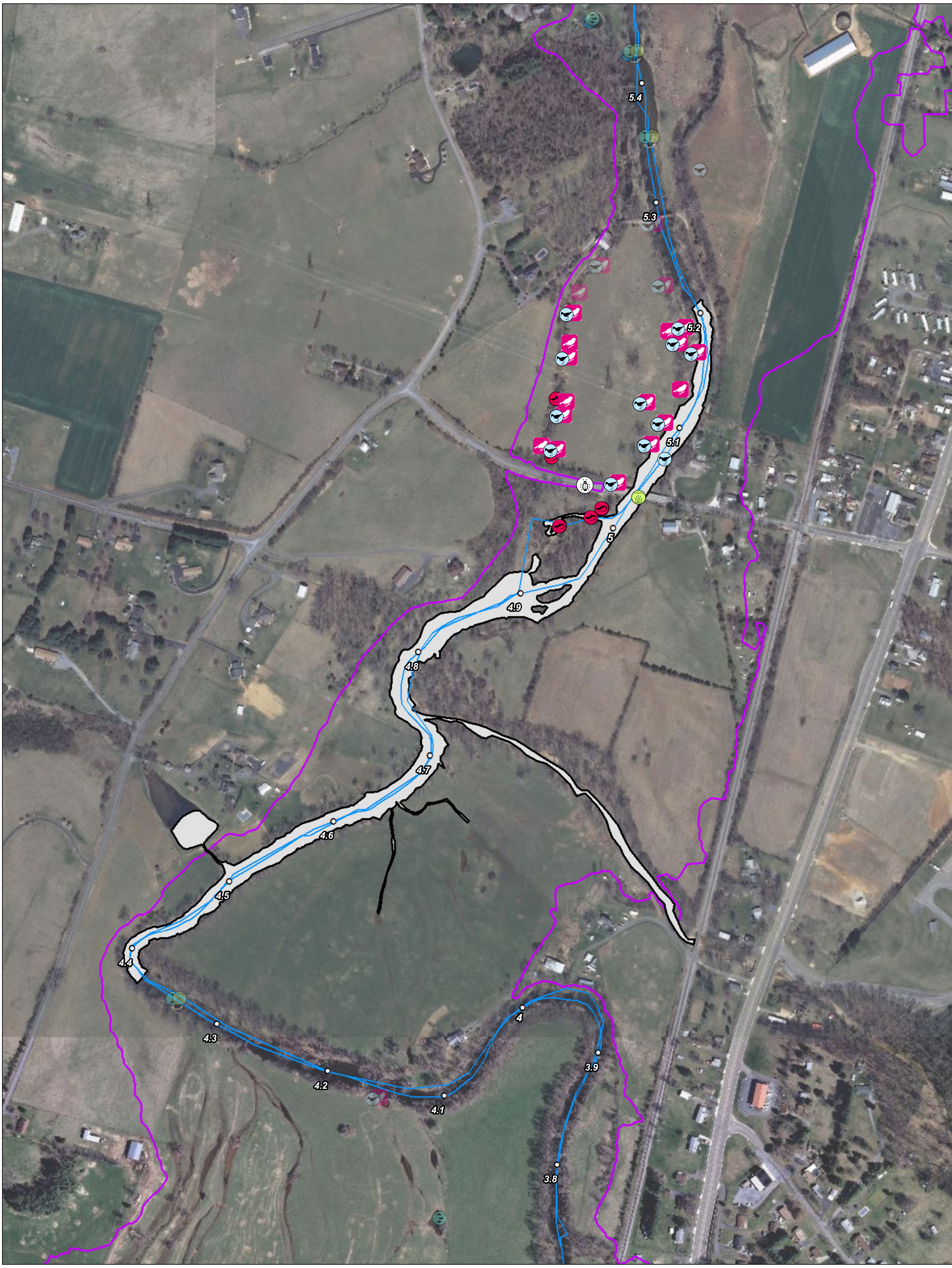

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 550 1,100 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

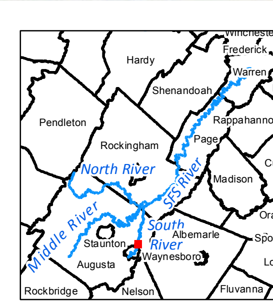

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Figure 5-2
Panel 7 of 20: Biological Sample Reach
RRM 4.4 to 5.2
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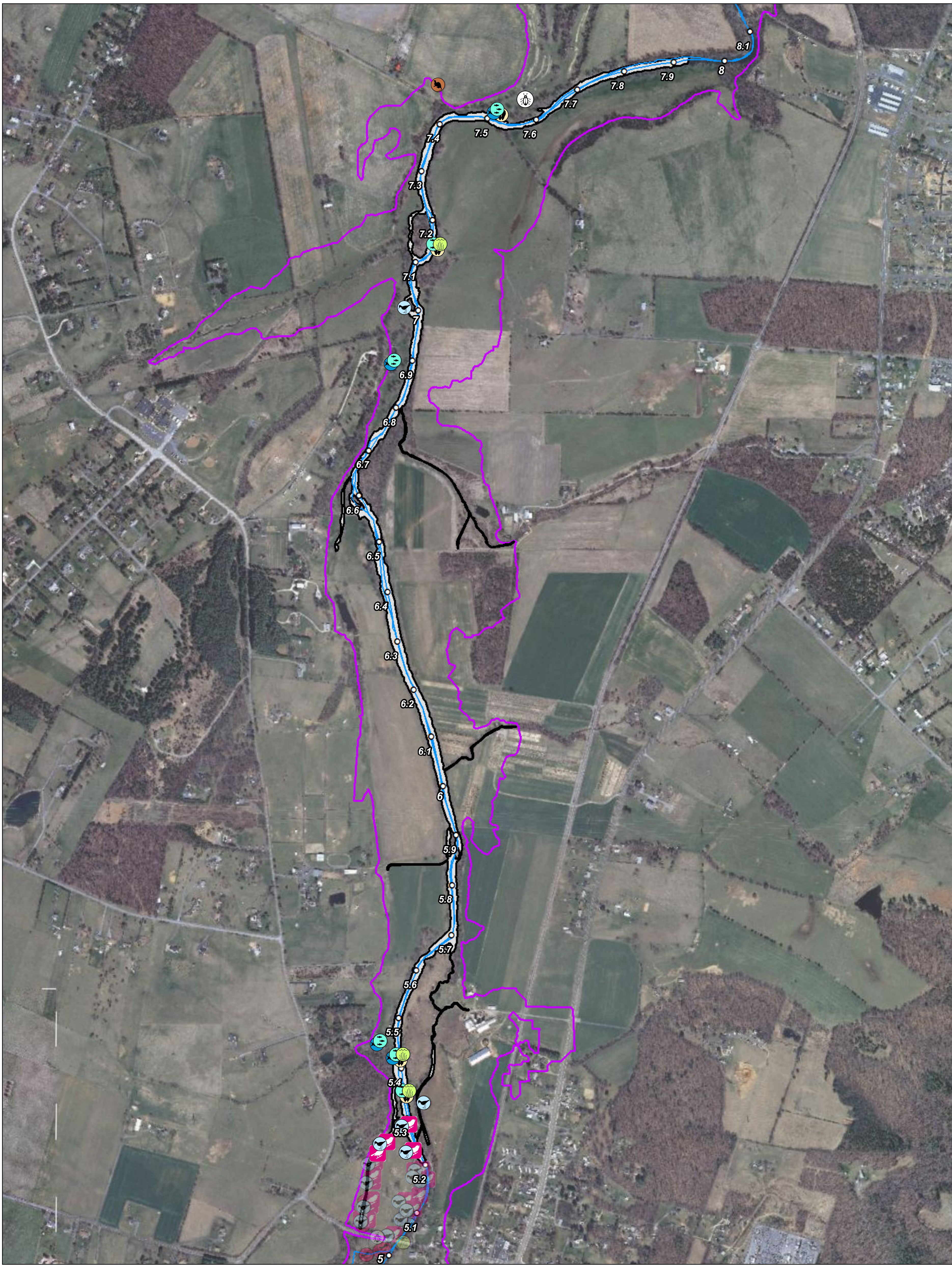

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 1,300 2,600 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

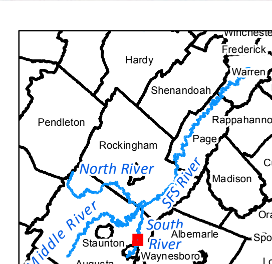

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Figure 5-2
Panel 8 of 20: Biological Sample Reach
RRM 5.2 to 7.9
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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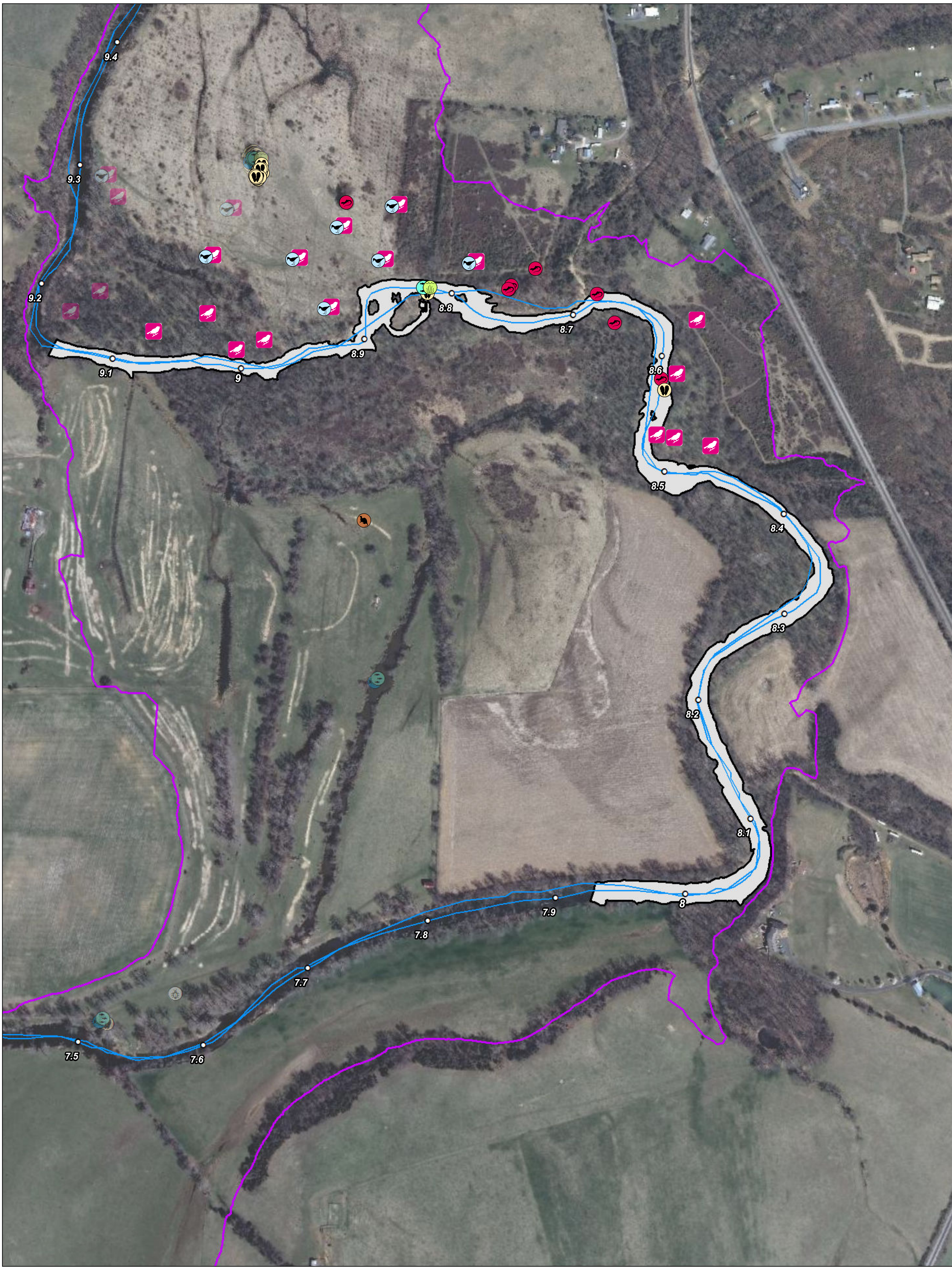

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

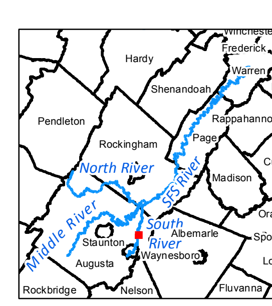

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Figure 5-2
Panel 9 of 20: Biological Sample Reach
RRM 7.9 to 9.2
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Waynesboro, Virginia

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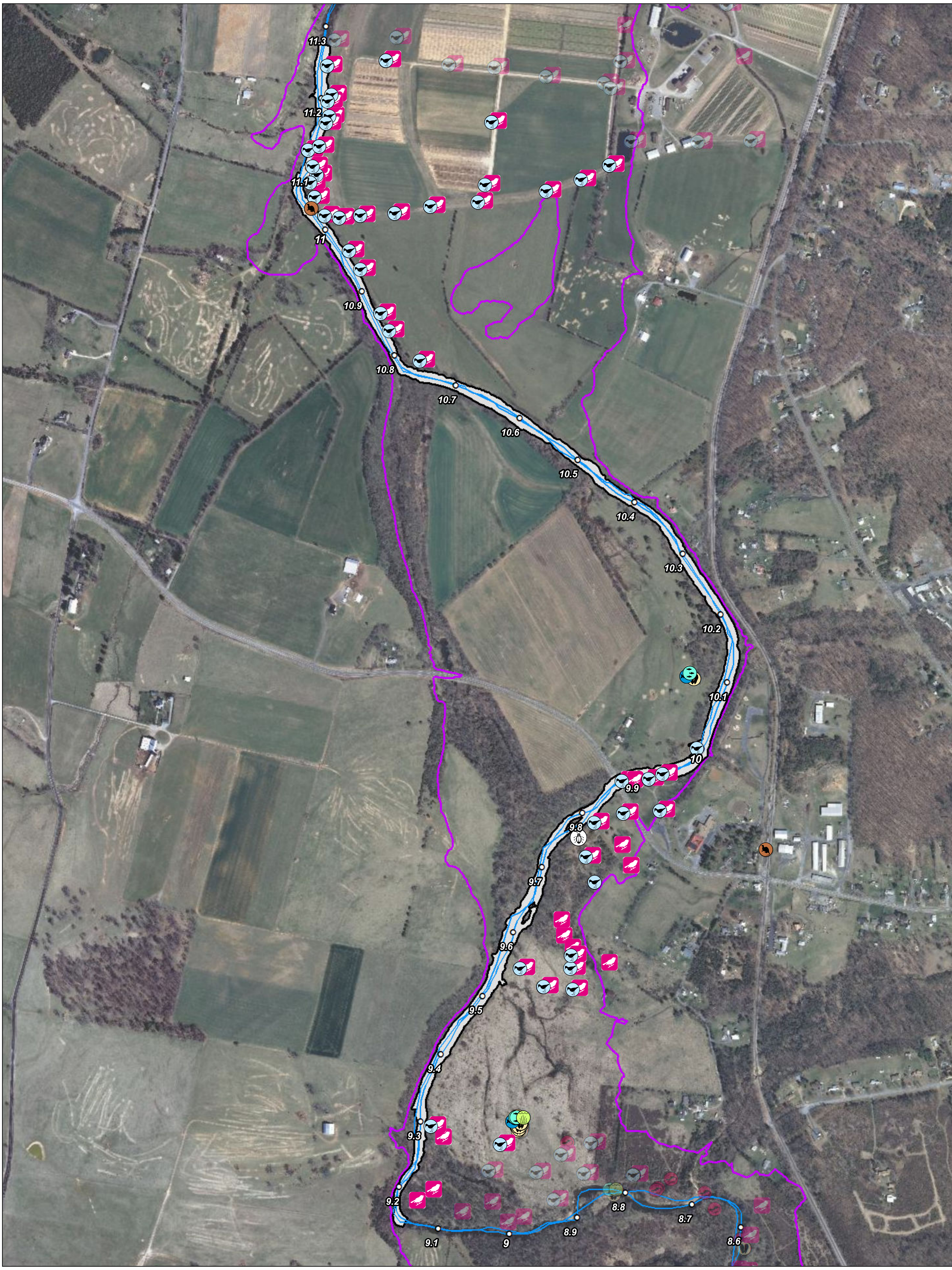

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

N

0 900 1,800 Feet

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

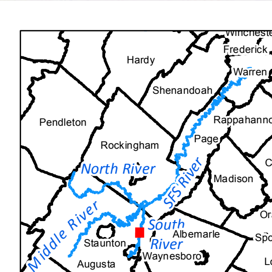

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Figure 5-2
Panel 10 of 20: Biological Sample Reach
RRM 9.2 to 11.3
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Waynesboro, Virginia

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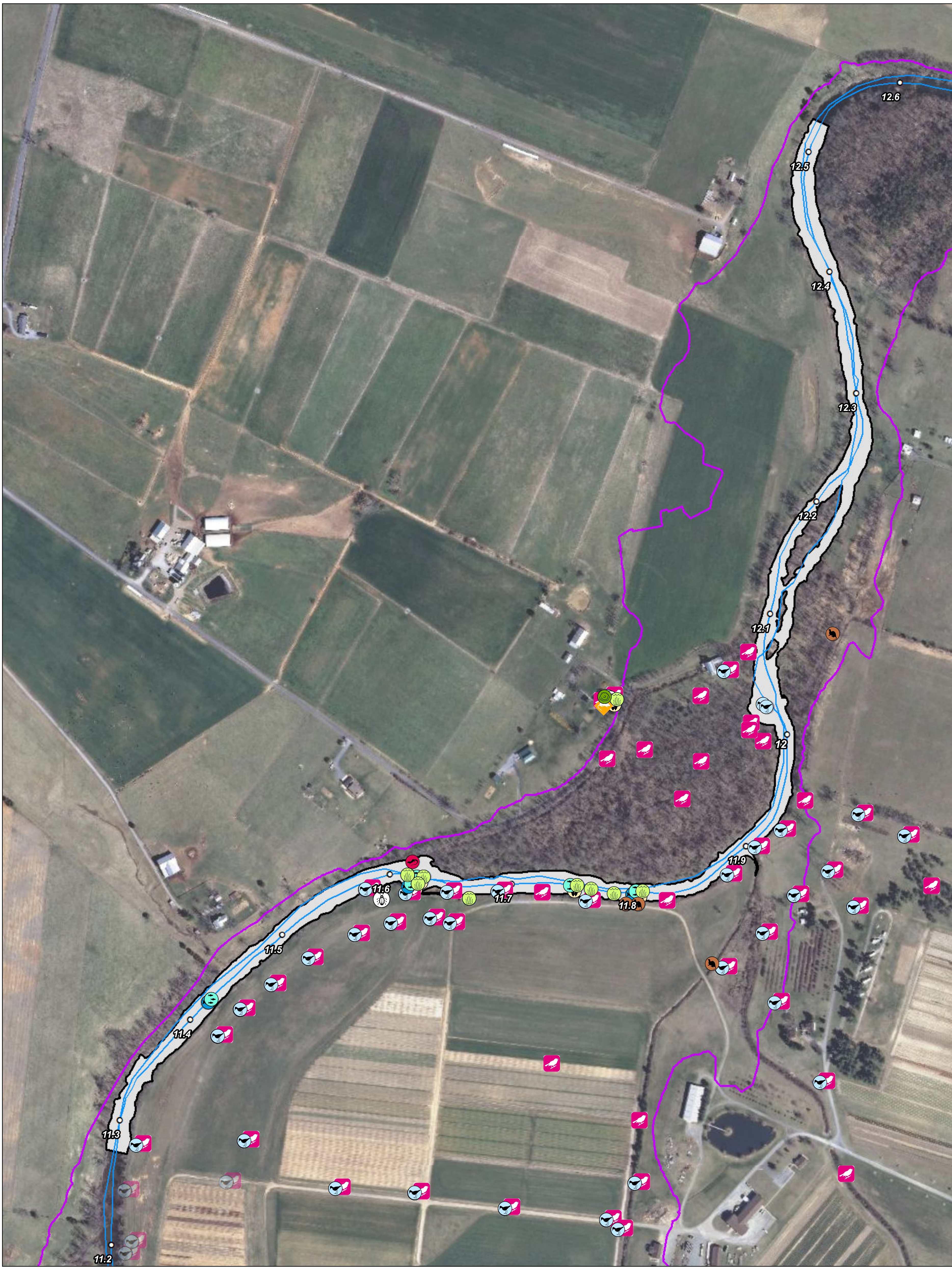

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

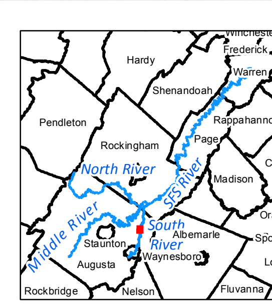

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Figure 5-2
Panel 11 of 20: Biological Sample Reach
RRM 11.3 to 12.5
AOC 4 Ecological Risk Assessment Report
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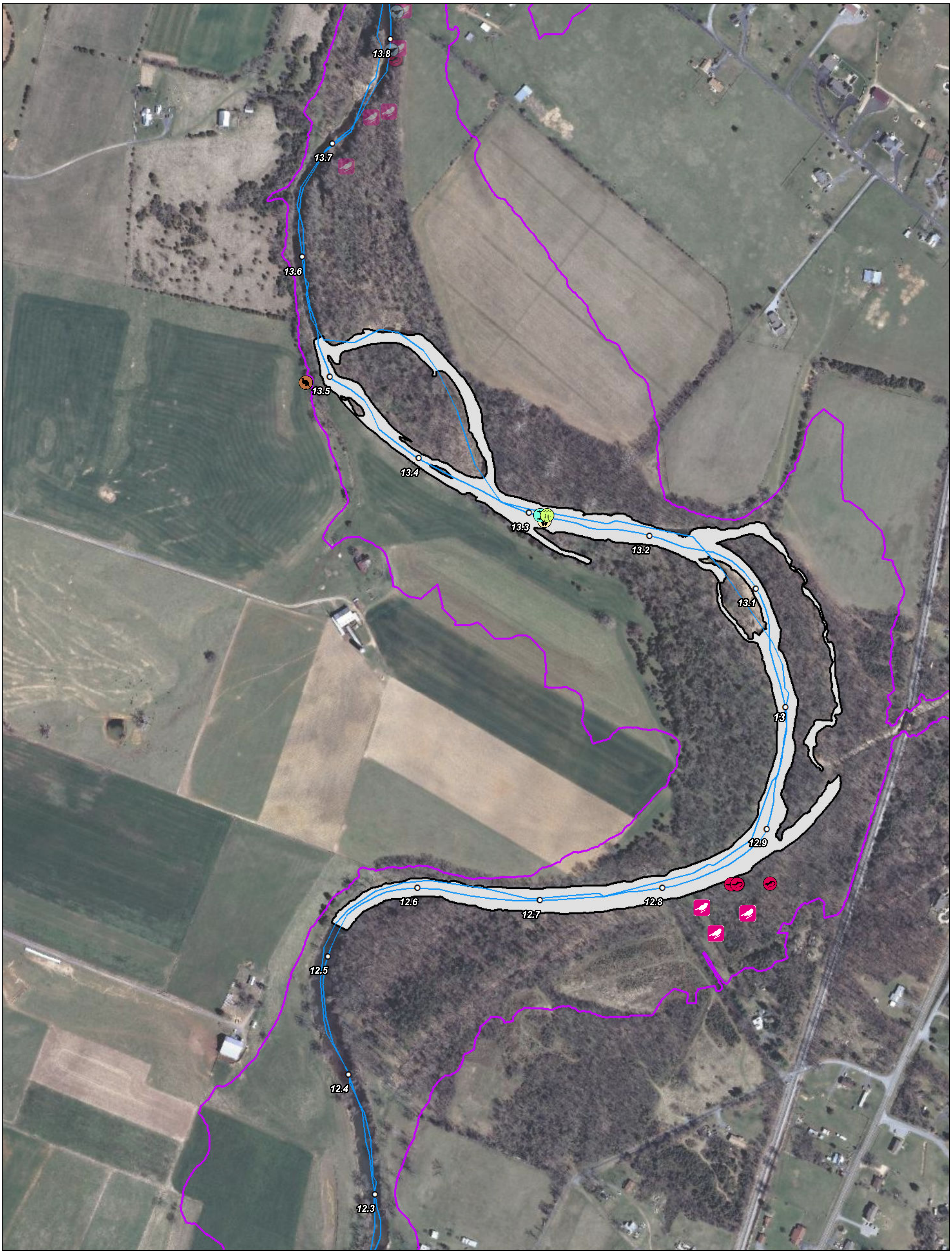

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 500 1,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

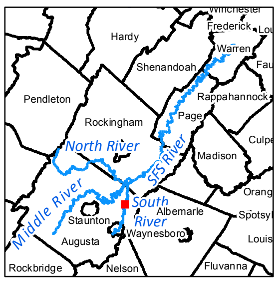

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Figure 5-2
Panel 12 of 20: Biological Sample Reach
RRM 12.5 to 13.5
AOC 4 Ecological Risk Assessment Report
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Waynesboro, Virginia

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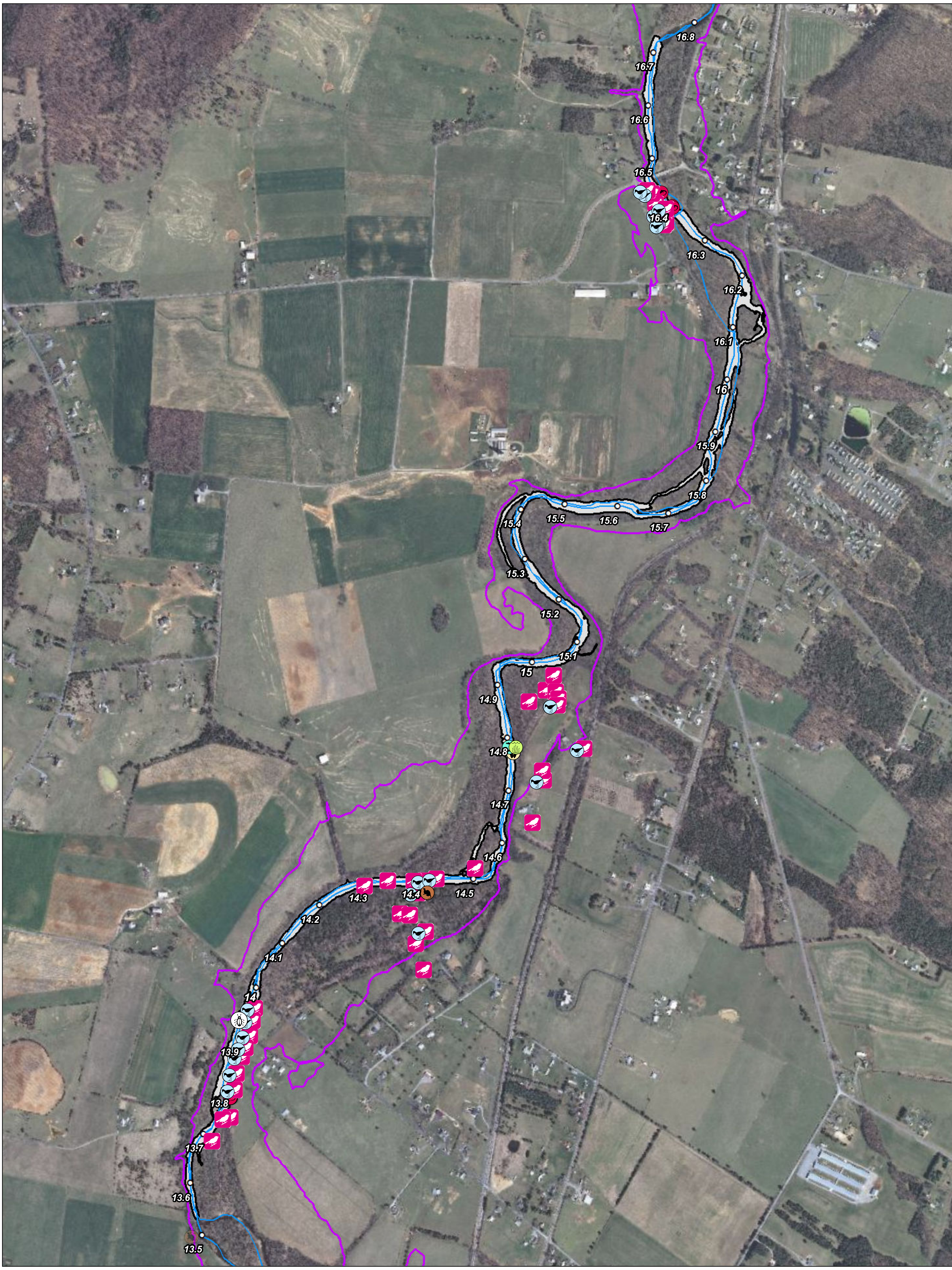

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 1,250 2,500 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

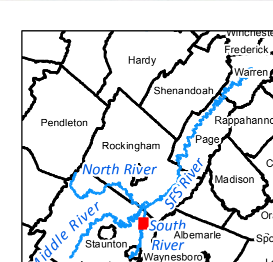

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Figure 5-2
Panel 13 of 20: Biological Sample Reach
RRM 13.5 to 16.7
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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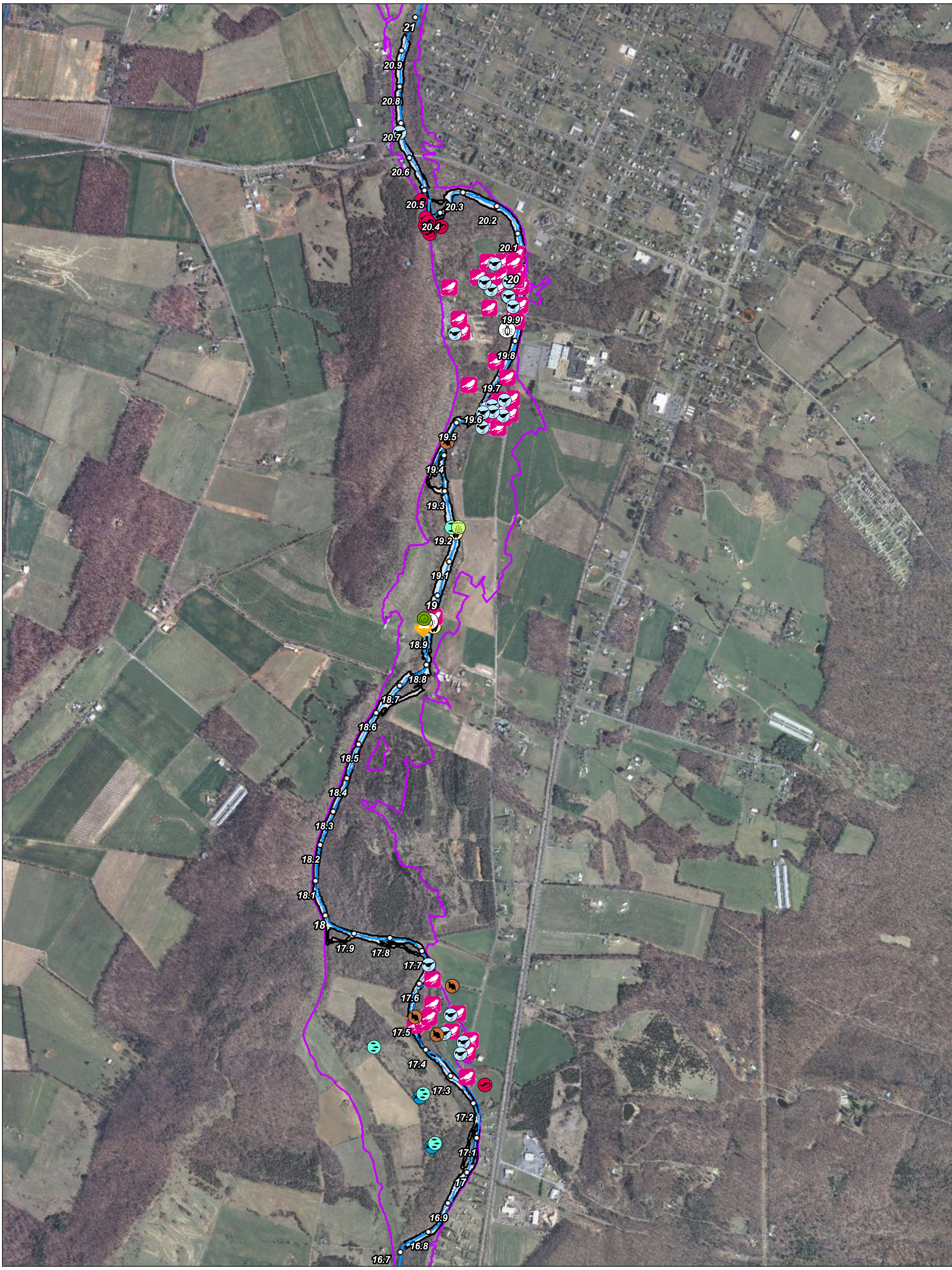

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 1,850 3,700 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

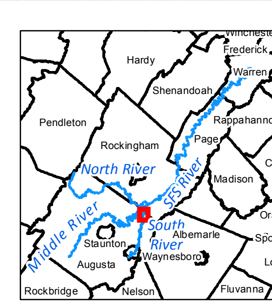

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Figure 5-2
Panel 14 of 20: Biological Sample Reach
RRM 16.7 to 20.9
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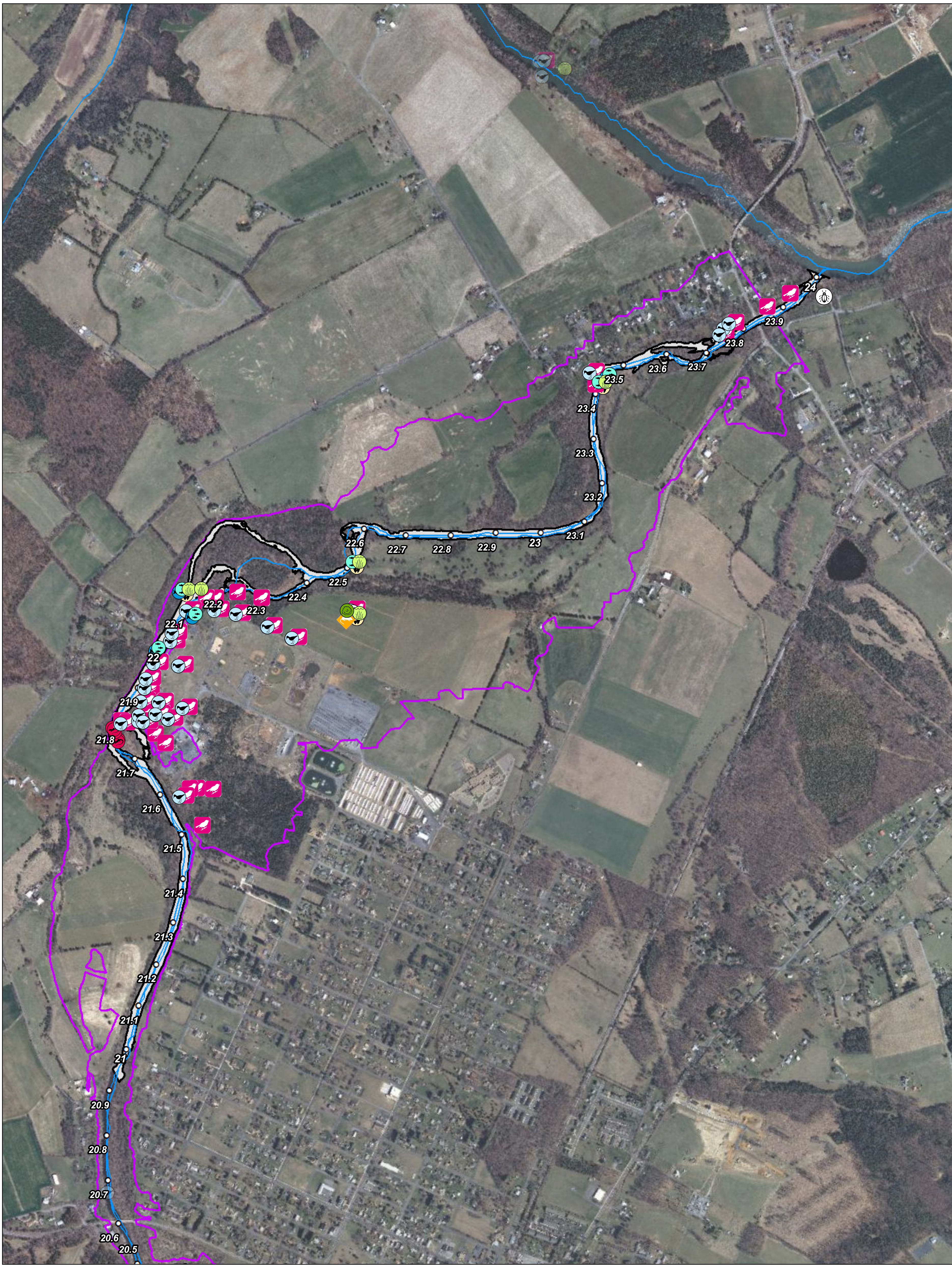

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 1,450 2,900 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

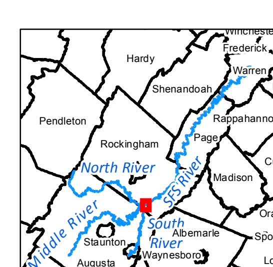

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Figure 5-2
Panel 15 of 20: Biological Sample Reach
RRM 20.9 to 24.0
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Legend

Aquatic Vegetation	Small Birds	Terrestrial Plants	RRM Intervals (Mile)
All Fish	Small Mammals	Aquatic Invrt.	Stream
Terrestrial Invrt.	Avian Receptors	Amphibian	62-Year Floodplain
Fish (Bass Only)	Mammalian Receptors		LiDAR Reach

0 2,000 4,000 8,000 12,000 16,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

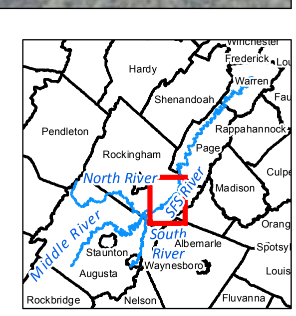

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Figure 5-2
Panel 16 of 20: Biological Sample Reach
SFSR
AOC 4 Ecological Risk Assessment Report
Former Dupont Waynesboro Plant
Waynesboro, Virginia

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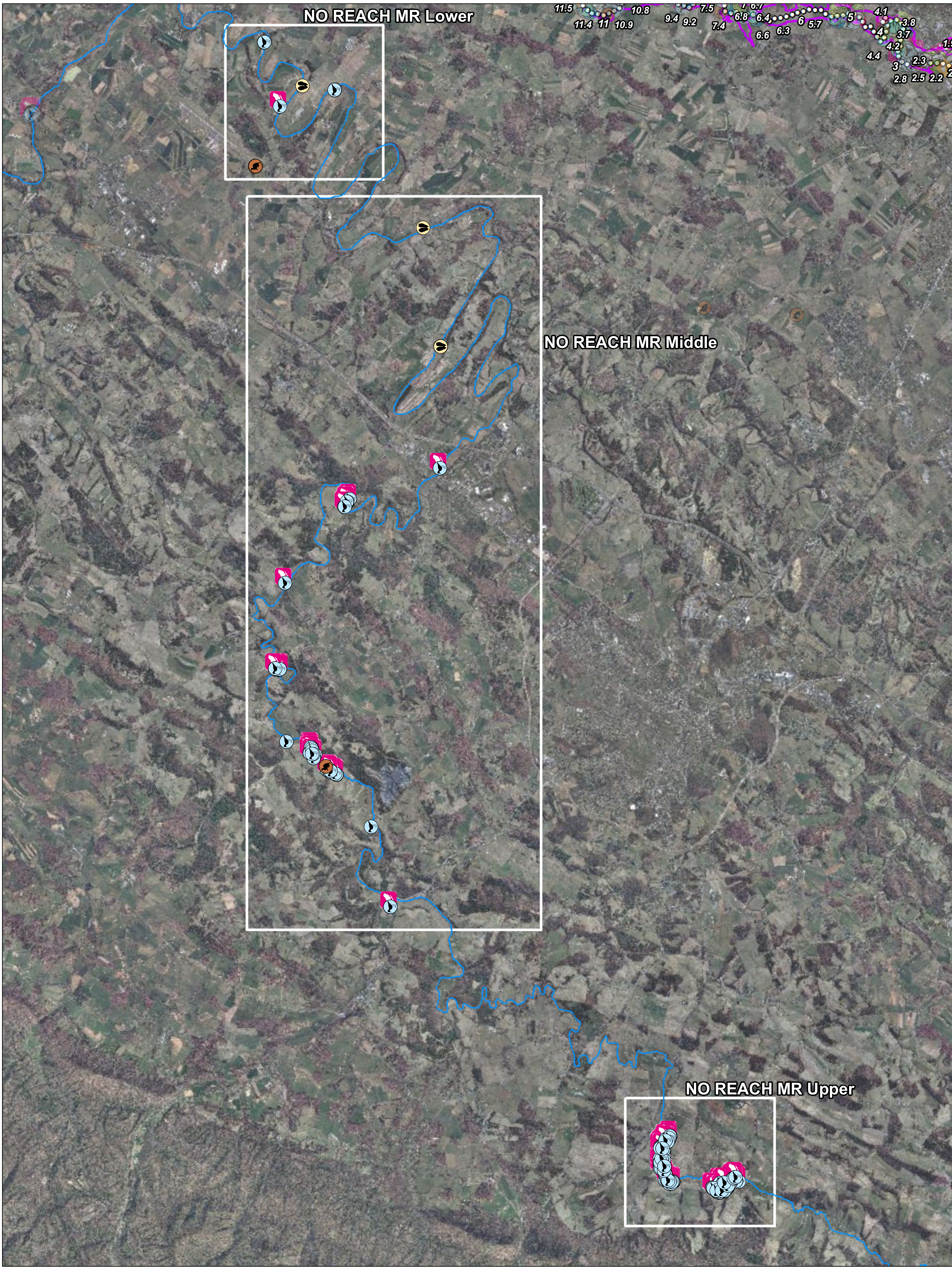

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 2,000 4,000 8,000 12,000 16,000 20,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

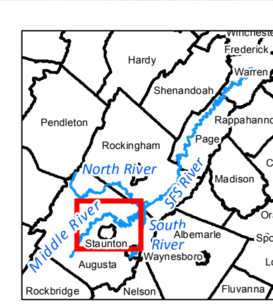

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Figure 5-2
Panel 17 of 20: Biological Sample Reach
Middle River Reference Reaches
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Former Dupont Waynesboro Plant
Waynesboro, Virginia

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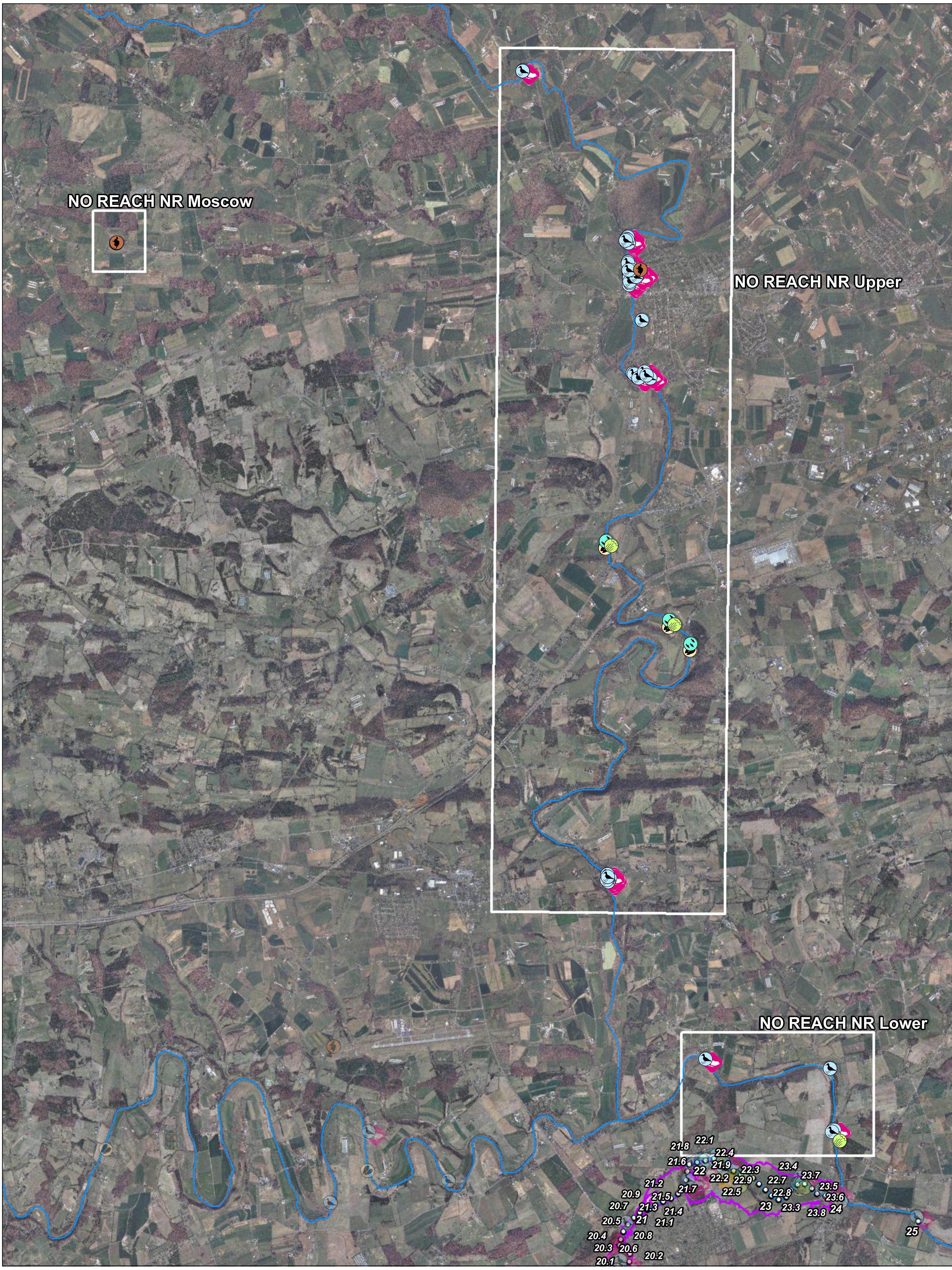

Legend

Aquatic Vegetation	Small Birds	Terrestrial Plants	RRM Intervals (Mile)
All Fish	Small Mammals	Aquatic Invrt.	Stream
Terrestrial Invrt.	Avian Receptors	Amphibian	62-Year Floodplain
Fish (Bass Only)	Mammalian Receptors		LiDAR Reach

0 2,000 4,000 8,000 12,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

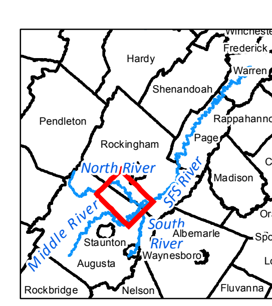

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Figure 5-2
Panel 18 of 20: Biological Sample Reach
North River Reference Reaches
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Former Dupont Waynesboro Plant
Waynesboro, Virginia

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Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 2,000 4,000 8,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

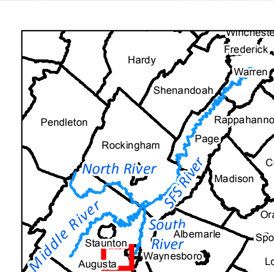

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Figure 5-2
Panel 19 of 20: Biological Sample Reach South River - Waynesboro Nursery Properties (WNP) Reference Reaches AOC 4 Ecological Risk Assessment Report
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Waynesboro, Virginia

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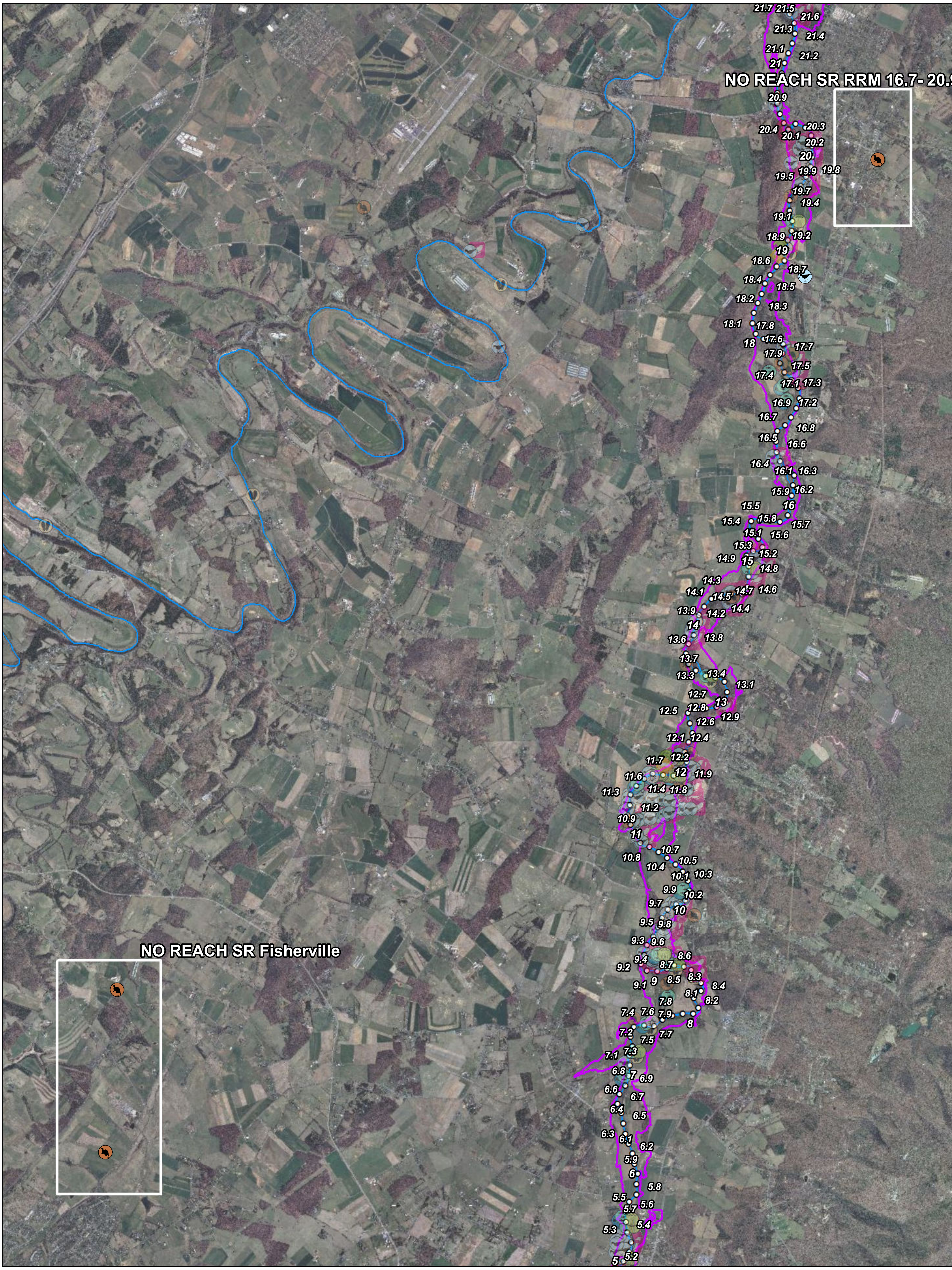

Legend

- Aquatic Vegetation
- All Fish
- Terrestrial Invrt.
- Fish (Bass Only)
- Small Birds
- Small Mammals
- Avian Receptors
- Mammalian Receptors
- Terrestrial Plants
- Aquatic Invrt.
- Amphibian
- RRM Intervals (Mile)
- Stream
- 62-Year Floodplain
- LiDAR Reach

0 2,000 4,000 8,000 12,000 Feet

N

Notes:
Sample location may have multiple samples for a single point.

LiDAR reaches start and end within the panel extent.

Reference:
VBMP Most Recent Imagery

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

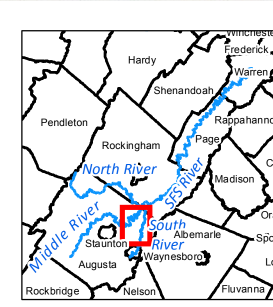

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Figure 5-2
Panel 20 of 20: Biological Sample Reach
South River - Outside the 62-Year Floodplain Reference Reaches
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Former Dupont Waynesboro Plant
Waynesboro, Virginia

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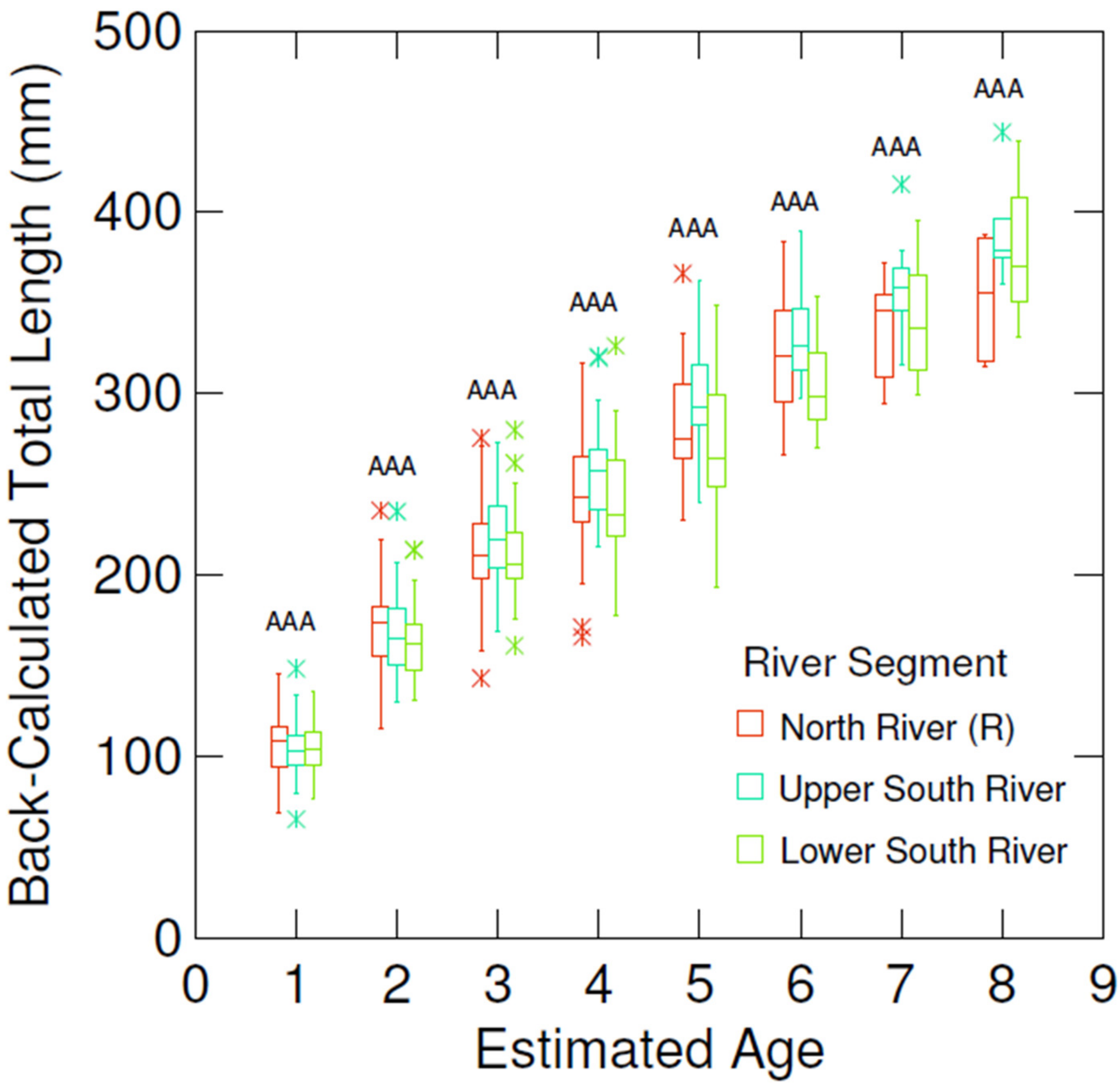
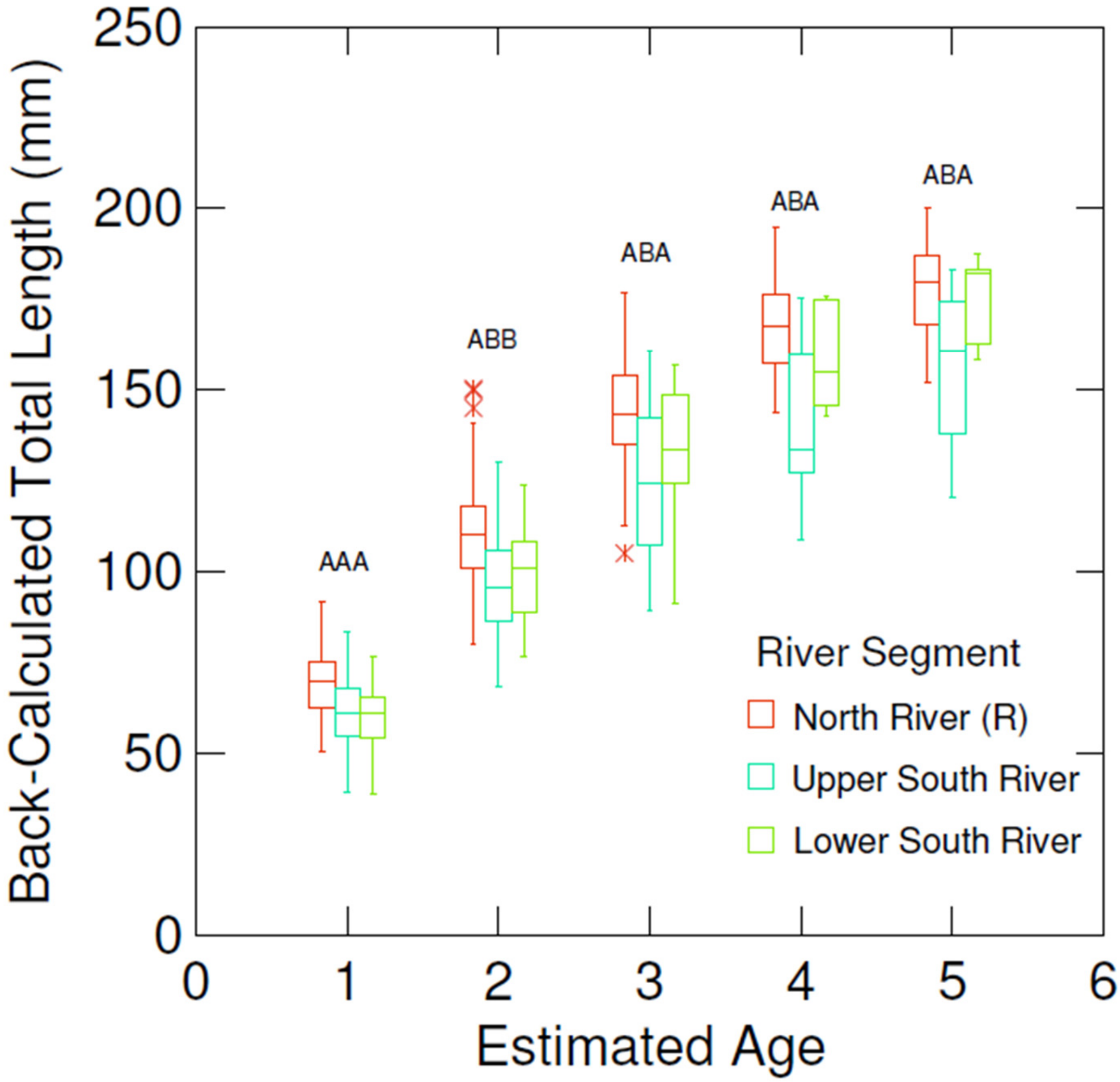
Figure 6-1
Comparison of Smallmouth Bass Growth among River Segments
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia



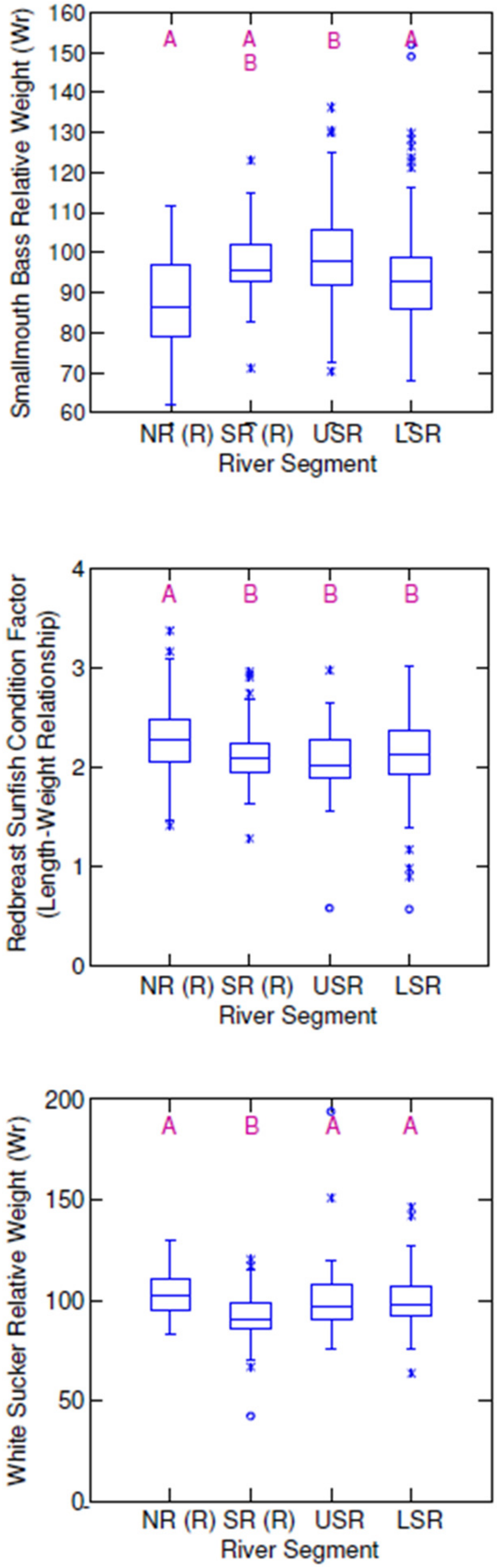
Notes:
Age information was taken from Murphy (2004).
Back-calculated total length at age data for each river segment were grouped by age, plotted as box plots, and tested by a two-way analysis of variance (ANOVA), with a Tukey-Kramer Honest Significant (HSD) post-hoc test (SYSTAT 11, SYSTAT Software, San Jose, CA). River segments not collected by the same letter were significantly different (p<0.05) from the North River reference area. Inter-age differences among river segments and intra-age differences between river segments on the South and South Fork Shenandoah rivers were analyzed but not shown.
MM = millimeter, R = reference.

Figure 6-2
Comparison of Redbreast Sunfish Growth among River Segments
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia



Notes:
Age information was taken from Murphy (2004).
Back-calculated total length at age data for each river segment were grouped by age, plotted as box plots, and tested by a two-way analysis of variance (ANOVA), with a Tukey-Kramer Honest Significant (HSD) post-hoc test (SYSTAT 11, SYSTAT Software, San Jose, CA). River segments not collected by the same letter were significantly different (p<0.05) from the North River reference area. Inter-age differences among river segments and intra-age differences between river segments on the South and South Fork Shenandoah rivers were analyzed but not shown.
MM = millimeter, R = reference.

Figure 6-3
Comparison of Fish Condition among River Segments
AOC 4 Ecological Risk Assessment Report
Former DuPont Waynesboro Plant, Waynesboro, Virginia



<u>Notes:</u>

Length and weight data taken from VDEQ and URS fish fillet database.

Data evaluations included comparison of condition for fish in assessment areas with mercury concentrations above 0.44 ppm wet weight to fish in references areas.

Fish condition data were grouped by river segment, plotted as box plots, and tested by a one-way analysis of covariance (ANCOVA) using total length as a covariate, with a Bonferroni post-hoc test (SYSTAT 11, SYSTAT Software, San Jose, CA). River segments not collected by the same letter were significantly different (*p*<0.05) from the North River reference area. Differences between river segments on the South River were analyzed but not shown.

NR (R) = North River reference, SR(R) = South River reference, USR = Upper South River, LSR = Lower South River

Appendicies

Vollume II

- Appendix A – Retrospective Data Quality Assessment
- Appendix B Phase I Soil and Sediments Screening Memorandum

Volume III

- Appendix C Mercury and Ecological Effects Analysis
- Appendix D Wildlife Exposure Factors for Dose Rate Modeling
- Appendix E Exposure Point Concentration
- Appendix F Dose Rate Modeling Calculations
- Appendix G Weight of Evidence Evaluation Approach