VIRGINIA WATER RESOURCES RESEARCH CENTER

Development of
Aquatic Life Use Assessment Protocols
for
Class VII Waters in Virginia

2019 Report of the Academic Advisory Committee
for
Virginia Department of Environmental Quality

Virginia
WATER RESOURCES
Research Center

SPECIAL REPORT

VIRGINIA TECH

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
BLACKSBURG, VIRGINIA

SR62-2019
June 2019

This special report is a publication of the Virginia Water Resources Research Center. The research was supported with funds provided by the Virginia Department of Environmental Quality. The views expressed are those of the individual authors and do not necessarily reflect the views or polices of the Virginia Department of Environmental Quality or the Virginia Water Resources Research Center. The mention of commercial products, trade names, or services does not constitute an endorsement or recommendation.

This report is available online at http://vwrrc.vt.edu.

Virginia Water Resources Research Center (MC 0444)
210 Cheatham Hall, Virginia Tech
310 West Campus Drive
Blacksburg, VA 24061
(540) 231-5624
FAX: (540) 231-6673
E-mail: water@vt.edu

Stephen Schoenholtz, Director

DEVELOPMENT OF AQUATIC LIFE USE ASSESSMENT PROTOCOLS FOR CLASS VII WATERS IN VIRGINIA

2019 Report of the Academic Advisory Committee for Virginia Department of Environmental Quality

Written on behalf of the Academic Advisory Committee by:

Andrew L. Garey, PhD
Water Quality Monitoring Team Leader
Virginia Department of Environmental Quality

Edited by:
Jane L. Walker
Virginia Water Resources Research Center

Publication of the
Virginia Water Resources Research Center
210 Cheatham Hall, Virginia Tech
310 West Campus Drive
Blacksburg, VA 24061

SR62-2019
June 2019

Members of the 2019 Academic Advisory Committee to the Virginia Department of Environmental Quality

Stephen H. Schoenholtz, Chair
Virginia Water Resources Research Center / Department of Forest Resources and Environmental Conservation, Virginia Tech

E. Fred Benfield
Department of Biology, Virginia Tech

Paul Bukaveckas
Department of Biology / Rice Rivers Center / Center for Environmental Studies, Virginia Commonwealth University

Gregory C. Garman
Department of Biology / Rice Rivers Center / Center for Environmental Studies, Virginia Commonwealth University

Erin R. Hotchkiss
Department of Biology, Virginia Tech

Carl Hershner
Department of Biology / Center for Coastal Resources Management, Virginia Institute of Marine Science, College of William and Mary

Wu-Seng Lung
Department of Civil and Environmental Engineering, University of Virginia

Kevin J. McGuire
Virginia Water Resources Research Center / Department of Forest Resources and Environmental Conservation, Virginia Tech

Daniel McLaughlin
Virginia Water Resources Research Center / Department of Forest Resources and Environmental Conservation, Virginia Tech

Durelle T. Scott IV
Department of Biological Systems Engineering, Virginia Tech

Leonard A. Shabman
Resources for the Future

Eric P. Smith
Department of Statistics, Virginia Tech

Leonard A. Smock
Department of Biology, Virginia Commonwealth University

Meredith Steele
School of Plant and Environmental Sciences, Virginia Tech

Kurt Stephenson
Department of Agricultural and Applied Economics, Virginia Tech

Jane L. Walker
Virginia Water Resources Research Center, Virginia Tech

Kang Xia
School of Plant and Environmental Sciences, Virginia Tech

Carl E. Zipper
School of Plant and Environmental Sciences, Virginia Tech

Author Biography

Andrew Garey began his participation in this investigation in 2012 while working at Virginia Commonwealth University (VCU) as the manager of the Aquatic Ecology Lab, under the direction of Dr. Leonard Smock (AAC member). Andrew became a member of the Academic Advisory Committee (AAC) in 2013. Andrew was employed at VCU and served on the AAC until September, 2016, when he was hired by the Virginia Department of Environmental Quality (DEQ). He now serves as the Water Quality Monitoring Team Leader for DEQ. Andrew participates as a DEQ-based investigator and technical consultant on projects of the AAC.

Introduction

Swamp waters are legally defined in Virginia as: "waters with naturally occurring low pH and low dissolved oxygen caused by (i) low flow velocity that prevents mixing and reaeration of stagnant, shallow waters and (ii) decomposition of vegetation that lowers dissolved oxygen concentrations and causes tannic acids to color the water and lower the pH" (Virginia Code: 9VAC25-260-5). Systems of interest in this investigation are freshwater, non-tidal waters in the Coastal Plain Physiographic Province of Virginia. The working definition of swamps used here is the subset of these waters that fit the criteria described in 9VAC25-260-5. For regulatory purposes, these systems are referred to as Class VII waters.

Swamp waters present a unique challenge for the Virginia Department of Environmental Quality (DEQ), which is tasked with regulatory assessment of these and all waters of the Commonwealth. The low pH and dissolved oxygen (DO) levels that often occur in swamps present naturally stressful conditions for biota. Therefore, pH, DO, and biological assemblage criteria that are applied to free-flowing fresh waters (Class III waters) are not appropriate for swamp waters. Whereas water-quality criteria for Class III waters indicate that pH should range between 6.0 and 9.0, the acceptable pH range for designated Class VII waters is between 3.7 and 8.0. Furthermore, DO should not fall below an instantaneous value of 4.0 mg/L or a daily mean of 5.0 mg/L in Class III waters, and aquatic life in these waters is assessed with the Virginia Coastal Plain Macroinvertebrate Index (VCPMI; Dail *et al*. 2013). In contrast, no DO criteria or biological assemblage characteristics are used to assess Class VII waters.

Since 2012, the Academic Advisory Committee (AAC) has worked to enhance DEQ's swamp waters assessment process by addressing two major objectives: (1) to improve the agency's protocol for correctly classifying waters as swamps, and thus correctly identify which waters should be assessed using Class VII criteria (rather than criteria for Class III waters); and (2) to develop an effective protocol for evaluating aquatic life use in Class VII waters.

During Virginia fiscal years (FYs) 2012 and 2013 (July 1, 201–June 30, 2013), exploratory analyses were conducted to determine the feasibility of using biological assemblage metrics to assess the ecological condition of swamp waters. Preliminary evidence from these investigations indicated that several fish species occurred exclusively or predominantly in swamp systems (referred to as blackwater guild species). Results also indicated that the number and percentage of blackwater guild species in a sample are positively related to overall ecological integrity in swamps. Furthermore, the number and percentage of more cosmopolitan, opportunist species within a sample are negatively related to ecological integrity in swamp waters (Garman *et al.* 2012, 2013).

Development of a rapid habitat assessment protocol for classifying swamp waters, referred to as the Blackwater Habitat Protocol (BHP), also began in FY 2012. The BHP includes eight metrics associated with channel and riparian zone morphology, hydrology, and vegetation. The BHP is scored on a 0–24 point scale, with higher scores indicating more characteristics indicative of Class VII waters. Blackwater Habitat Protocol scores at 44 study sites in the FY 2013 investigation showed strong agreement with the best professional judgements of biologists regarding the distinction between swamps and streams. The FY 2014 investigation (July 1,

2013–June 30, 2014) showed that the BHP exhibited high precision, with little variation among trained investigators with respect to the overall habitat scores. With the submission of the FY 2014 report, the currently used version of the BHP was complete (Garey *et al.* 2014).

In FYs 2015 and 2016 (July 1, 2014–June 30, 2016), the AAC began collecting data in the Chowan River and Albemarle Sound basins for the purpose of developing a multimetric index (constructed using biological assemblage data) to be used for assessment of aquatic life use in swamp waters. The result was the Blackwater Condition Index (BCI), an 8-metric fish index that was shown to be responsive to watershed disturbance at 67 study sites in these river basins (Garey *et al*. 2015, 2016). In FY 2017 (July 1, 2016–June 30, 2017), efforts to develop a biological index were extended to the Chesapeake Bay Basin where preliminary evidence from 17 study sites indicated that fish assemblage metrics were also responsive to watershed disturbance in this basin (Garey *et al.* 2017).

Efforts for FY 2019 have been refocused on developing methods for identifying swamp waters and therefore correctly assigning waters of the Commonwealth to Class VII. Data that describe in-stream and landscape conditions (*e.g.*, the BHP and geographic information system (GIS)-derived data) will be evaluated to determine whether they correspond with aquatic communities and water quality in a manner that makes them effective for classifying systems as swamps. This focus on development of classification methods, rather than on methods for assessing aquatic life use, will likely continue into the FY 2020 phase of this project.

Study Design and Objectives

Data are presented from study sites visited in 2018 and 2019 in support of this project (see Appendix A for site information). Also presented are historical data from these study sites from past years that were retrieved from DEQ's Environmental Data Application System (EDAS) and Comprehensive Environmental Database System (CEDS) databases and the Virginia Commonwealth University (VCU) Interactive Stream Assessment Resource (INSTAR) database. Sites selected were from the Coastal Plain portion of the Chowan River Basin. Chosen sites primarily appeared to have the least watershed disturbance based on a review of aerial imagery in Google Earth and Virginia Geographic Information Network (VGIN) and land-cover imagery from the latter (http://vgin.maps.arcgis.com). Following this review and in-the-field site reconnaissance, sites were given an initial condition rating (reference or altered) and an initial site classification (stream or swamp). Reference sites were considered least-disturbed sites based on observations of watershed land cover and on-site habitat, whereas altered sites were considered substantially disturbed as observed from the land cover and on-site habitat.

Stream sites were those considered appropriate to be assessed using existing assessment criteria; that is, streams with minimal anthropogenic disturbance were expected to exhibit DO levels above the minimum criteria of 4.0 mg/L, pH between 6.0 and 9.0, and VCPMI scores above the minimum acceptable 40 points (see Dail *et. al* 2013 and https://law.lis.virginia.gov/admincode/title9/agency25/chapter260/section50/). In contrast, swamps were those where, even under minimal anthropogenic disturbance, natural conditions (low flow and decomposition of organic matter) would cause pH, DO, and VCPMI scores to fall below the respective minimum stream criteria.

Analyses conducted to date for this report and those that are ongoing are focused on the following: (1) determining whether sites should be considered in reference (least-disturbed) condition, and then (2) determining what natural characteristics are most effective for classification based on the characteristics that best explain differences among the biotic communities at the study sites. Final assignment of swamp sites to the reference condition (best-available) category is based on a series of swamp water-quality and site conditions previously developed by the AAC (referred to hereafter as proposed reference filters; Garey *et al.* 2014). The proposed reference filters for swamps are provided in Table 1. Reference filters for coastal streams were derived in development of the VCPMI, and they differ slightly from those used for swamps. Relevant differences are described in this report in the sections that follow. For a complete list of coastal stream reference filters, see Dail *et al.* (2013).

Because the focus of the 2019 investigation was on classification of swamp waters under least-disturbed conditions, prospective reference sites are the focus of this report. Several prospective altered sites were evaluated in 2018 to support development of the assessment tool. Data from these sites are included in appendices of this report, as they have not been presented previously to the AAC.

Table 1: Proposed reference filters for swamp waters.

Parameter	Reference Threshold	Stressed Threshold
Physicochemistry		
Specific Conductance	<150 µS/cm	>350 µS/cm
Total Nitrogen	<1.5 mg/L	>3 mg/L
Total Phosphorus	<0.05 mg/L	>0.1 mg/L
pH	<6.5	>7.5
Other	No other measured parameters indicate site should be listed as impaired	Other chemical stressors present that are likely to affect the aquatic community
Land Cover		
GIS Land Use/Land Cover	>70 percent forested land cover in watershed	<50 percent forested land cover
Intact Riparian Vegetation	>50 m from both banks	<10 m, either bank, or <25 m from both banks
General Site Characteristics		
Point Sources/Others	No VPDES sites within watershed	NA*
Site Reconnaissance Land Use/Land Cover	No extensive development in the watershed that is likely to impact the system	NA*
Visible System Alteration	No visible signs of direct alteration to the water body (*e.g.*, dams, weirs, levees, artificial channelization)	NA*

VPDES = Virginia Pollutant Discharge Elimination System
NA* = Not applicable; these filters are not typically used to designate systems as stressed.

Fifteen study sites were evaluated as part of the 2019 effort: nine sites initially characterized as swamps and six sites initially characterized as streams (Appendix A). All sites visited in 2019 were initially characterized as reference. Three of the nine swamp sites and three of the six stream sites visited in 2019 were also visited in 2018. Nine new sites – six prospective reference swamps and three prospective reference streams – were investigated in 2019 (Appendix A).

Broad objectives presented in the FY 2019 scope of work along with the data produced in support of these objectives are summarized below.

Objective 1a) Evaluate Effectiveness of Blackwater Habitat Protocol (BHP) for Classifying Swamps.

The BHP was used to classify prospective reference sites based on in-stream and riparian-zone characteristics. Blackwater Habitat Protocol scores were expected to correspond with variations in biotic communities among sites.

Virginia Coastal Plain Macroinvertebrate Index scores were calculated from sites initially classified as reference to determine if VCPMI and BHP scores correspond. Reference sites with

high BHP scores, indicating swamp conditions (*e.g.*, slow flow and undefined channels), were expected to receive low VCPMI scores, whereas sites with low BHP scores, indicating stream conditions, were expected to correspond with higher VCPMI scores. Such results at sites that represent relatively undisturbed conditions would indicate that the VCPMI is responding to natural environmental conditions rather than anthropogenic disturbance. They would also suggest that the VCPMI is inappropriate for assessment of swamp waters.

Benthic macroinvertebrate data from all sites investigated in 2018 were supplemented with historical data collected from 2005–2016, where available, to support objective 1a. Macroinvertebrate and fish data from sites visited in 2019 are not yet available. These data will be used in the next phase of this effort to evaluate more completely the effectiveness of the BHP.

Objective 1b) Evaluate Temporal Variability in BHP, Benthic Macroinvertebrate, Fish, and Water-Quality Data at Swamp Sites.

Once available, the 2019 macroinvertebrate and fish community data will be compared to those from previous years at the same sites to assess temporal variability in the aquatic assemblages. Changes in water quality, habitat (BHP), and watershed land cover will be evaluated to determine whether these factors explain the observed temporal variations in the aquatic assemblages.

Objective 1c) Evaluate GIS-based Methods for Classification of Swamp Waters and Objective 2) Develop GIS-based Tools for Quantifying Anthropogenic Disturbance of Swamp Waters.

The DEQ watersheds program has contracted with VCU to conduct GIS analysis associated with these tasks. Progress to date is described below in Methods and in Appendix B. Analysis is currently being conducted to determine what GIS-derived watershed characteristics best explain differences in biota between stream and swamp sites. Additionally, analysis is underway to quantify land-cover types and the temporal change in land cover that has occurred within the study watersheds.

Objective 3) Complete Dataset from FY 2018 Sites

Water-quality data and benthic-macroinvertebrate community data as well as BHP scores from all sites visited in 2018 are presented in this report.

Methods

Geographic Information System (GIS) Analysis

DEQ staff initially delineated watershed polygons using the automated process in ArcGIS, Version 10.1, based on a LIDAR (Light Detection and Ranging) digital elevation model (DEM) from the VGIN (http://vgin.maps.arcgis.com), and a 10-m DEM from the United States Geological Survey (USGS) National Elevation Dataset (http://ned.usgs.gov/). The polygons originally produced were then manually adjusted based on stream locations that were estimated using a flow-accumulation raster generated using the VGIN LIDAR dataset. The watersheds were also manually corrected for artificial breaks in the DEM's caused by features such as culverted roadways. All GIS tasks described below are based on these watershed delineations.

The DEQ Watersheds Program has begun developing GIS data for swamp systems in order to aid in the best monitoring and management strategies for coastal watersheds. The Watersheds Program has contracted with VCU for this work. Funding for these tasks, and therefore, the timeline for deliverables are outside the scope of work for this report. However, these data will be produced for the study sites of interest in this investigation, and therefore, they will be featured in the next phase of this study.

Produced GIS data associated with watershed topography, morphology, and soil types will be evaluated to determine their effectiveness for classifying swamps and streams. Data associated with land cover and land-cover change will be used to quantify the degree of potential anthropogenic disturbance that has occurred at each study site.

To date, GIS data have been acquired for 62 Chowan River Basin study sites, including 26 of the 29 sites investigated in 2018 and 2019 for this report. All analyses have been conducted at the watershed scale (within entire study watersheds) and local scale (within 1 km up gradient from each site). Analyses within 50, 100, and 200-m riparian buffer zones within each watershed are ongoing.

The methodology used and data derived for each GIS task completed to date are provided for AAC review in the DEQ Swamp GIS Task Project Report generated by VCU (Appendix B). Analyses of these data for classification and evaluation of swamp waters will be completed in a future phase of this project, following further input from the AAC.

Data on watershed land cover are summarized below. All other GIS datasets described are available upon request (e-mail: andrew.garey@deq.virginia.gov).

The VGIN land-cover dataset was used to determine whether study sites met the reference-filter threshold. For this report, the VGIN land-cover classes were re-classified and simplified into one of four classes as follows:

- *Natural* – Includes *Open Water, Forest, Tree, Scrub/Shrub* and *National Wetlands Inventory (NWI)/other* classes;
- *Developed* – Includes *Barren, Extracted Impervious* and *Internal Impervious* classes;
- *Agriculture* – Includes *Pasture* and *Cropland* classes*;* and
- *Other* – Includes *Harvested/Disturbed* and *Turf Grass* classes.

The results were evaluated against the swamp reference-filter threshold of 70% watershed coverage by forest. Although the original threshold was referred to as *Forest*, the intent was to characterize *Natural* land cover classes, and therefore inclusion of these classes in evaluating reference conditions was considered appropriate.

Water Quality

A YSI multimeter was used to record the pH, DO, temperature, and specific conductance (SpC) of surface water at each sampling site. Water samples were collected for analysis of total nitrogen (TN) and total phosphorus (TP). All water samples were submitted for analysis to the Virginia Division of Consolidated Laboratory Services (DCLS). Due to a miscommunication between DEQ and DCLS, all of the TN samples and many of the TP samples collected in 2018 were analyzed after the DCLS recommended holding time of 28 days. This delay is not expected to affect the results because TP samples were immediately preserved in the field with sulfuric acid and all samples were kept frozen until analysis. In order to ensure that the long holding time did not affect the 2018 data, three TN and three TP samples collected in 2019 were duplicated (*i.e.*, two pairs of each were collected at three different sites) so that samples submitted to DCLS within the holding time could be compared to those held for three months.

Habitat

The eight-metric BHP (Garey *et al*. 2014) was used to evaluate habitat conditions at each study site. The BHP is a rapid, field-based method to identify swamp systems using characteristics such as channel and floodplain geomorphology, hydrology, and vegetation. The BHP field datasheet and detailed explanations of each metric are included in Appendices C and D, respectively.

Benthic Macroinvertebrates

At each site, VCU and DEQ biologists collected macroinvertebrate samples using a D-frame dip net along a reach of approximately 100 meters. They followed the multihabitat procedure of Barbour *et al*. (1999). These methods were in accordance with DEQ standard operating procedures (SOP; DEQ 2008).

Following the DEQ SOP, 200 individuals were randomly sorted from each sample (or the entire sample was sorted if less than 200 individuals were present), and samples were identified to the lowest possible taxonomic level (usually genus or family). All samples collected in 2018 were processed and identified by AAC member Dr. Leonard Smock, and samples collected in other years were processed and identified by DEQ staff.

Virginia Coastal Plain Macroinvertebrate Index scores were calculated for each benthic macroinvertebrate sample. The VCPMI is DEQ's official assessment index for coastal streams. For the Chowan River Basin, the VCPMI consists of seven community metrics associated with diversity, ecological habit, habitat, and pollution tolerance. These metrics are explained briefly in Appendix E, and additional explanation is provided in Dail *et al*. (2013). Before calculation of the VCPMI, sample data were simplified to the family level, and samples with greater than 110 individuals were randomly rarefied to 110 individuals.

Fish

Fish collections were made following U.S. Environmental Protection Agency (EPA) protocols (Barbour *et al*. 1999). At each site, a single pass was made using a direct-current backpack electrofisher. The sampling area at each site encompassed approximately 100–120 meters along the main channel of the system, as well as several sweeps in backwater habitat adjacent to the channel. Fish samples were collected and identified in 2018 and earlier by Dr. Stephen McIninch and Mr. David Hopler (VCU ichthyologists). Samples were collected and identified in 2019 by S. McIninch, D. Hopler, and DEQ staff.

Results

GIS: Watershed Land Cover

Virginia Geographic Information Network land-cover data for 22 swamp sites (Table 2) and seven stream sites (Table 3) in the study are presented. Land cover has not been assessed for two of the swamp sites and one of the stream sites. Fourteen of the sixteen prospective reference swamp sites for which land cover has been evaluated met the land-cover conditions to be classified as reference (>70% natural land cover). These prospective reference swamps include the nine swamp sites in the 2019 field investigation. Only two of the five prospective reference streams where land cover has been evaluated met the VCPMI reference-filter thresholds (>67.5 % natural land cover and <4% developed land cover; Dail *et al.* 2013). All sites initially classified as altered were in watersheds with insufficient natural land cover to be considered reference (Tables 2 and 3).

Water Quality

Only four of the nine potential reference swamp sites visited in 2019 exhibited pH values less than the proposed reference threshold for swamps (pH<6.5; Table 4), whereas nine of the twelve potential reference swamp sites investigated in 2018 exhibited pH less than the reference threshold (Table 5). Interestingly, only one of the three sites revisited in 2019 (Ivy Branch) met the pH reference condition in both 2018 and 2019; the other two sites, Warren Swamp and an unnamed tributary (UNT) to Seacorrie Swamp, exceeded the pH threshold in 2019. None of the stream sites investigated exceeded the pH reference-filter threshold for streams (pH<7.5, Table 6). Most swamp and stream sites, with the exception of one swamp site (UNT Blackwater River 2; Table 5), were within the specific conductance reference threshold (spec. cond.<150 µS/cm for swamps and <200 µS/cm for streams).

Nutrient data for swamps sampled in 2019 are not yet available as lab analysis is ongoing. Seven of the twelve prospective reference swamps investigated in 2018 exhibited TP concentrations less than the reference-filter threshold (<0.05 mg/L; Table 5). Of the five sites that exceeded the TP reference threshold, two sites (Seacorrie Swamp and UNT Blackwater River 3) indicated stressed conditions (>0.1 mg/L; Table 5). One prospective reference swamp site that exceeded the TP reference-filter threshold (UNT Poplar Swamp) also exceeded the TN reference-filter threshold (<1.5 mg/L). The other prospective swamp reference sites visited in 2018 exhibited TN concentrations less than the reference filter threshold. All of the prospective altered swamp sites visited in 2018 exhibited TP concentrations above the proposed reference threshold, but none exceeded the proposed reference TN threshold. Among the prospective reference streams, Hazel Swamp consistently exhibited TP and TN concentrations above the VCPMI reference filters (TP<0.05 mg/L and TN<1.5 mg/L). This stream site even exceeded the proposed stressed conditions for swamp waters on one sampling day (TP>0.1 mg/L and TN>3.0 mg/L; Table 6).

Table 2: Summary of watershed land cover at sites initially classified as swamps.

Agency Site Code	Water Body Name	Initial Condition rating	Initial Classification	FY 2018	FY 2019	Natural Land Cover (%)	Developed Land Cover (%)	Agriculture Land Cover (%)	Other Land Cover (%)
5AIVY001.37	**Ivy Branch**	Reference	Swamp	YES	YES	84.12	0.84	6.53	8.51
5AJNH010.18	**Jones Hole Swamp**	Reference	Swamp	NO	YES	71.07	3.66	13.09	12.19
5AMS000.40	**Mill Swamp**	Reference	Swamp	NO	YES	76.55	0.98	7.54	14.94
5APRK000.40	***Parker Run***	Reference	Swamp	NO	YES	71.92	0.76	22.49	4.83
5AWRN000.46	**Warren Swamp**	Reference	Swamp	YES	YES	82.39	2.86	7.46	7.29
5AXBRa001.40	**UNT Blackwater River 1**	Reference	Swamp	NO	YES	84.30	1.92	5.82	7.97
5AXJH000.31	**UNT Johnchecohunk Swamp**	Reference	Swamp	NO	YES	70.04	0.21	0.33	29.42
5AXJO000.10	**UNT Joseph Swamp**	Reference	Swamp	NO	YES	91.42	1.95	1.59	5.04
5AXSRE000.13	**UNT Seacorrie Swamp**	Reference	Swamp	YES	YES	90.08	0.94	4.90	4.08
5ADBS002.75	Dobie Swamp	Reference	Swamp	YES	NO	90.51	1.32	4.34	3.85
5AJOE007.60	Joseph Swamp	Reference	Swamp	YES	NO	NA	NA	NA	NA
5AOTR000.88	Otterdam Swamp	Reference	Swamp	YES	NO	89.58	0.94	0.09	9.38
5ASRE004.17	Seacorrie Swamp	Reference	Swamp	YES	NO	92.41	0.69	6.69	0.22
5AXBRa001.08	UNT Blackwater River 2	Reference	Swamp	YES	NO	NA	NA	NA	NA
5AXBRb000.20	UNT Blackwater River 3	Reference	Swamp	YES	NO	44.13	2.97	46.58	6.32
5AXNOT001.00	UNT Nottoway River 1	Reference	Swamp	YES	NO	69.95	1.74	20.16	8.15
5AXNOTb000.45	UNT Nottoway River 2	Reference	Swamp	YES	NO	86.09	1.24	0.00	12.67
5AXPPL000.11	UNT Poplar Swamp	Reference	Swamp	YES	NO	83.00	1.25	8.25	7.51
5ABBS001.35	Black Branch	Altered	Swamp	YES	NO	55.26	1.70	14.42	28.63
5ACOU001.40	Council Swamp	Altered	Swamp	YES	NO	67.14	2.18	22.93	7.75
5ATRR008.25	Tarrara Creek	Altered	Swamp	YES	NO	60.61	1.11	30.30	7.97
5AXDMR001.60	UNT Darden Swamp	Altered	Swamp	YES	NO	63.56	0.87	31.21	4.36

FY = fiscal year; UNT = unnamed tributary. Shaded cells indicate values that do not meet the swamp waters reference-filter threshold (>70% natural land cover). FY 2018 indicates sites visited in 2018, and FY 2019 indicates sites visited in 2019. ***Bolded, italicized*** site names indicate sites visited by DEQ personnel in 2019, and **bolded, underlined** sites indicate sites visited by D. Hopler and S. McIninch in 2019. NA = data not yet available (analysis pending).

Table 3: Summary of watershed land cover at sites initially classified as streams.

Agency Site Code	Water Body Name	Initial Condition rating	Initial Classification	FY 2018	FY 2019	Natural Land Cover (%)	Developed Land Cover (%)	Agriculture Land Cover (%)	Other Land Cover (%)
5AGRV000.08	***Gravelly Run***	Reference	Stream	YES	YES	68.87	2.86	11.35	16.92
5AHZL000.77	***Hazel Swamp***	Reference	Stream	YES	YES	66.06	2.28	23.66	8.00
5AMRN000.38	***Mill Run***	Reference	Stream	YES	YES	62.76	1.13	30.11	6.00
5AXHAT000.40	***UNT Hatcher Run***	Reference	Stream	NO	YES	NA	NA	NA	NA
5AXNOTc000.04	***UNT Nottoway River 3***	Reference	Stream	NO	YES	66.09	1.26	21.86	10.79
5AXSCKa001.82	**UNT Seacock Swamp**	Reference	Stream	NO	YES	74.75	0.21	17.28	7.78
5ACABR000.64	Caney Branch	Altered	Stream	YES	NO	55.47	4.29	22.72	17.52

FY = fiscal year; UNT = unnamed tributary. Shaded cells indicate values do not meet the VCPMI reference-filter thresholds (>67.5% natural land cover and <4% developed land cover). FY 2018 indicates sites visited in 2018, and FY 2019 indicates sites visited in 2019. ***Bolded, italicized*** site names indicate sites visited by DEQ personnel in 2019, and **bolded, underlined** sites indicate sites visited by D. Hopler and S. McIninch in 2019. NA = data not yet available (analysis pending).

Table 4: Water-quality data for prospective swamp sites visited in 2019.

Agency Site Code	Water Body Name	Initial Condition rating	Initial Classification	Date	Time	TN (mg/L)	TP (mg/L)	pH	Temp. (°C)	DO (mg/L)	Spec. Cond. (µS/cm)
5AIVY001.37	Ivy Branch	Reference	Swamp	3/27/2019	13:15	NA	NA	6.30	14.6	8.9	25.0
5AWRN000.46	Warren Swamp	Reference	Swamp	4/25/2019	9:10	NA	NA	6.70	18	4.8	51.5
5AXBRa001.40	UNT Blackwater River 1	Reference	Swamp	4/17/2019	12:05	NA	NA	6.90	18.2	4.23	84.5
5AXSRE000.13	UNT Seacorrie Swamp	Reference	Swamp	3/27/2019	11:10	NA	NA	7.60	7.9	10.6	24.0
5AJNH010.18	Jones Hole Swamp	Reference	Swamp	4/25/2019	10:40	NA	NA	6.45	19.9	3.53	49.6
5AMS000.40	Mill Swamp	Reference	Swamp	4/17/2019	9:10	NA	NA	7.16	15	5.68	51.0
5APRK000.40	Parker Run	Reference	Swamp	4/11/2019	11:00	NA	NA	5.47	15.13	8.86	55.0
5AXJO000.10	UNT Joseph Swamp	Reference	Swamp	4/17/2019	13:22	NA	NA	5.90	24.1	4.98	32.1
5AXJH000.31	UNT Johnchecohunk Swamp	Reference	Swamp	4/17/2019	11:30	NA	NA	6.72	14.5	7.69	31.0

TN = total nitrogen; TP = total phosphorus; Temp. = temperature; DO = dissolved oxygen; Spec. Cond. = specific conductance; UNT = unnamed tributary. Light shaded cells do not meet the proposed swamp waters reference threshold (pH<6.5). Dark shaded cells exceed the proposed threshold for stressed swamp waters (pH>7.5). NA = data not yet available (analysis pending).

Table 5: Water-quality data for prospective swamp sites visited in 2018 including historical data.

Agency Site Code	Water Body Name	Initial Condition rating	Initial Classification	Date	Time	TN (mg/L)	TP (mg/L)	pH	Temp. (°C)	DO (mg/L)	Spec. Cond. (µS/cm)
5AIVY001.37	Ivy Branch	Reference	Swamp	4/13/2018	16:00	0.68*	BDL	5.4	23.3	6.2	34.6
5AWRN000.46	Warren Swamp	Reference	Swamp	4/11/2018	12:00	0.48*	BDL	5.8	14.3	6.7	84.7
5AXBRa001.08	UNT Blackwater River 2	Reference	Swamp	4/20/2018	11:30	0.61*	BDL	6.8	11.9	6.2	179.0
5AXSRE000.13	UNT Seacorrie Swamp	Reference	Swamp	4/12/2018	11:20	0.25*	BDL	5.8	11.2	9.2	23.4
5AXNOTb000.45	UNT Nottoway River 2	Reference	Swamp	3/28/2018	11:07	0.8*	BDL	5.6	13.1	8.0	52.3
5AJOE007.60	Joseph Swamp	Reference	Swamp	4/24/2018	10:15	0.61*	0.10*	6.4	16.5	4.5	48.6
5ADBS002.75	Dobie Swamp	Reference	Swamp	4/20/2018	12:35	0.68*	BDL	6.6	19.4	5.7	126.0
5AOTR000.88	Otterdam Swamp	Reference	Swamp	4/20/2018	10:00	0.76*	BDL	6.3	10.9	6.3	74.2
5ASRE004.17	Seacorrie Swamp	Reference	Swamp	4/12/2018	13:10	0.84*	0.20*	5.9	13.1	4.7	63.0
5AXBRb000.20	UNT Blackwater River 3	Reference	Swamp	5/3/2018	13:35	1.35*	0.20*	6.6	19.2	7.8	40.0
5AXNOT001.00	UNT Nottoway River 1	Reference	Swamp	3/28/2018	13:10	1.07*	0.10*	5.7	18.8	8.1	89.1
5AXPPL000.11	UNT Poplar Swamp	Reference	Swamp	4/13/2018	13:00	1.74*	0.10*	5.5	21.6	8.5	32.2
5ABBS001.35	Black Branch	Altered	Swamp	4/26/2018	13:10	0.74*	0.10*	6.6	18.2	8.6	41.8
5ACOU001.40	Council Swamp	Altered	Swamp	5/3/2018	11:15	1.03*	0.10*	6.7	20.0	6.0	100.1
5ATRR008.25	Tarrara Creek	Altered	Swamp	5/1/2018	12:00	1.03*	0.10*	6.3	19.1	7.8	119.0
5AXDMR001.60	UNT Darden Swamp	Altered	Swamp	5/1/2018	12:00	0.87*	0.10*	5.8	16.6	4.8	100.0

TN = total nitrogen; TP = total phosphorus; Temp. = temperature; DO = dissolved oxygen; Spec. Cond. = specific conductance; UNT = unnamed tributary; BDL = below detection limit. Light shaded cells do not meet the proposed swamp waters reference threshold (TN<1.5 mg/L; TP <0.05 mg/L; pH<6.5; Spec. Cond. <150 µS/cm). Dark shaded cells exceed the proposed threshold for stressed swamp waters (TP>0.1 mg/L). *Sample analyzed by the lab in exceedance of method holding time.

Table 6: Water-quality data for prospective stream sites visited in 2018 and 2019 including historical data.

Agency Site Code	Water Body Name	Initial Condition rating	Initial Classification	Date	Time	TN (mg/L)	TP (mg/L)	pH	Temp. (°C)	DO (mg/L)	Spec. Cond. (µS/cm)
5AGRV000.08	Gravelly Run	Reference	Stream	1/3/2019	7:50	0.59	0.03	6.5	9.7	10.8	63.0
5AGRV000.08	Gravelly Run	Reference	Stream	2/11/2019	9:00	NA	NA	6.7	6.7	12.0	61.0
5AGRV000.08	Gravelly Run	Reference	Stream	3/14/2019	9:40	NA	NA	6.5	9.3	11.2	57.0
5AGRV000.08	Gravelly Run	Reference	Stream	4/4/2019	9:40	0.41	NA	7.4	10.4	10.6	64.0
5AHZL000.77	Hazel Swamp	Reference	Stream	4/22/2014	13:15	1.81	0.10	6.6	14.3	9.3	107.0
5AHZL000.77	Hazel Swamp	Reference	Stream	11/19/2014	11:15	6.32	0.40	6.1	4.8	8.5	189.0
5AHZL000.77	Hazel Swamp	Reference	Stream	4/3/2019	10:10	2.74	NA	6.7	8.9	11.5	95.0
5AMRN000.38	Mill Run	Reference	Stream	4/12/2019	11:00	NA	NA	6.6	17.7	7.8	101.0
5AXHAT000.40	UNT Hatcher Run	Reference	Stream	4/4/2019	14:30	NA	NA	6.9	14.2	9.5	41.0
5AXSCKa001.82	UNT Seacock Swamp	Reference	Stream	4/25/2019	12:40	NA	NA	6.5	22.0	NA	76.8
5AXNOTc000.40	UNT Nottoway River 3	Reference	Stream	4/11/2019	13:00	NA	NA	6.7	18.4	9.5	84.0
5ACABR000.64	Caney Branch	Altered	Stream	4/11/2018	8:45	0.76*	0.10*	7.0	9.6	8.6	55.3

TN = total nitrogen; TP = total phosphorus; Temp. = temperature; DO = dissolved oxygen; Spec. Cond. = specific conductance; UNT = unnamed tributary. Light shaded cells do not meet the VCPMI reference threshold (TN<1.5 mg/L; TP <0.05 mg/L). Dark shaded cells exceed proposed threshold for stressed swamp waters (TN>3.0 mg/L; TP>0.1 mg/L). *Sample analyzed by the lab in exceedance of method holding time. NA = data not yet available (analysis pending).

In considering the water-quality results thus far obtained and the watershed land-cover results presented in the preceding section, six swamp sites and three stream sites thus far qualify as reference sites. The swamp sites include Ivy Branch, Jones Hole Swamp, Parker Run, UNT Joseph Swamp, UNT Nottoway River 2, and Otterdam Swamp. Nutrient data have yet to be obtained for four of these sites: Ivy Branch, Jones Hole Swamp, Parker Run, and UNT Joseph Swamp (Table 4). It is recommended that Parker Run be excluded from the list of prospective reference sites because extensive clearcutting areas were observed upstream of the site during the site visit in 2019. The three stream sites that currently qualify as reference based on both land cover and water quality include Gravelly Run, UNT Hatcher Run, and UNT Seacock Swamp. However, land cover is not yet available for the stream site UNT Hatcher Run (Table 3), and pending nutrient data for all three sites may eliminate these sites from the reference dataset (Table 6). Thus, the upcoming acquisition of data may affect establishment of a reference dataset using the currently proposed thresholds.

Habitat

Figure 1 shows the total BHP scores of all prospective reference sites investigated in 2018 and 2019. Evaluations conducted on the same day varied by ≤3 points on the 0–24 point BHP scale. With the exception of one site (UNT Blackwater River 1), little variability in habitat conditions were observed among dates. UNT Blackwater River 1 scores varied by 6 points between the two observation dates. The site was given a score of 13 by A. Garey on March 1, 2013 and a score of 19 by D. Hopler on April 17, 2019. Further investigation is needed to determine whether differences between the evaluations of the investigators or changing site conditions caused this discrepancy.

The BHP scores provide a relatively clear separation between prospective reference stream and swamp sites. The range of BHP scores between the two groups exhibited a nearly complete separation. The BHP scores for stream sites ranged from 1–9 and for swamp sites ranged from 9–23 (Figure 1).

In support of objective three from the FY 2019 scope of work (completion of dataset from FY 2018), BHP scores for investigations conducted in 2018, along with those from 2019, and all historical data from previous years are included in Appendix F.

Benthic Macroinvertebrates

Figure 2 shows VCPMI scores collected at prospective reference sites in 2018 and previous years (see Appendix E for full list of VCPMI metric values, total scores, and sampling dates).

The VCPMI scores at stream sites were generally greater than were those at swamp sites. Samples evaluated from 15 swamp sites exhibited scores below the impairment threshold score of 40 points (on a 0–100 point scale) with one exception: UNT Seacorrie Swamp, sampled on April 12, 2018, received a VCPMI score of 47.07. In contrast, samples collected at the three stream sites consistently exhibit VCPMI scores above 40 with one exception, which occurred on April 19, 2011 when the stream site, Hazel Swamp, received a failing VCPMI score of 17.42.

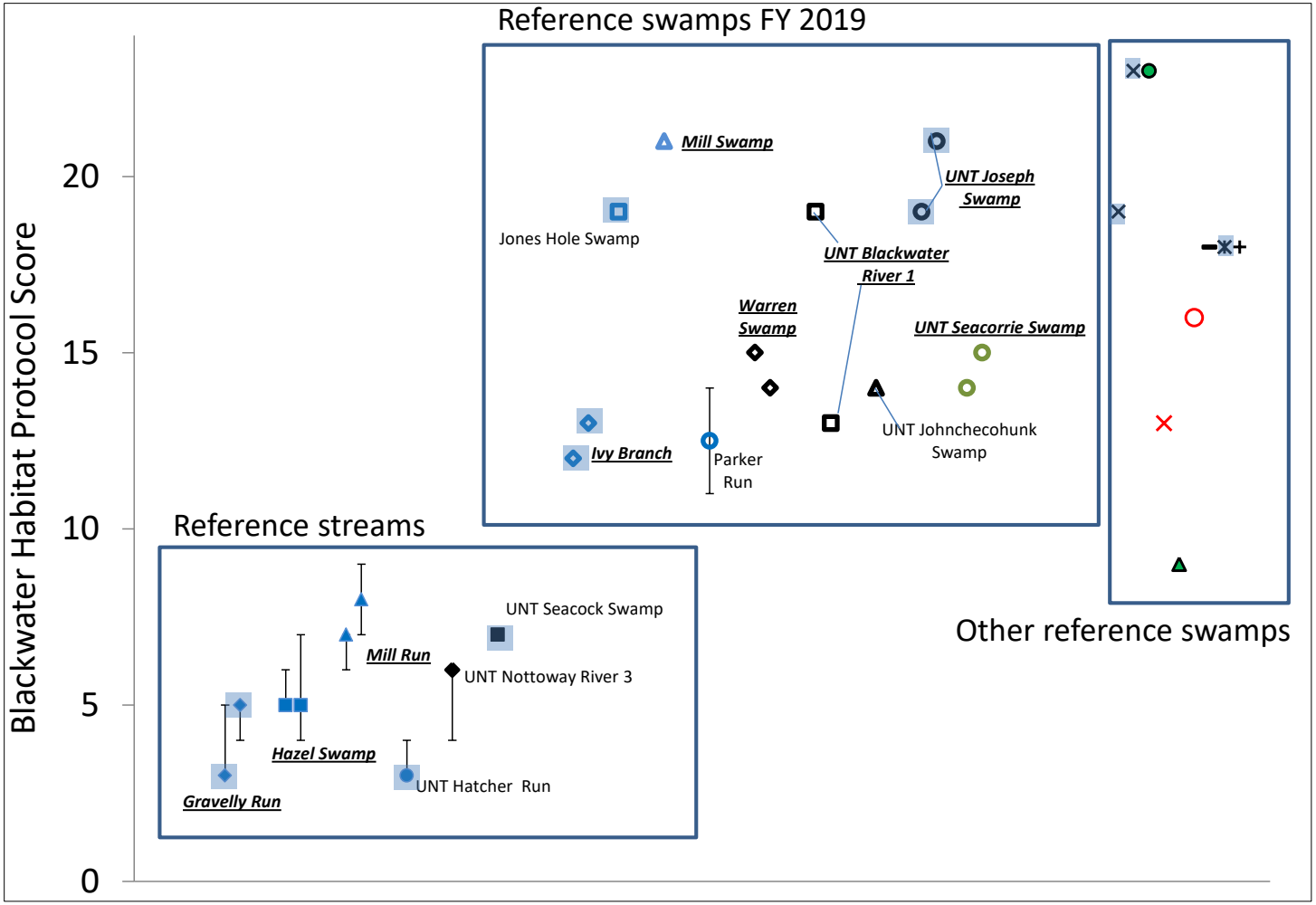

Figure 1: Blackwater habitat protocol scores for all prospective reference sites evaluated in 2018 and 2019. Points with error bars (indicating ranges) were evaluated by multiple (two or three) investigators simultaneously. Points noted with the same symbol indicate scores from the same site on different dates. Labeled sites are those that were visited in 2019. Sites with multiple visits were visited in 2018 and 2019 except for UNT Blackwater River 1 and UNT Joseph Swamp, which were visited in 2016 and 2019, and Otterdam Swamp (blue highlighted X symbols), which was visited in 2013 and 2018 (Appendix F). Blue highlighted (boxed) symbols indicate sites that meet all reference-filter conditions for which data are available. Parker Run was not highlighted because extensive clearcutting was observed upstream of this site during the 2019 site visit.

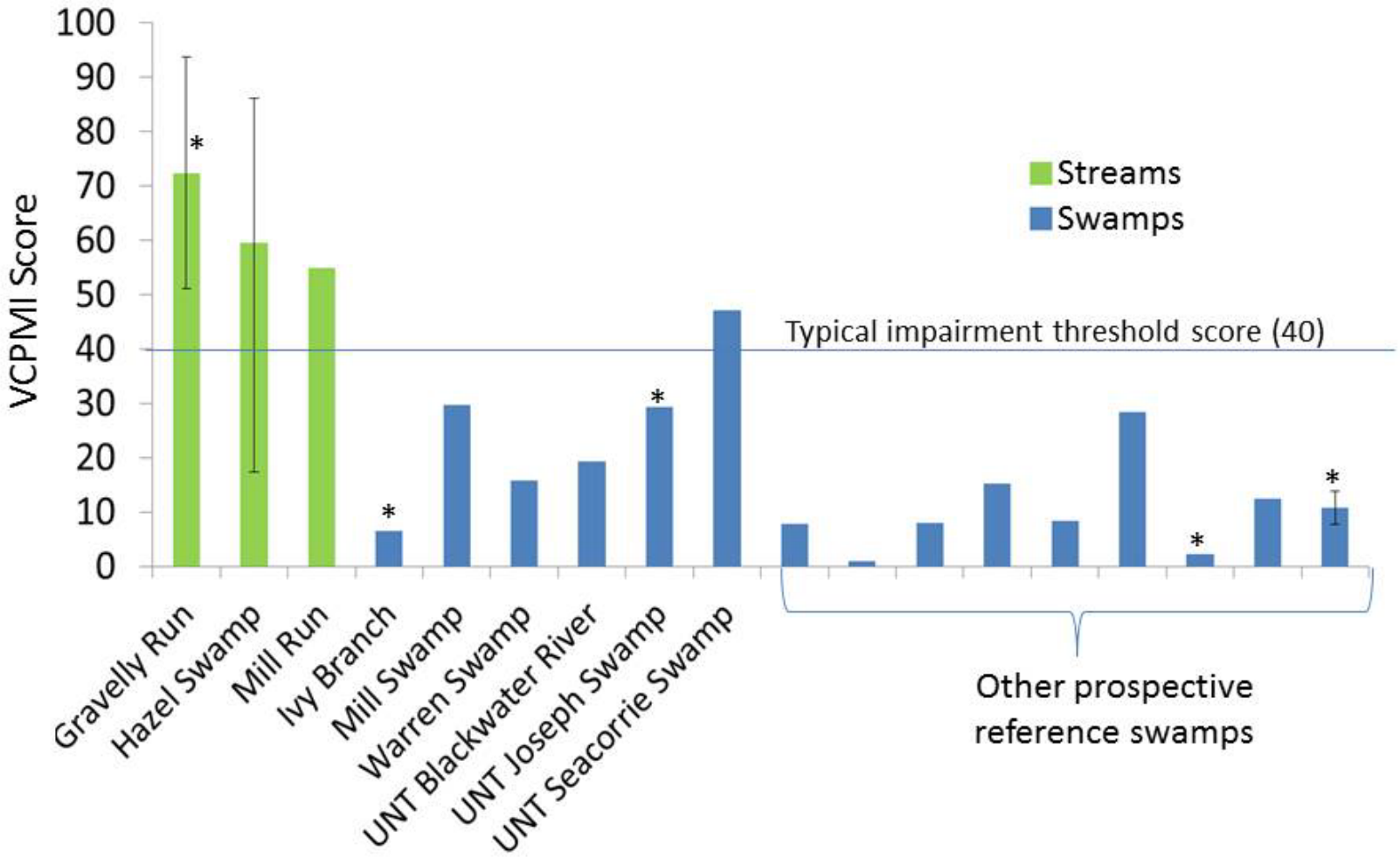

Figure 2: Virginia Coastal Plain Macroinvertebrate Index (VCPMI) scores for prospective reference sites where data were available. Data are from 2018 with the following exceptions: Gravelly Run was sampled twice in 2013; Hazel Swamp was sampled twice in 2011 and twice in 2014; Mill Swamp was sampled in 2005; and Otterdam Swamp (far right of plot) was sampled in 2003 as well as 2018. See Appendix E for full list of sites and sampling dates. Labeled sites are those that were visited in 2019. Sites shown with error bars were sampled multiple times (these bars indicate medians and error bars indicate ranges).

Macroinvertebrate data are available for four of the five swamp sites that currently meet all reference thresholds: Ivy Branch, UNT Joseph Swamp, UNT Nottoway River 2, and Otterdam Swamp (data are not yet available for Jones Hole Swamp). The VCPMI scores for these four sites range from 2.23 to 29.29 (Appendix E), well below the typical impairment threshold of 40. With respect to the three stream sites that meet all reference-filter conditions for which data are available, Gravelly Run received scores of 51.05 and 93.74 on April 11, 2013 and December 5, 2013, respectively (Appendix E). Macroinvertebrate data are not yet available from the other two potential reference streams (UNT Hatcher Run and UNT Seacock Swamp).

Macroinvertebrate samples were collected at all sites visited in 2019, and processing is ongoing. To provide completion of the FY 2018 dataset, benthic macroinvertebrate data from all sites visited in 2018 are provided in Appendix G. Academic Advisory Committee member Len Smock identified the macroinvertebrates to fulfill the AAC deliverable requirements for FY 2019.

Fish

Fish were collected at all sites visited in 2019. The 2019 fish data collected by D. Hopler and S. McIninch were received on May 2, 2019 and have not been analyzed. Fish collections made by DEQ staff include several voucher specimens for which identification confirmation is needed. Therefore, the fish dataset is not yet complete and ready for analysis. Upon completion, data from 2019 will be compared to those from previous years in order to evaluate temporal variation in fish communities at the Chowan Basin swamp and stream sites. Data for fish collections made by S. McIninch and D. Hopler in fulfillment of their deliverable requirements for FY 2019 along with collections made in FY 2018 are included in Appendix H.

Conclusions and Future Work

The focus of the 2019 investigation has shifted largely toward developing an effective classification method for swamp waters. The method must be accurate, rapid, easy to use, adaptable, and correspond to differences in aquatic assemblages at coastal sites that are not attributable to anthropogenic disturbance. Based on the analysis presented here, the BHP provides clear separation between sites categorized (based on professional judgement) as streams and those categorized as swamps. This separation of BHP scores corresponds with a separation in VCPMI scores. Sites with high BHP scores (above 9 or 10), indicating swamp waters, consistently exhibit VCPMI scores below the impairment threshold of 40. In contrast, the stream sites selected for this report (*i.e.*, those with predominantly forested watersheds) exhibit low BHP scores and VCPMI scores that are generally greater than the impairment threshold. The ongoing GIS analyses should provide additional empirical tools for proper classification of swamp waters.

The major challenge in developing a classification system has been in locating appropriate reference systems in the Chowan Basin, especially reference systems that exhibit stream-like characteristics (*i.e.*, low BHP scores). These systems typically flow through upland areas that are amenable to agriculture, and therefore, agricultural land cover dominates the watersheds. In addition, many have been ditched and channelized to dewater surrounding areas. Based on data from the few reference systems evaluated to date, it is difficult to ensure that the observed distinctions in habitat characteristics and in benthic macroinvertebrate assemblages among the systems are due to natural variability as opposed to anthropogenic disturbance.

Work for the next phase of this project will include completion of the fish, macroinvertebrate, water-quality, and GIS datasets for the sites investigated in 2019. Field work will likely be conducted to identify and investigate additional reference systems. It is expected that only a few sites (10 or fewer) will be identified and confirmed as having reference conditions based on the currently proposed reference-filter thresholds.

Request for Input from AAC on Future Tasks

Based on comments from AAC members and on challenges encountered in conducting this investigation, DEQ requests further input from the AAC on the topics described below. This input may include basic advice on best approaches or implementation of specific tasks to be included in the FY 2020 work plan. As needed, DEQ will coordinate with AAC members to develop the FY 2020 work plan and to assess if agency funding is feasible for the associated tasks.

Modification of Study Approach to Account for Lack of Reference Sites

DEQ requests that the AAC evaluate the options for modifying the general study approach presented here based on the lack of suitable reference systems in the Coastal Plain portion of the Chowan River Basin. Such options include: (1) modify the reference-filter thresholds; (2) use the existing thresholds but accept sites that exhibit intermediate levels of anthropogenic disturbance; (3) include sites at all levels of anthropogenic disturbance and use anthropogenic disturbance variables as covariates, rather than exclude sites that do not meet a given set of thresholds; and (4) expand the investigation to include sites outside of the Chowan River Basin. This investigation has been limited to the Chowan River Basin because of biogeographical differences in the aquatic assemblages between this basin and others that drain to the Chesapeake Bay. These differences were considered a potential confounding factor in the development of a bioassessment index. However, if the focus is limited to classification of the factors that distinguish Class VII waters (swamps) and Class III waters (streams), it may be appropriate to include swamps and streams from the Coastal Plain portion of the Chesapeake Bay Basin.

Use of Continuous Monitoring to Classify Swamp Waters

The AAC members have commented that single measurements of DO and pH are likely insufficient to characterize water quality in the systems of interest. DEQ has recently acquired YSI EXO3 water-quality sondes to be deployed for continuous monitoring. A potential study approach for swamp waters is to deploy sondes for 1–3 weeks during the summer when DO and pH levels are expected to be lowest. Measurements of pH, DO, temperature, specific conductance, and turbidity obtained at 15-minute intervals during this period would be compared between suspected Class VII and Class III waters (swamps and free-flowing streams, respectively).

Virginia DEQ requests input from the AAC on this study approach, additional factors that should be considered (*e.g.*, spatial variability in water-quality results, accounting for flow and hydrologic stage at the time of measurement), and methods to account for these factors. In addition, DEQ is interested in proposals from the AAC to assist with calibration, deployment, and maintenance of continuous monitoring equipment.

Expanded Water-Quality Analysis: Inclusion of Dissolved Organic Matter and Nutrient Constituents

The AAC members have indicated that analysis of dissolved organic matter (DOM) or colored dissolved organic matter (CDOM) may provide utility in classifying swamps and streams. In addition, AAC members have recommended measuring organic and inorganic nutrients (as opposed to only total nitrogen and total phosphorus) to better evaluate the degree of

anthropogenic water-quality disturbance at the study sites. Although the AAC has provided helpful suggestions on these topics, DEQ would welcome additional input, specifically on the details of the study design for implementing this monitoring.

Continued GIS Analysis

The GIS work for this project is ongoing. Virginia DEQ requests input from the AAC on the following components of this task:

1) Watershed morphology: The mean and standard deviation of slope have been calculated as estimates of overall slope and slope variability, respectively, within the study watersheds. AAC members have indicated that evaluations of wetland water storage within the study watersheds may provide utility for differentiating between swamps and streams (*e.g.*, Jones *et al*. 2017). Input on these methods and suggestions for other GIS-based methods for characterizing watershed morphology are requested.

2) Stream network analysis: Input is requested on methods for summarizing stream gradient for each watershed and for calculating symmetric and asymmetric flow distances (the latter accounts for flow direction). Input is also requested for statistical approaches to evaluate and, if needed, account for spatial autocorrelation of water-quality and biotic-assemblage data among study sites. Finally, the National Hydrography Dataset (https://www.usgs.gov/core-science-systems/ngp/national-hydrography) does not clearly define stream channels for many study watersheds. In others, stream channel lines are non-contiguous. The intended approach for such cases is to generate a flow-accumulation layer in ArcGIS using the VGIN LIDAR dataset and to represent stream channels at study sites as the locations of the highest flow-accumulation values. Virginia DEQ requests input on this approach and other recommendations.

3) Determining the effects of artificial impoundments: Artificial impoundments may serve as confounding factors in evaluating natural variability in water quality, physical habitat, and biotic assemblages among the study systems. The standard dam dataset in Virginia is the Department of Conservation and Recreation's Dam Safety Inventory (https://www.dcr.virginia.gov/dam-safety-and-floodplains/ds-dsis). The minimum dam size (dams ≥ 6 ft. high with ≥ 15 acre-feet of storage capacity) and other requirements for inclusion in this database limit its utility for this project, as it excludes small impoundments that are relatively common in the region. The agency is evaluating the Southeast Aquatic Barrier Prioritization Tool (https://connectivity.sarpdata.com/) as a source of additional dam records. Virginia DEQ requests input regarding this dataset and other geospatial datasets related to dams and impoundments. Furthermore, DEQ requests input on methods for quantifying the potential influences of impoundments within the study watersheds.

4) Use of GIS-derived soils data to classify study sites: The U.S. Department of Agriculture soil series data (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/) have been quantified for the study watersheds. Input is requested on the best methods of summarizing these data to evaluate differences among study watersheds and on evaluating other soils characteristics that might explain differences among the watersheds of streams and swamps.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers*. USEPA, Washington, D.C.

Dail, M.R., J.R. Hill, and R.D. Miller. 2013. *The Virginia Coastal Plain Macroinvertebrate Index*. VDEQ Technical Bulletin WQA/2013-002. Virginia Department of Environmental Quality, Richmond, Va. Available at: https://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/ProbabilisticMonitoring/vcpmi.pdf (accessed May 7, 2019).

DEQ. 2008. Appendix 1: Standard operating procedures in Biological Monitoring Program Quality Assurance Project Plan for Wadeable Streams and Rivers. Available at: https://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/BiologicalMonitoring/BioMonQAPP_13Aug2008.pdf (accessed May 7, 2019).

Garman, G.C., L.A. Smock, and A.L. Garey. 2012. *Development of Aquatic Life Use Assessment Protocols for Class VII Waters in Virginia: Report of the Academic Advisory Committee for Virginia Department of Environmental Quality*. SR52-2012. Virginia Water Resources Research Center, Blacksburg, Va. Available at http://www.vwrrc.vt.edu/water-quality-academic-advisory-committee/ (accessed May 7, 2019).

Garman, G.C., L.A. Smock, A.L. Garey, and S.P. McIninch. 2013. *Development of Aquatic Life Use Assessment Protocols for Class VII Waters in Virginia: 2013 Report of the Academic Advisory Committee for Virginia Department of Environmental Quality*. SR53-2013. Virginia Water Resources Research Center, Blacksburg, Va. Available at http://www.vwrrc.vt.edu/water-quality-academic-advisory-committee/ (accessed May 7, 2019).

Garey, A.L., G.C. Garman, and L.A. Smock. 2014. *Development of Aquatic Life Use Assessment Protocols for Class VII Waters in Virginia: 2014 Report of the Academic Advisory Committee for Virginia Department of Environmental Quality*. SR55-2014. Virginia Water Resources Research Center, Blacksburg, Va. Available at http://www.vwrrc.vt.edu/water-quality-academic-advisory-committee/ (accessed May 7, 2019).

Garey, A.L., G.C. Garman, and L.A. Smock. 2015. *Development of Aquatic Life Use Assessment Protocols for Class VII Waters in Virginia: 2015 Report of the Academic Advisory Committee for Virginia Department of Environmental Quality*. SR56-2015. Virginia Water Resources Research Center, Blacksburg, Va. Available at http://www.vwrrc.vt.edu/water-quality-academic-advisory-committee/ (accessed May 7, 2019).

Garey, A.L., G.C. Garman, and L.A. Smock. 2016. *Development of Aquatic Life Use Assessment Protocols for Class VII Waters in Virginia: 2016 Report of the Academic Advisory Committee for Virginia Department of Environmental Quality*. SR58-2016. Virginia Water Resources Research Center, Blacksburg, Va. Available at http://www.vwrrc.vt.edu/water-quality-academic-advisory-committee/ (accessed May 7, 2019).

Garey, A.L., G.C. Garman, and L.A. Smock. 2017. *Development of Aquatic Life Use Assessment Protocols for Class VII Waters in Virginia: 2017 Report of the Academic Advisory Committee for Virginia Department of Environmental Quality*. SR61-2017. Virginia Water Resources Research Center, Blacksburg, Va. Available at http://www.vwrrc.vt.edu/water-quality-academic-advisory-committee/ (accessed May 7, 2019).

Jones, C.N., G.R. Evenson, D.L. McLaughlin, M.K. Vanderhoof, M.W. Lang, G.W. McCarty, H.E. Golden, C.R. Lane, and L.C. Alexander. 2017. Estimating restorable wetland water storage at landscape scales. *Hydrological Processes* 32: 305-313.

Appendix A: Site information for study sites included in this report.

Agency Site Code	Water Body Name	Location Description	Latitude	Longitude	Initial Condition Rating	Initial Class.	FY 2018 Field Work	FY 2019 Field Work
5AIVY001.37	Ivy Branch	Upstream of Rte 626	37.0196	-77.1639	Reference	Swamp	YES	YES
5AJNH010.18	Jones Hole Swamp	Downstream of Rte 606	37.1009	-77.3999	Reference	Swamp	NO	YES
5AMS000.40	Mill Swamp	Upstream of Rte 626	37.0791	-76.8070	Reference	Swamp	NO	YES
5APRK000.40	Parker Run	Downstream of Rte 607	36.8597	-77.1715	Reference	Swamp	NO	YES
5AWRN000.46	Warren Swamp	Upstream of Carson Road (Rte. 703)	37.0387	-77.4140	Reference	Swamp	YES	YES
5AXBRa001.40	UNT Blackwater River 1	Downstream of Rte 613	37.0795	-77.1149	Reference	Swamp	NO	YES
5AXJH000.31	UNT Johnchecohunk Swamp	Upstream of Rte 611	37.1035	-76.9687	Reference	Swamp	NO	YES
5AXJO000.10	UNT Joseph Swamp	Upstream of Rte 662 (Hair Road)	37.0834	-77.2800	Reference	Swamp	NO	YES
5AXSRE000.13	UNT Seacorrie Swamp	Approx. 500 ft downstream of road	36.9507	-77.0798	Reference	Swamp	YES	YES
5ADBS002.75	Dobie Swamp	Upstream of Cabin Plank Road	37.0487	-77.2586	Reference	Swamp	YES	NO
5AJOE007.60	Joseph Swamp	500 ft east of Rte. 659	37.0716	-77.2474	Reference	Swamp	YES	NO
5AOTR000.88	Otterdam Swamp	Upstream of Rte 602	37.1292	-77.1239	Reference	Swamp	YES	NO
5ASRE004.17	Seacorrie Swamp	Upstream (east) of road influence	36.9426	-77.0570	Reference	Swamp	YES	NO
5AXBRa001.08	UNT Blackwater River 2	Upstream of Petersburg Rd. (Rte 613)	37.0793	-77.1195	Reference	Swamp	YES	NO
5AXBRb000.20	UNT Blackwater River 3	Upstream of Rte 58	36.6504	-76.8603	Reference	Swamp	YES	NO
5AXNOT001.00	UNT Nottoway River 1	5-600m upstream (Northwest) of Rte 671	36.6459	-77.0284	Reference	Swamp	YES	NO
5AXNOTb000.45	UNT Nottoway River 2	600m Southwest of Delaware Rd (Rte 687)	36.5854	-76.9630	Reference	Swamp	YES	NO
5AXPPL000.11	UNT Poplar Swamp	Upstream of confluence with Poplar Swamp upstream of Rte 635	36.7752	-77.3556	Reference	Swamp	YES	NO
5ABBS001.35	Black Branch	Upstream of Walkers Mill Road (Rte 665)	36.9791	-77.4964	Altered	Swamp	YES	NO
5ACOU001.40	Council Swamp	Upstream of Rte 13	36.6301	-76.6563	Altered	Swamp	YES	NO
5ATRR008.25	Tarrara Creek	Upstream of White Meadow Rd. (Rte. 665)	36.6169	-77.2207	Altered	Swamp	YES	NO
5AXDMR001.60	UNT Darden Swamp	Upstream of Woodland Road (Rte 682)	36.5911	-77.0463	Altered	Swamp	YES	NO
5AGRV000.08	Gravelly Run	Upstream of Duncan Road (Rte 670)	37.0945	-77.4749	Reference	Stream	YES	YES
5AHZL000.77	Hazel Swamp	Upstream of Rte 618	37.0755	-76.9041	Reference	Stream	YES	YES
5AMRN000.38	Mill Run	Upstream of Rte 35	36.7702	-77.0947	Reference	Stream	YES	YES
5AXHAT000.40	UNT Hatcher Run	Five Forks National Battlefield Park	37.1488	-77.6109	Reference	Stream	NO	YES
5AXNOTc000.04	UNT Nottoway River	Downstream of Rte 632	36.9130	-77.2191	Reference	Stream	NO	YES
5AXSCKa001.82	UNT Seacock Swamp	Off Rte 618	36.9487	-76.9229	Reference	Stream	NO	YES
5ACABR000.64	Caney Branch	Just upstream of confluence with drainage ditch	36.6779	-77.4923	Altered	Stream	YES	NO

INPUT DATASETS

- DEQ supplied:
    - Delineated watersheds in shapefile format
    - Monitoring station locations in shapefile format
- High resolution National Hydrography Dataset (NHDPlus High Resolution https://www.usgs.gov/core-science-systems/ngp/national-hydrography/about-national-hydrography-products). The NHD high resolution dataset is compiled at a 1:24,000 scale or better. "USGS Map Accuracy standards for 1:24,000 scale require ninety percent of well-defined features to lie within 40 feet of their true geographic position" (1).
- Elevation:
    - The VGIN DEM derived raster dataset was used for all watersheds but one. The VGIN DEM has a 1 meter by 1-meter cell size with the following accuracy values:
        - USGS Virginia Sandy CVA- Consolidated Vertical Accuracy (CVA) of 0.61 feet (2)
        - FEMA Middle Counties- CVA 0.61 feet (3)
        - FEMA Southampton- CVA 0.78 feet (4)
        - USGS Eleven County- CVA 1.2 feet (5)
    - The VGIN derived DEM was not available for one watershed site, LOC_CODE 5ACABR000.64. Where the VGIN DEM data was not available, the most recent USGS 1/3 arc National Elevation Dataset (NED) was downloaded and used as part of the elevation base raster layer. The USGS NED (1/3 arc second) is a 10-meter by 10-meter elevation grid. The accuracy of the NED will be different at different locations because the accuracy is determined by the input DEM used to derive the NED. The absolute vertical accuracy is reported out as having an RMSE value of 2.44 meters and the relative vertical accuracy is 1.64 meters (3). "Whereas absolute accuracy accounts for the combined effects of systematic and random errors, relative accuracy is a measure of just random errors. Averaged over all 9,187 point pairs, the relative vertical accuracy is 1.64 meters" (6).
- DCR Dam Location Data information is collected as part of the Virginia Department of Conservation and Recreation Division of Dam and Floodplain Safety. Dam location information is input by citizens. "DCR has made reasonable efforts to ensure that the data are correct, however, no guarantee is made as to the positional, thematic or other accuracy of the data" (7).
- VDOT LRS Roads feature class "consists of approximately 192,000 features representing around 70,000 miles of Interstate, Primary, Secondary and Urban roads throughout the State of Virginia. The Linear Referencing System is based on the Virginia Department of Transportation's Source System of Record for road inventory, Roadway Inventory Management System (RIMS)" (8). VDOT LRS horizontal accuracy is reported as 53 feet +/- 0.01 miles (8).

- USDA SSURGO Soils data. This dataset was compiled at different scales depending on input data sources for compilation. In general, USDA SSURGO maps are at 1:12,000 scale which has a National Map Accuracy a horizontal standard of +/- 33 feet. (9)
- VGIN Land Cover was created using a supervised and trained classification process and also including existing vector layers. The classification accuracy of the land cover data is 85-95% (10).
- The Multi-Resolution Land Characteristics Consortium (MRLC) provides the National Land Cover Database (NLCD) data on land cover at a 30 -meter resolution with a 16-class classification scheme based on a modified Anderson Level II classification system. Overall accuracy for 2011 is 82% and accuracy for 2001 is 83% (11).

METHODS

ELEVATION

Elevation was downloaded for each watershed area using the Virginia Geographic Information Network (VGIN) LiDAR download site (7). Dates of the DEM downloaded range from 2010 to 2014. The 4 main areas where the DEM tiles were downloaded were from the 2014 USGS Virginia Sandy CVA, the 2012 FEMA Middle Counties area, the 2011 FEMA Southampton area, and, the 2010 USGS Eleven County area. See appendix for list of watershed and corresponding DEM tiles. The level of accuracy for each grid area:

1. USGS Virginia Sandy CVA- Consolidated Vertical Accuracy (CVA) of 0.61 feet (2)
2. FEMA Middle Counties- CVA 0.61 feet (3)
3. FEMA Southampton- CVA 0.78 feet (4)
4. USGS Eleven County- CVA 1.2 feet (5)

A corresponding spreadsheet lists all the DEQ watersheds along with the available DEM's. Note, some watersheds cross in to multiple tile areas and will show that multiple DEM's are available. The most recent DEM was selected (if appropriate) but most DEM areas are clipped to the tile areas so multiple DEM's were needed to create a seamless coverage for watersheds.

After download, all DEM tiles were mosaiced by year. The data were all resampled and cell values converted to meters. Tile areas were mosaiced and projected. The tiled mosaiced where then mosaiced to one elevation raster layer.

Sinks in DEMs represent areas where the cell (the sink) is lower than all surrounding cells and cannot flow out towards the pour point. It is important to fill the sink to allow for watershed flow. Because the watershed areas of interest are in low lying areas, a z-value was calculated to use in the sink function instead of using the ESRI default value. To calculate the z-value, the sink depth value was determined by creating a raster of sinks, generating watersheds with the sinks as the pour point, creating a raster of minimum values per watershed, creating rasters of the lowest elevation along the watershed boundary and then calculating the difference to find the sink depth. The max sink depth value was used as the z-value. For a full explanation of the methods, refer to the ArcGIS

Resource Center "Finding sink depth" topic (12). A z value of 2.76 meters was used to fill the sinks in the mosaiced DEMs creating the final elevation raster.

TASKS ITEMS

Task A. Aid in the final delineation of watershed boundaries using filled Digital Elevation Model (DEM) data.

Input Datasets:

Elevation:

- Where available, the VGIN DEM (available at (https://ftp.vgingis.com/Download_2/LiDAR/2016/cva/Chesapeake_Bay_VA_QL2_LiDAR_Project_Report_USGS.pdf) derived raster dataset was used. The VGIN DEM has a 1 meter by 1-meter cell size with the following accuracy values:
    - "DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft. (10 cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz =0.28 ft (8.53 cm), equating to +/- 0.55 ft. (16.8 cm) at 95% confidence level. Actual VVA accuracy was found to be +/- 0.72 ft. (21.9 cm) at the 95th percentile." (2)
- The VGIN derived DEM is not available for all of Virginia. Where the VGIN DEM data is not available, the most recent USGS 1/3 arc National Elevation Dataset (NED) will be downloaded and used for tasks. The USGS NED (1/3 arc second) is a 10-meter by 10-meter elevation grid. The accuracy of the NED will be different at different locations because the accuracy is determined by the input DEM used to derive the NED. The absolute vertical accuracy is reported out as having an RMSE value of 2.44 meters and the relative vertical accuracy is 1.64 meters (3). "Whereas absolute accuracy accounts for the combined effects of systematic and random errors, relative accuracy is a measure of just random errors. Averaged over all 9,187 point pairs, the relative vertical accuracy is 1.64 meters" (4).

Methods:

Download all DEM data. Convert each raster to proper projection, set units and cell size, mosaic data together. Use the filled DEM (see DEM methods for description of fill process) to use hydrologic tools to generate flow accumulation, flow direction and watershed boundaries.

Deliverables:

- Detailed methodology report with defined task, methods and results
- File geodatabase with raster filled DEM layer
- Watershed boundary polygon feature class

Task B. Gradient of stream course within watershed- proposal should include scale at which gradient will be measured over, and error estimate.

Input datasets:

- DEQ supplied delineated watersheds in shapefile format
- High resolution National Hydrography Dataset
- VGIN DEM elevation filled layer

Methods:

The gradient was calculated as the vertical difference in elevation divided by horizontal distance, for each stream course (defined as the length of the stream within the watershed) the difference in the elevation from the start point to the end point divided by the stream course distance.

The high resolution USGS National Hydrography Dataset (https://www.usgs.gov/core-science-systems/ngp/national-hydrography) was downloaded for the study area. Data were intersected which allowed for isolating the data per watershed while attributing stream segments in a watershed with watershed attribute information. Data were projected. To reduce create stream length courses, reach codes per watershed area were dissolved by reach and watershed ID to represent single stream segments. Stream segments were also manually edited to clean remaining segments not dissolved. Segments lines were converted to a beginning and an ending vertex point. The points were then attributed with the elevation values, using the compiled and filled elevation layers. Point information was joined back to the stream segments and used to attribute the stream segment attribute table. A field called GRADIENT was added and calculated as:

(start elevation – end elevation)/stream length

Units are meters.

Deliverables:

- Deliverable3.gdb\Stream_Gradient: Flowlines attributed with:
  - ReachCode: NHD reach code for stream segment
  - LOC_CODE: Watershed Loc_Code
  - Stream: Stream segment information from DEQ watershed
  - LOC_NAME: Location name of site from DEQ watershed data
  - StartElev: Elevation value (units meters) of the start point of the segment.
  - EndElevation: Elevation value (units meters) of the end point of the segment
  - Length of stream (in meters): GIS calculated stream segment length in meters
  - GRADIENT: Calculated gradient value for segment
- Excel spreadsheet with watershed (attributed with watershed ID) and gradient value

---

Task C. Total relief of watershed

The total relief of the watershed being the total relief of the delineated basin (and not the stream channel relief) defined as the difference between the highest and lowest elevations in a watershed (not relief ratio).

Input datasets:

- DEQ supplied:
    - Delineated watersheds in shapefile format
- Elevation: Compiled and filled DEM

Methods:

Total relief is defined as the difference between the highest and lowest elevation values within the delineated basin, Spatial Analyst Zonal Statistics was used to compute the RANGE value within each delineated basin.

Deliverables:

- Relief geodatabase table with range, min, max, standard deviation, area value for each watershed.
- Relief excel table with range, min, max, standard deviation, area value for each watershed.

Task D. Slope in entire watershed

Slope within the entire watershed as well as the mean and median slope values for each delineated watershed.

Input datasets:

- DEQ supplied:
    - Delineated watersheds in shapefile format
- Elevation: Compiled and filled DEM

Methods:

The Spatial Analyst Slope function was used to calculate each delineated watershed slope value in degrees, percent rise using the Planar method and the Geodesic method.

Taken from https://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/how-slope-works.htm:

"Planar method

For each cell, the tool calculates the maximum rate of change in value from that cell to its neighbors. Basically, the maximum change in elevation over the distance between the cell and its eight neighbors identifies the steepest downhill descent from the cell.

Geodesic method

The geodesic method measures slope in a geocentric 3D coordinate system—also called the Earth Centered, Earth Fixed (ECEF) coordinate system—by considering the shape of the earth as an ellipsoid. The computation result will not be affected by how the dataset is projected. It will use the z-units of the input raster if they are defined in the spatial reference. If the spatial reference of the input does not

define the z-units, you will need to do so with the z-unit parameter. The geodesic method produces a more accurate slope than the planar method."

The Spatial Analyst Zonal Statistics tool was used to calculate mean, median and range.

Deliverables:

- Detailed methodology report with defined task, methods and results
- The following layers in the Deliverables_2.gdb including:
    - Slope_geo_d: Slope derived using the geodesic methods with cell values in degrees
    - Slope_geo_p: Slope derived using geodesic method with cell values in percent
    - Slope_deg: Slope derived using planar method, cell values in degrees
    - Slope_per: Slope derived using planar method, units in percent.
    - Stats_Slope_deg: Zonal statistics run on slope derived using planar method where cell values are degrees
    - Stats_Slope_Per: Zonal statistics run on slope derived using planar method, cell values in percent.
    - Stats_Slope_Geo_deg: Zonal statistics run on slope derived using geodesic method, cell values in degrees.
    - Stats_Slope_Geo_P: Zonal statistics run on slope derived using geodesic method, cell values in percent
    - Excel spreadsheets for each geodatabase table.

Task E. Soil types within each watershed

Identify the soil types within each delineated watershed.

Input datasets:

- DEQ supplied:
    - Delineated watersheds in shapefile format
- USDA SSURGO Soils data. This dataset was compiled at different scales depending on input data sources for compilation. In general, USDA SSURGO maps are at 1:12,000 scale which has a National Map Accuracy a horizontal standard of +/- 33 feet (9).

Methods:

SSURGO soils data was downloaded for the entire state from the USDA Geospatial Data Gateway located at https://gdg.sc.egov.usda.gov/. Metadata for the layer is included in the deliverable/metadata folder.

Data was projected to match the Virginia Lambert Conformal Conic NAD 1983 projection. The mapunit table was joined to the soils polygon features. The tabulate intersect tool was used to calculate the total area and percent area of unique soil type per watershed.

Per the Web Soil Survey, the update date of the soils data for the study area watersheds was August 2018.

Deliverables:

Table of unique soil type with area detailed for each watershed (excel spreadsheet and as a table in the file geodatabase). The excel spreadsheet is titled Soils_PerWatershed.xls and contains the following fields:

- LOC_CODE: The unique ID of the watershed
- MAPUNIT_NAME: Soil name
- MAPUNIT_SYMBOL: Unique soil ID
- AREA_SQMETERS: Total area (units are square meters) of soils polygon in the watershed
- PERCENTAGE: Percent area of the soil type within the watershed

---

Task F. VGIN land cover data within each watershed

Identify and quantify the different land cover types within each watershed using the VGIN land cover dataset.

Input datasets:

- DEQ supplied:
    - Delineated watersheds in shapefile format
- VGIN Land cover dataset

Methods:

See methodology section for compilation and processing of elevation data.

The VGIN Landcover data was downloaded for the study areas of interest from the online VGIN Landcover website located at <https://www.vita.virginia.gov/integrated-services/vgin-geospatial-services/land-cover/>. Data was appended to one feature class, then projected to the Virginia Lambert Conformal Conic NAD 1983. The DEQ watershed layer was also projected to the Virginia Lambert Conformal Conic NAD 1983 projection.

ArcGIS Analysis Tabulate Intersection tool was used to calculate the total area (in square meters) of each unique land cover class per each unique watershed, along with the percentage of the land cover area of the entire watershed. The table contains the following fields:

- LOC_CODE: Unique ID of the sampling station and watershed
- CLASS_ID: VGIN Landcover unique ID for the land cover type
- AREA_SQMETERS: Total area, units in square meters

- PERCENTAGE: Percent area of the complete watershed
- LandCover: A text field with descriptive text used to name the land cover class as defined by the VGIN Metadata. Metadata includes field descriptions, also included here for reference:

  "The Land Cover data is created based on the following revised Anderson classifications:11. Open Water - Includes drainage network and basins such as rivers, streams, lakes, canals,

  waterways, reservoirs, ponds, bays, estuaries, and ocean as defined by the NHD.21. Extracted Impervious - Includes areas characterized by a high percentage of constructed materials such as asphalt and concrete, buildings and parking lots, and infrastructure as defined by the EPA, that extends beyond local planimetric data provided.22. External Impervious - Includes locally maintained planimetric data such as buildings, parking lots, edge of pavement, roads, and any other paved surface data.31. Barren - Includes areas with little or no vegetation characterized by bedrock, desert pavement, beach and other sand/rock/clay accumulations, as well as areas of extractive mining activities with significant surface expression as defined by the EPA.41. Forest - Includes areas characterized by tree cover of natural or semi-natural woody vegetation as defined by the EPA, encompassing an acre in size; this class includes deciduous, evergreen, and mixed foliage types.42. Tree - Includes areas characterized by tree cover of natural or semi-natural woody vegetation as defined by the EPA, that does not encompass atleast an acre in size; this class includes deciduous, evergreen, and mixed foliage types.51. Scrub/Shrub - Includes areas characterized by natural or semi-natural woody vegetation with aerial stems generally less than 6 meters tall; features classified here will include those that would otherwise be determined Harvested/Disturbed but appear to show unmanaged stunted growth, or managed as easements.61. Harvested/Disturbed - Includes areas of forest clear-cut, temporary clearing of vegetation, and other dynamically changing land cover due to land use activities as defined by the EPA; these features should be categorized only where there is 30% canopy cover or less.71. TurfGrass - Primarily grasses; including vegetation planted in developed settings for erosion control or aesthetic purposes, as well as natural herbaceous vegetation and undeveloped land, including upland grasses and forbs, as defined by the EPA.81. Pasture - Includes areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops as defined by the EPA.82. Cropland - Includes areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber, or is maintained in developed settings for specific purposes as defined by the EPA.91. NWI/Other - Includes all areas where forest, shrubland vegetation, or perennial vegetation accounts for 25% to 100% of the cover and the soil or substrate is periodically saturated with or covered with water, as provided by the TMI & NWI; this class has an additional attributed subclass to correspond with the extracted software output had external wetland data not been incorporated. The data provided here is a compilation of feature extraction utilizing Textron Systems Feature Analyst software, a third party extension to ESRI's ArcGIS Desktop software, and a variety of state and locally managed geospatial datasets. Locality datasets include Parcels, building footprints, edge of pavement and additional impervious layers, and hydrography. State and federal data includes hydro features from NHD, wetland features from TMI and NWI and VBMP RCL centerline data. Additional datasets were acquired from state agencies to improve

upon the QA of certain classifications. For updated digital Tidal Marsh Inventory data, please visit http://ccrm.vims.edu/gis_data_maps/static_maps/gis/tmi_updated.html</abstract>".

The classification accuracy of the land cover data is 85-95% (10)

Deliverables:

- Table of unique land cover type with area detailed for each watershed (excel spreadsheet and as a table in the file geodatabase)

Task G. 10-year land cover change analysis

Conduct a change analysis looking at land cover change over the past 10 years in the delineated watershed.

Input datasets:

- DEQ supplied:
  - Delineated watersheds in shapefile format
- NLCD:
  - Use 2001 and 2011 NLCD data if 2016 NLCD data is not available

Methods:

The Multi-Resolution Land Characteristics Consortium (MRLC) provides the National Land Cover Database (NLCD) data on land cover at a 30 meter resolution with a 16-class classification scheme based on a modified Anderson Level II classification system (https://www.mrlc.gov/data?f%5B0%5D=category%3Aland%20cover).

The 2016 NLCD data is not available at this date of April 9 2019. The 2001 and 2011 NLCD raster data were downloaded from https://www.mrlc.gov/data?f%5B0%5D=category%3Aland%20cover. The NLCD data is a 30 meter x 30 meter resolution dataset. Overall accuracy for 2011 is 82% and accuracy for 2001 is 83% (11).

For this task, the NLCD data for each year was extracted to the Counties containing the sites using the the Spatial Analyst Extract by Mask. The two extracted rasters were converted to Virginia Lambert Conformal Conic NAD 1983 to match the delineated watershed layer. To ensure the analysis included all areas, converted the raster to a vector to use geoprocessing tools. When running area calculations with tools such as Tabulate Area, it is recommended to work with input and zone features in raster format. For this analysis, and to retain the watershed polygon area, decided to use the vector analysis approach. Rasters were converted to polygons, features were not generalized. The Analysis Tool, Tabulate Intersect, was used to calculate the total area and percent area of each unique land cover type within

each watershed. All outputs were visually checked and summary statistics run to ensure each watershed polygon's percentages added up to 100%.

Outputs were joined and calculations to show change over time were calculated as:

(Area of x land cover 2011) - (Area of x land cover 2001)

A final excel workbook was created with 4 worksheets:

- Change Analysis: A worksheet containing the area change in time for 2011 - 2001 land cover for each watershed. Area units are in square meters.
- Land Cover 2001: A worksheet containing the area of each 2001 NLCD land cover class per watershed. Area units are in square meters.
- Land Cover 2011: A worksheet containing the area of each 2011 NLCD land cover class per watershed. Area units are in square meters.

For each worksheet, fields are labeled to show the class descriptive name, the class land cover category value and the year.

Deliverables:

- Table of change analysis for each watershed reporting the total area of land cover time for year 1 and for year 10, and reporting change in area. Called Landcover_Change.xls.
- Total, individual area and percent calculation tables called:
    - Deliverables.gdb\LandCover_PerWatershed_2001
    - Deliverables.gdb\LandCover_PerWatershed_2011
    - Deliverables.gdb\LandCoverChangeAnalysis

Task H. VDOT road layer (most recent) buffered using DCR Python Script (see: https://github.com/VANatHeritage/RCL-Tools/blob/master/ProcRoads.py more information available if needed).

To assess the VDOT right of way and generate a polygon vector layer representing road right of way for each DEQ watershed.

Input datasets:

- DEQ supplied:
    - Delineated watersheds in shapefile format
- VDOT Roads obtained from the Virginia Department of Transportation

Methods:

VDOT maintains a robust Linearly Referenced set of road centerline data. In discussion with VDOT, personnel recommended the use of the LRS and pavement width to more accurately portray road surface area then road right of way. VDOT provided a centerline feature class that had the lane count as well as pavement width data from tbl_planning_data with lines mapped on the RTE_MASTER_LRS. The information was used to calculate buffer widths that represent the area of paved surface. The data is accurate but VDOT is not aware of when the data were updated last and (personal communication).

The planning data was missing some road data. The most recent LRS was downloaded (http://vdot.maps.arcgis.com/home/item.html?id=fd30255fbf2b440b9cfda0f648a21044). Using the

polygon buffer area, the roads that had pavement area already were erased. A field was added to the data and based on VDOT specifications were attributed as:

'Interstate', 'Interstate Frontage Road', and 'Interstate Ramp' as Interstate, 'State Highway Primary' and 'US Highway Primary' as primary, and the rest as secondary.

In terms of lane count to paved surface, VDOT recommended 14 feet on the interstates, 12 feet on primaries and 10 feet on Secondaries.

The updated paved surface area was loaded in to the paved surface area layer. An intersect and summary statistics were used to calculate the total area of paved surface area and percent area.

Deliverables:

Deliverable3.gdb
\Watershed_Roads_PavementArea: Buffered roads layer. Fields include:

- FID_DEQ_Watersheds: FID of the DEQ delineated watersheds
- LOC_CODE: LOC_CODE of the watershed the roads falls within
- FID_TBL_PLANNING_DATA_Widths_lam83: VDOT LRS field which represents road width
- ROUTE_NO: VDOT LRS field which represents the route number of the road segment
- PAVEMENT_WIDTH: VDOT LRS field representing pavement width of the road
- AVG_LANE_WIDTH: VDOT LRS field representing average lane width of the segment
- MEDIAN_WIDTH: VDOT LRS field representing median lane width
- Buffer_FT: Generated buffer distance for use in the buffer tool
- BUFF_DIST: Buffered distance
- ORIG_FID: FID or road segment
- Shape_Length: ESRI generated field representing length (in projection units of meters)
- Shape_Area: ESRI generated field representing area (in projection units of meters)

\PavedArea_PerWatershed: geodatabase table with the total paved area per watershed as well as the percent area.

- LOC_CODE: LOC_CODE of the watershed the roads falls within
- PercentArea: Percent area of the buffer compared to the entire watershed area (calculated as area of buffer /total area of watershed * 100)
- BufferArea: Total area of the paved surface area per watershed

Task I. Number and surface area of impoundments within each watershed and distances to study sites

For this task, impoundments are defined as the location of dams in Virginia. This data is tracked by the Virginia Department of Conservation and Recreation (http://www.dcr.virginia.gov/dam-safety-and-floodplains/ds-dsis) and the National Inventory of Dams (http://nid.usace.army.mil/cm_apex/f?p=838:1:0::NO). Dams that are NOT tracked are dams that fulfill particular criteria such that:

> "All dams in Virginia are subject to the Dam Safety Act and Dam Safety Regulations unless specifically excluded. A dam is excluded if it:
>
> - is less than six feet high;
> - has a maximum capacity less than 50 acre-feet and is less than 25 feet in height;
> - has a maximum capacity of less than 15 acre-feet and is more than 25 feet in height;
> - is operated primarily for agricultural purposes and has a maximum capacity of less than 100 acre-feet or is less than 25 feet in height (if the use or ownership changes, the dam may be subject to regulation);
> - is owned or licensed by the federal government;
> - is operated for mining purposes under 45.1-222 or 45.1-225.1 of the *Code of Virginia*;
> - is an obstruction in a canal used to raise or lower water levels." (5)

Input datasets:

- DEQ supplied:
  - Delineated watersheds in shapefile format
- Dam data from Virginia Department of Conservation and Recreation Division of Dam Safety and Floodplains

Methods:

Only five of the watersheds have DCR dams located in the watershed. The spatial join tool was used to generate a COUNT field. OF the monitoring sites located within watersheds that contained dam location, two sites were not along the same gradient of the dam so were removed from the NEAR analysis. The NEAR command was run on the sample sites to located nearest impoundment upstream of site.

Deliverables:

- Deliverable3.gdb:
  - DCR_Dams_012019: DCR dam location data
  - DCR_Dams_PerWatershed: Watershed polygon layer attributed with a COUNT of the number of dams located within the watershed

- Sites_With_Dams: Monitoring sites that have dam locations on the same stream network upstream of the site. The Distance_Dam_M field represents the distance from the point to the nearest dam (units in meters)

Task J. Repeat of tasks C through I in watershed area within 1 km from monitoring station. Following the same methodology detailed for the proposed tasks in previous sections, the same input datasets besides the 1 km generated buffer of the monitoring stations, and the same deliverables. The buffer areas are defined as having a 1 kilometer radius and upstream within the watershed.

Monitoring sites were joined to watersheds to ensure each monitoring site with a watershed was selected. Overlapping watershed areas were generated separately. Buffers were generated around the

DEQ monitoring sites using a 1 kilometer option and then intersected with the DEQ watersheds. The ID is the monitoring site Site_Code.

Task C. Total relief of watershed within 1 km of monitoring station.

The total relief of the watershed being the total relief of the delineated basin (and not the stream channel relief) defined as the difference between the highest and lowest elevations in a watershed (not relief ratio).

Methods:

Relief was calculated using Spatial Analyst Zonal Statistics to generate range, min, max, standard deviation and area values. The compiled DEM raster layer and buffer areas were used.

Deliverable:

The output table contains area, minimum cell value, maximum cell value, range, standard deviation, and sum of cell values. The table is in the deliveable geodatabase and as an excel spreadsheet.

Task D. Slope within a 1 km generated buffer of the monitoring station.

Slope was calculated in a previous task. For this task, the slope rasters were extracted to the buffer areas. Zonal statistics were run using the buffer areas as the zone layer and the master slope layer for the slope.

Methods:

Using zonal statistics, the mean, range and median values can be determined for each watershed using the existing slope layer as the input raster and the intersected 1 km buffers.

Deliverables:

- Slopegeod_1kmbuff: Slope derived using the geodesic methods with cell values in degrees
- Slopegeop_1km: Slope derived using geodesic method with cell values in percent
- Slopedeg_1kmbuff: Slope derived using planar method, cell values in degrees
- Slopeper_1kmbuff: Slope derived using planar method, units in percent.
- statsbuff_slope_deg: Zonal statistics run on slope derived using planar method where cell values are degrees
- statsbuff_slope_per: Zonal statistics run on slope derived using planar method, cell values in percent.
- statsbuff_slope_geo_deg: Zonal statistics run on slope derived using geodesic method, cell values in degrees.
- statsbuff_slope_geop: Zonal statistics run on slope derived using geodesic method, cell values in percent
- Excel spreadsheets for each geodatabase table.

Task E. Soil types within a 1 km generated buffer of the monitoring station.

Methods:

The sample site points that fall within (or within several meters) were selected to create the station location point file. The sites were buffered at 1 kilometer. Buffers were intersected with the SSURGO soils layer joined with the soil type table using the Tabulate Intersect tool.

Deliverables:

The output table is in the Deliverable.gdb and an excel spreadsheet, Soils_1kmBuff.xls with the following fields:

- Site Code: The unique ID of the monitoring site.
- Soil Type: SSURGO soil type.
- Area_SQMeters: Total area (square meters) of the soil type within the watershed.
- Percentage: Percent of the soil type within the watershed.

Task F. VGIN land cover data within a 1 km generated buffer of the monitoring station.

Methods:

Using the 1 kilometer buffers generated for the sample sites within 100 meters of the watershed polygons, the tabulate intersect was used to get the total area of land cover type within each watershed.

Deliverables:

The output table is in the Deliverable.gdb and an excel spreadsheet, VGIN_LC_1kmBuff.xlsx with the following fields:

- Site Code: The unique ID of the monitoring site.
- CLASS_ID: Unique ID of land cover type.
- Area_SQMeters: Total area (square meters) of the land cover type within the watershed.
- Percentage: Percent of the land cover type within the watershed.

Task G. 10-year land cover change analysis within a 1 km generated buffer of the monitoring station.

Methods:

Using the 1 kilometer buffers generated for the sample sites within 100 meters of the watershed polygons, the tabulate intersect was used to get the total area of 2011NLCD and 2001 NLCD land cover type within each watershed. A unique join ID was created using the SITE CODE and GRID CODE (land cover code) to set up a proper join of unique land cover classes per watershed. The table was exported and the change in area and percentage was calculated as:

For each unique buffer,

(land cover area in square meters 2011) - (land cover area in square meters 2001)

(percent area in square meters 2011) - (percent area in square meters 2001)

Deliverables:

The output table is in the Deliverable.gdb and an excel spreadsheet, LC_ChangeAnalysis.xlsx with the following fields:

- Site Code: The unique ID of the monitoring site.
- Land Cover Code: Unique ID of land cover type.
- Area_SQMeters (with respective date of dataset): Total area (square meters) of the land cover type within the watershed.
- Percentage (with respective date of dataset): Percent of the land cover type within the watershed.
- Change in Area SQ Meters 2011 - 2001: Difference in land cover area from 2011 to 2001.
- Change in Percentage 2011 - 2001: Difference in percent composition of land cover from 2011 - 2001.

Task H. VDOT road layer (most recent) buffered to show road right of way width

To assess the VDOT right of way and generate a polygon vector layer representing road right of way.

Methods:

The 1 km buffer of the DEQ monitoring sites was used as the study area. In discussion with VDOT, personnel recommended the use of the LRS and pavement width to more accurately portray road surface area then road right of way.

VDOT maintains a robust Linearly Referenced set of road centerline data. VDOT provided a centerline feature class that had the lane count as well as pavement width data from tbl_planning_data with lines mapped on the RTE_MASTER_LRS. The information was used to calculate buffer widths that represent the area of paved surface. The data is accurate but VDOT is not aware of when the data were updated last and (personal communication). Spot checking will be done to evaluate accuracy.

The roads were intersected with the buffer areas of the monitoring stations.

Deliverables:

Deliverable3.gdb\BufferArea_Roads_PavementArea: Buffered roads layer. Fields include:

- FID_DEQ_Watersheds: FID of the DEQ delineated watersheds
- LOC_CODE: LOC_CODE of the watershed the roads falls within
- FID_TBL_PLANNING_DATA_Widths_lam83: VDOT LRS field which represents road width
- ROUTE_NO: VDOT LRS field which represents the route number of the road segment
- PAVEMENT_WIDTH: VDOT LRS field representing pavement width of the road
- AVG_LANE_WIDTH: VDOT LRS field representing average lane width of the segment
- MEDIAN_WIDTH: VDOT LRS field representing median lane width
- Buffer_FT: Generated buffer distance for use in the buffer tool
- BUFF_DIST: Buffered distance
- ORIG_FID: FID or road segment
- Shape_Length: ESRI generated field representing length (in projection units of meters)
- Shape_Area: ESRI generated field representing area (in projection units of meters)

Task I. Number and surface area of impoundments within a 1 km generated buffer of the monitoring station and distance from impoundment to monitoring station.

For this task item, using the DCR dam data, no dams were present within the 1 km buffer areas.

Task K. Repeat of above analysis at distances of 50, 100 and 200m from stream channels within each watershed.

The stream channels were generated using the BUFFER tool in ArcGIS. Each stream channel is a single buffer polygon that represents stream channel width at 50 meters, 100 meters and 200 meters. Each polygon area is attributed with the watershed ID (LOC_CODE) the buffer falls within.

Task C. Total relief of 50, 100, and 200-meter stream channel.

The total relief of the watershed being the total relief of the delineated basin (and not the stream channel relief) defined as the difference between the highest and lowest elevations in a watershed (not relief ratio). The compiled and filled DEM was used as the elevation layer. The Spatial Analyst Zonal

Statistics tool was used with the buffer areas as input zones to calculate range as well as mean, median, maximum, minimum, sum and standard deviation of the elevation values within the stream channel.

Deliverables:

- Relief_50m_StreamChannel: A table in the file geodatabase representing derived statistics for elevation within the 50-meter stream channel for each unique watershed.
- Relief_100m_StreamChannel: A table in the file geodatabase representing derived statistics for elevation within the 100-meter stream channel for each unique watershed.
- Relief_200m_StreamChannel: A table in the file geodatabase representing derived statistics for elevation within the 200-meter stream channel for each unique watershed.

Task D. Slope within 50, 100, and 200-meter stream channel.

Extract data by mask to each buffer area to create subset slope grids - extract from the geodesic percent slope as the primary slope grid. See above methods for a description of the derivation of this slope layer. Zonal statistics were run for each unique watershed (LOC_CODE) using the Spatial Analyst Zonal Statistics as a Table tool.

Deliverables:

- Slope_50mStreamChannel: A raster layer of the geodesic derived slope (units in percent rise) extracted to the 50-meter stream channel area for all watersheds.
- Slope_100mStreamChannel: A raster layer of the geodesic derived slope (units in percent rise) extracted to the 100-meter stream channel area for all watersheds.
- Slope_200mStreamChannel: A raster layer of the geodesic derived slope (units in percent rise) extracted to the 200-meter stream channel area for all watersheds.
- SlopeStats_50m_StreamChannel: A table with statistics (MEAN, MEDIAN, MAX, MIN, SUM, STD DEVIATION) run on the slope (unit percent rise) within each watershed's 50-meter stream channel area.
- SlopeStats_100m_StreamChannel: A table with statistics (MEAN, MEDIAN, MAX, MIN, SUM, STD DEVIATION) run on the slope (unit percent rise) within each watershed's 100 meter stream channel area.
- SlopeStats_200m_StreamChannel: A table with statistics (MEAN, MEDIAN, MAX, MIN, SUM, STD DEVIATION) run on the slope (unit percent rise) within each watershed's 200 meter stream channel area.

Task E. Soil types within 50, 100, and 200-meter stream channel.

SSURGO soils polygon data was joined with the Component table to tabulate the total area of each unique type of soil within each watershed's 50 meter, 100 meter and 200-meter stream channel. The Tabulate Intersect tool was used to calculate total square meters (AREA) of unique soil type within the stream channel areas as well as the percent area the soil type makes up per watershed stream channel.

Deliverables:

- Soils_50mStreamChannel: A geodatabase table with total area and percent area of each unique soil type in each unique watershed stream channel.
- Soils_100mStreamChannel: A geodatabase table with total area and percent area of each unique soil type in each unique watershed stream channel.
- Soils_200mStreamChannel: A geodatabase table with total area and percent area of each unique soil type in each unique watershed stream channel.

Each table contains the following fields:

- LOC_CODE: Unique ID that corresponds to the watershed
- MapUnitName: SSURGO soil type name
- AREA: The total area. Units are square meters
- PERCENTAGE: Percent area the soil type makes per watershed stream channel area.

Task F. VGIN land cover data within 50, 100, and 200-meter stream channel

Using the compiled VGIN land cover data (2015) for the study area, the Tabulate Intersect tool was used to calculate the total area (in square meters) and percent area of each unique land use type per each watershed 50 meter, 100 meter and 200-meter stream channel.

Deliverables:

- VGINLC_50mStreamChannel: File geodatabase table containing the total area (unit square meters) and percentage (percent area) of each unique land cover type that falls within the 50-meter stream channel tabulated for each unique watershed.
- VGINLC_100mStreamChannel: File geodatabase table containing the total area (unit square meters) and percentage (percent area) of each unique land cover type that falls within the 100-meter stream channel tabulated for each unique watershed.
- VGINLC_200mStreamChannel: File geodatabase table containing the total area (unit square meters) and percentage (percent area) of each unique land cover type that falls within the 200-meter stream channel tabulated for each unique watershed.

Tables include the following fields:

- LOC_CODE: Unique watershed ID
- CLASS_ID: Unique ID of the land cover type
- LC_DESC: Text description of the land cover type
- AREA: Total area of land cover type, units in square meters
- PERCENTAGE: Percent area the land cover type makes of the entire watershed

Task G. 10-year land cover change analysis within 50, 100, and 200-meter stream channel.

For this task, the difference in total area of land cover type per watershed, as well as the change in percent area, was calculated using the 2011 and 2001 National Land Cover Dataset (NLCD). NLCD data

was extracted to the study area and projected to Virginia Lambert Conformal Conic. The Tabulate Intersect tool was used to calculate total areas and percent area of each land cover type within the 50-meter stream channel, the 100-meter stream channel and the 200-meter stream channel.

Deliverables:

- LC_Change_50mStreamChannel: A file geodatabase table representing area calculations for 2011 and 2001 land cover types, percent area of land cover type and difference between 2011 to 2001 for the 50-meter stream channel within each unique watershed.
- LC_Change_100mStreamChannel: A file geodatabase table representing area calculations for 2011 and 2001 land cover types, percent area of land cover type and difference between 2011 to 2001 for the 100-meter stream channel within each unique watershed.
- LC_Change_200mStreamChannel: A file geodatabase table representing area calculations for 2011 and 2001 land cover types, percent area of land cover type and difference between 2011 to 2001 for the 200-meter stream channel within each unique watershed.

Fields include:

- LOC_CODE: Watershed unique ID
- Gridcode: A code representing land cover type.
- Area: Total area of land cover type within the watershed stream channel. This is the area of the 2011 NLCD land cover. Units are in square meters.
- Percentage: Percent area of land cover type within the watershed stream channel. This is the percent area of the 2011 land cover type.
- DIFF_2011_2001: Difference in area from 2011 - 2001. Units are in square meters.
- ChangePerc: Difference in percent area from 2011 - 2001.
- Area_1: Total area of land cover type within the watershed stream channel. This is the area of the 2001 NLCD land cover. Units are in square meters.
- Percentage_1: Percent area of land cover type within the watershed stream channel. This is the percent area of the 2001 land cover type.
- LC_Description: The NLCD land cover type description.

Excel tables included in tables folder.

Task H. VDOT road layer (most recent) buffered using DCR Python Script

The total area and percent area of road within the 50 meter, 100 meter and 200 meter stream channels. The paved road area was calculated using the VDOT roads LRS and road centerline data. Buffers were set based on the widths detailed by VDOT personnel for road type (interstate, highway, primary roads and secondary roads). See task H for detailed methodology for road buffer area.

The Tabulate Intersect tool was used to calculate the total area and percent area of the paved surfaces within each watershed 50 meter, 100 meter and 200-meter stream channels.

Deliverables:

- PavedArea_50mStreamChannel: File geodatabase table with the area (square meters) and percent area of paved area within the watershed 50-meter stream channel.

- PavedArea_100mStreamChannel: File geodatabase table with the area (square meters) and percent area of paved area within the watershed 100-meter stream channel.
- PavedArea_200mStreamChannel: File geodatabase table with the area (square meters) and percent area of paved area within the watershed 200-meter stream channel.

Fields include:

- LOC_CODE: Watershed unique ID
- AREA: Total area of paved surface within the stream channel. Units are in meters.
- PERCENTAGE: The percent area of the stream channel covered by paved area.

Excel tables included in tables folder.

Task I. Number and surface area of impoundments within 50, 100, and 200-meter stream channel.

Using a Spatial Join, each DCR Dam location was counted within each watershed 50 meter, 100 meter and 200-meter stream channel.

Deliverables:

- Dams_50mStreamChannel: Polygon feature class of the stream channel buffer with the count of dams that fall within the stream channel.
- Dams_100mStreamChannel: Polygon feature class of the stream channel buffer with the count of dams that fall within the stream channel.
- Dams_200mStreamChannel: Polygon feature class of the stream channel buffer with the count of dams that fall within the stream channel.

Fields include:

- LOC_CODE: Watershed unique ID.
- Count_: Total number of dams that fall within the stream channel.
- Shape_Length: Area length field, units in meters.
- Shape_Area: Total area of the stream channel polygon, units in square meters.

CITATIONS

(1) USGS, 2019. What is the positional accuracy of the National Hydrography Dataset (NHD)?. Accessed 1/10/2019. Url: < USGS Map Accuracy standards for 1:24,000 scale require ninety percent of well-defined features to lie within 40 feet of their true geographic position.>

(2) Digital Aerial Solutions, LLC. 2014. Project Report LiDAR Collection, Processing and QA/QC. Accessed 2019 url: <https://ftp.vgingis.com/Download_2/LiDAR/2014/sandy_cva/FY14_Virginia-Sandy_G10PC00093_LiDAR_Project_Report_Final.pdf>

(3) Dewberry. 2012. Middle Counties Acquisition and Classification for FEMA VA LiDAR. Accessed 2019 url:
<https://ftp.vgingis.com/Download_2/LiDAR/2012/fema/project_reports/Dewberry_ProjectReport_MiddleCounties.pdf>

(4) Dewberry. 2012. Southern Virginia Counties Acquisition and Classification for FEMA VA LiDAR. Accessed 2019 url:
<https://ftp.vgingis.com/Download_2/LiDAR/2011/fema/shp/Dewberry_ProjectReport_Southampton.pdf>

(5) Dewberry. 2011. USGS Eleven County Virginia LiDAR – ARRA LiDAR. Accessed 2019 url:
<https://ftp.vgingis.com/Download_2/LiDAR/2010/arra/Final%20Project%20Report%20for%20USGS%20Virginia%20LiDAR_01312011.pdf>

(6) Maune, D., (ed,), 2007, Digital elevation model technologies and applications: the DEM user's manual (2nd edition), chapter 4. Courtesy of Dean Gesch, USGS, url
<https://hazards.fema.gov/femaportal/docs/National%20Elevation%20Dataset_2007.pdf>

(7) Virginia Department of Conservation and Recreation. *Division of Dam Safety and Floodplains, Virginia Dam Safety Inventory System*. 2019, https://www.dcr.virginia.gov/dam-safety-and-floodplains/ds-dsis.

(8) Commonwealth of Virginia Department of Transportation. *Master Routes with Official State Mileage Measures - Linear Referencing System Metadata. 2019,*
https://vdot.maps.arcgis.com/home/index.html#.

(9) USDA. Description of SSURGO Database, USDA Department of Agriculture, Accessed 2019 url <
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627>

(10) Worldview Solutions, LLC. 2016. Technical Plan of Operations Virginia Statewide Land Cover Data Development. Accessed 2019
<https://www.vita.virginia.gov/media/vitavirginiagov/integrated-services/pdf/LandCover_TechnicalPlanOfOperations_v7_20160506.pdf>

Appendix C: Blackwater habitat protocol sheet.

Site name: _____ Date: _____
Site code: _____ Time on: _____
Field crew members: _____ Time off: _____
Location description: _____

Metric	Subcategories (metrics 1 and 2)	Raw values	Weights	Scoring
1) Channel Development		Percentage of channel	Weight	Percentage*weight
	One defined bed/bank flow path		2	
	Multiple defined bed/bank flow paths		1	
	No defined bed/bank flow paths		0	
		Total weighted percentage:		
Comments:			Metric score:	
2) Flow Score		Percentage of channel	Weight	Percentage*weight
	No perceptible flow /flow extremely sluggish		0	
	Slow flow (see reverse for description)		1	
	Moderate, laminar flow (appx 0.1-0.2 m/s)		2	
	Rapid, laminar flow (>0.2 m/s)		3	
	Rapid, turbulent flow		4	
		Total weighted percentage:		
Comments:			Metric score:	
3) Flood plain elevation	Value (cm):		Metric score:	
4) Submerged and emergent vegetation	abs: 0, rare:1, common:2, abundant: 3		Metric score:	
5) Benthic organic matter		Percentage:	Metric Score:	
6) Forest type	see criteria on reverse		Metric score:	
Dominant tree/vegetation cover species:		Comments:		
7) Wetland width	Percentage of 200-m area as wetland:		Metric score:	
Comments:				
8) Canopy	Percentage of overhead cover:		Metric score:	
Comments:				

Class 7 Status __ Class 7 __Not Class 7

Comments (system type, level of impairment observed):

NOTE and describe beaver activity

Field data

DO (mg/l): DO Sat %: Photos (y/n)
pH: Fish (y/n)
Temp (°C) spCond: Bugs (y/n)
Other data/comments: Nutrient samples (y/n)

Appendix D: Blackwater habitat protocol metric explanations.

Metric Explanations	Metric value calculation	Scoring criteria				
1) Channel Development Percentages of 100m reach comprised of bed/bank flow paths, multiple flow paths (i.e. braided-channel systems) and undefined flow paths (large standing-water areas).	Metrics 1 and 2: multiply precentages for each subcategory by the subcategory weights to get weighted percentages, sum these values to get the total weighted percentage, and compare the total weighted percentage to the scoring criteria values listed to get the metric score	Total Weighted %	200	145-199	100-144	0-99
		Metric score	0	1	2	3
2) Flow Score Percentages of 100m reach comprised of each flow regime indicated on the field data sheet. Slow flow is clear evidence of slow, downstream flow visible from 3 meters away from wetted surface.		Total Weighted %	155 and greater	100-154	20-99	0-19
		Metric score	0	1	2	3
3) Flood plain elevation Average elevation of riparian floodplain above the wetted channel. Evaluate for a distance of 50m from either side of wetted area. Elevation may be highly variable. If so, estimate mean elevation and make a note regarding variability.	Compare the estimated value to the scoring criteria values	Elevation (cm)	40 and greater	25-39	10-24	0-9
		Metric score	0	1	2	3
4) Submerged and emergent vegetation Commonness of submerged and/or emergent vegetation within the wetted area.	Score based on criteria indicated	Category	Absent	Rare	Common	Abundant
		Metric score	0	1	2	3
5) Benthic organic matter Percentage of the benthic area covered by large woody debris, coarse particulate organic matter, or fine particulate organic matter.	Forest type	Percentage:	0-49	50-84	85-95	96 and greater
		Metric score	0	1	2	3
6) Forest type Commonness of blackwater-indicator trees: *Nyssa aquatica, N. biflora* (tupelo) and *Taxodium distichum* (bald cypress). Scores: Absent (0)- neither species present, Rare (1) other tree species are dominant, but either bald cypress or water tupelo are present, Common (2)- either bald cypress or water tupelo are present, and codominant with other tree species OR both species occur and are relatively common, but not the dominant species, Abundant (3)- water tupelo and/or bald cypress are the dominant tree species. **In addition to scoring, please list the dominant tree/vegetation species.**	Score based on criteria indicated	Category	Absent	Rare	Common	Abundant
		Metric score	0	1	2	3
7) Wetland width Within 100 meters, laterally, from the center of the wetted area (200m total including the wetted area), the percentage by area that is likely wetland (if variable, average over the 100m reach).	Score based on criteria indicated	Percentage:	0-24	25-44	45-74	75 and greater
		Metric score	0	1	2	3
8) Canopy Percentage of the overhead view of the sky above the wetted area that, at full leaf-out, would be obstructed (requires estimation in late-fall to early spring).	Score based on criteria indicated	Percentage:	0-19	20-49	50-69	70 and greater
		Metric score	0	1	2	3

Appendix E: Virginia Coastal Plain Macroinvertebrate Index metric values and final scores (see explanation of metrics below).

Agency Site Code	Water Body Name	Date	Total Taxa	HBI	EPT Taxa	Percent E	Percent PT Less Hydropsychidae	Percent Top 5 Dominant	Percent Clingers	**VCPMI**
5AIVY001.37	Ivy Branch	4/13/2018	6	6.27	0	0.00	0.00	100.00	0.00	**6.44**
5AMS000.40	Mill Swamp	5/13/2005	12	6.19	2	5.45	0.00	77.27	0.00	**29.75**
5AWRN000.46	Warren Swamp	4/11/2018	12	7.15	2	0.91	0.91	93.64	0.00	**15.73**
5AXBRa001.40	UNT Blackwater River 1	3/1/2016	13	6.13	1	6.36	0.00	100.00	0.00	**19.25**
5AXJO000.10	UNT Joseph Swamp	3/1/2016	8	5.53	1	28.18	0.00	100.00	0.91	**29.29**
5AXSRE000.13	UNT Seacorrie Swamp	4/12/2018	14	5.31	3	22.73	0.91	89.09	3.64	**47.07**
5ADBS002.75	Dobie Swamp	4/20/2018	5	6.05	0	0.00	0.00	100.00	0.00	**7.70**
5AJOE007.60	Joseph Swamp	4/26/2018	7	7.68	0	0.00	0.00	100.00	0.00	**0.86**
5AOTR000.88	Otterdam Swamp	12/21/2003	11	6.52	0	0.00	0.00	92.73	0.91	**13.80**
5AOTR000.88	Otterdam Swamp	4/20/2018	7	6.58	0	0.00	0.00	95.45	0.00	**7.67**
5ASRE004.17	Seacorrie Swamp	4/12/2018	2	6.00	0	0.00	0.00	100.00	0.00	**8.00**
5AXBRa001.08	UNT Blackwater River 2	4/20/2018	8	6.86	2	0.91	1.82	96.36	1.82	**15.21**
5AXBRb000.20	UNT Blackwater River 3	5/3/2018	5	5.95	0	0.00	0.00	100.00	0.00	**8.26**
5AXNOT001.00	UNT Nottoway River 1	3/28/2018	9	6.21	1	9.72	0.00	95.83	12.50	**28.31**
5AXNOTb000.45	UNT Nottoway River 2	3/28/2018	7	7.31	0	0.00	0.00	98.18	0.00	**2.23**
5AXPPL000.11	UNT Poplar Swamp	4/13/2018	6	6.33	1	6.36	0.00	98.18	0.00	**12.34**
5ABBS001.35	Black Branch	4/26/2018	10	6.09	0	0.00	0.00	91.46	0.00	**15.19**
5ACOU001.40	Council Swamp	5/3/2018	10	6.30	1	0.91	0.00	91.82	0.00	**16.14**
5ATRR008.25	Tarrara Creek	5/1/2018	13	6.40	1	3.64	0.00	90.91	0.00	**20.37**
5AXDMR001.60	UNT Darden Swamp	5/1/2018	12	6.33	1	3.64	0.00	87.27	0.91	**22.22**
5AGRV000.08	Gravelly Run	4/11/2013	11	5.22	4	36.36	3.64	92.73	3.64	**51.05**
5AGRV000.08	Gravelly Run	12/5/2013	18	4.63	8	24.55	21.82	75.45	26.36	**93.74**
5AHZL000.77	Hazel Swamp	4/19/2011	11	5.98	0	0.00	0.00	94.55	2.73	**17.42**
5AHZL000.77	Hazel Swamp	11/21/2011	17	5.05	4	27.27	10.91	72.73	18.18	**86.16**
5AHZL000.77	Hazel Swamp	4/22/2014	13	5.55	3	0.00	7.27	90.91	15.45	**51.26**
5AHZL000.77	Hazel Swamp	11/19/2014	13	4.85	4	41.82	4.55	92.73	40.91	**67.91**
5AMRN000.38	Mill Run	6/3/2009	17	5.63	4	14.55	0.91	86.36	14.55	**54.92**
5ACABR000.64	Caney Branch	4/11/2018	10	6.03	1	0.91	0.00	97.27	0.00	**15.14**

Explanation of metrics: Total Taxa: the total number of taxa observed in the sample; HBI: the average pollution-tolerance rating across all individual specimens collected; EPT taxa: the number of Ephemeroptera, Trichoptera and Plecoptera taxa observed in the sample; Percent E: percent of individuals in the sample that are in the order Ephemeroptera; Percent PT less Hydropsychidae: percent of individuals in the sample that are in the order Plecoptera and Trichoptera, excluding the Family Hydropsychidae; Percent top 5 dominant: percent of the sample comprised of the 5 most dominant taxa; Percent clingers: percent of individuals in the sample that cling to solid substrate.

Appendix F: Blackwater habitat protocol (BHP) scores

Site Code	Latitude	Longitude	Stream Name	Date	Investigator	BHP Score	Initial Class	Initial Condition Rating	2019 Field Work	In 2019 Report
5AGRV000.08	37.0945	-77.4749	Gravelly Run	4/26/18	Smigo, W.	5	Stream	Reference	YES	YES
				4/26/18	Shaver, M.	3	Stream	Reference	YES	YES
				4/26/18	Garey, A.	3	Stream	Reference	YES	YES
				4/4/19	Shaver, M.	4	Stream	Reference	YES	YES
				4/4/19	Garey, A.	5	Stream	Reference	YES	YES
				4/4/19	Smigo, W.	5	Stream	Reference	YES	YES
5AHZL000.77	37.0755	-76.9041	Hazel Swamp	4/26/18	Garey, A.	6	Stream	Reference	YES	YES
				4/26/18	Smigo, W.	5	Stream	Reference	YES	YES
				4/26/18	Shaver, M.	5	Stream	Reference	YES	YES
5AHZL000.77	37.0755	-76.9041	Hazel Swamp	4/3/19	Garey, A.	7	Stream	Reference	YES	YES
				4/3/19	Shaver, M.	4	Stream	Reference	YES	YES
				4/3/19	Smigo, W.	5	Stream	Reference	YES	YES
5AMRN000.38	36.7702	-77.0947	Mill Run	4/26/18	Shaver, M.	7	Stream	Reference	YES	YES
				4/26/18	Smigo, W.	6	Stream	Reference	YES	YES
				4/26/18	Garey, A.	7	Stream	Reference	YES	YES
5AMRN000.38	36.7702	-77.0947	Mill Run	4/12/19	Garey, A.	9	Stream	Reference	YES	YES
				4/12/19	Smigo, W.	7	Stream	Reference	YES	YES
5AXHAT000.40	37.1488	-77.6109	UNT Hatcher Run	4/4/19	Smigo, W.	4	Stream	Reference	YES	YES
				4/4/19	Garey, A.	3	Stream	Reference	YES	YES
				4/4/19	Shaver, M.	3	Stream	Reference	YES	YES
5AXNOTc000.40	36.9130	-77.2191	UNT Nottoway River 3	4/11/19	Carter, M.	4	Stream	Reference	YES	YES
				4/11/19	Garey, A.	6	Stream	Reference	YES	YES
				4/11/19	Shaver, M.	6	Stream	Reference	YES	YES
5AXSCKa001.82	36.9487	-76.9229	UNT Seacock Swamp	4/25/19	Hopler, D.	7	Stream	Reference	YES	YES
5AIVY001.37	37.0196	-77.1639	Ivy Branch	4/13/18	Hopler, D.	12	Swamp	Reference	YES	YES
				3/27/19	Hopler, D.	13	Swamp	Reference	YES	YES
5AJNH010.18	37.1009	-77.3999	Jones Hole Swamp	4/25/19	Hopler, D.	19	Swamp	Reference	YES	YES
5AMS000.40	37.0791	-76.8070	Mill Swamp	4/17/19	Hopler, D.	21	Swamp	Reference	YES	YES
5APRK000.40	36.8597	-77.1715	Parker Run	4/11/19	Shaver, M.	11	Swamp	Reference	YES	YES
				4/11/19	Garey, A.	14	Swamp	Reference	YES	YES

Site Code	Latitude	Longitude	Stream Name	Date	Investigator	BHP Score	Initial Class	Initial Condition Rating	2019 Field Work	In 2019 Report
5AWRN000.46	37.0387	-77.4140	Warren Swamp	4/11/18	Hopler, D.	15	Swamp	Reference	YES	YES
				4/25/19	Hopler, D.	14	Swamp	Reference	YES	YES
5AXBRa001.40	37.0795	-77.1149	UNT Blackwater River 1	4/17/19	Hopler, D.	19	Swamp	Reference	YES	YES
				3/1/16	Garey, A.	13	Swamp	Reference	YES	YES
5AXJH000.31	37.1035	-76.9687	UNT Johnchecohunk Swamp	4/17/19	Hopler, D.	14	Swamp	Reference	YES	YES
5AXJO000.10	37.0834	-77.2800	UNT Joseph Swamp	3/1/16	Hopler, D.	19	Swamp	Reference	YES	YES
				4/17/19	Hopler, D.	21	Swamp	Reference	YES	YES
5AXSRE000.13	36.9507	-77.0798	UNT Seacorrie Swamp	4/12/18	Hopler, D.	14	Swamp	Reference	YES	YES
				3/27/19	Hopler, D.	15	Swamp	Reference	YES	YES
5AOTR000.88	37.1292	-77.1239	Otterdam Swamp	4/13/13	Hopler, D.	19	Swamp	Reference	NO	YES
				4/20/18	Hopler, D.	23	Swamp	Reference	NO	YES
5AJOE007.60	37.0716	-77.2474	Joseph Swamp	4/26/18	Hopler, D.	23	Swamp	Reference	NO	YES
5ADBS002.75	37.0487	-77.2586	Dobie Swamp	4/20/18	Hopler, D.	13	Swamp	Reference	NO	YES
5ASRE004.17	36.9426	-77.0570	Seacorrie Swamp	4/12/18	Hopler, D.	9	Swamp	Reference	NO	YES
5AXBRb000.20	36.6504	-76.8603	UNT Blackwater River 3	5/3/18	Hopler, D.	16	Swamp	Reference	NO	YES
5AXNOTb000.45	36.5854	-76.9630	UNT Nottoway River 2	3/28/18	Hopler, D.	18	Swamp	Reference	NO	YES
5AXNOT001.00	36.6459	-77.0284	UNT Nottoway River 1	3/28/18	Hopler, D.	18	Swamp	Reference	NO	YES
5AXPPL000.11	36.7752	-77.3556	UNT Poplar Swamp	4/13/18	Hopler, D.	18	Swamp	Reference	NO	YES
5AXBRa001.08	37.0793	-77.1195	UNT Blackwater River 2	4/20/2018	Hopler, D.	16	Swamp	Reference	NO	YES
5ACOU001.40	36.6301	-76.6563	Council Swamp	5/3/18	Hopler, D.	12	Swamp	Altered	NO	NO
5ATRR008.25	36.6169	-77.2207	Tarrara Creek	5/1/18	Hopler, D.	16	Swamp	Altered	NO	NO
5AXDMR001.60	36.5911	-77.0463	UNT Darden Swamp	5/1/18	Hopler, D.	24	Swamp	Altered	NO	NO
5ABBS001.35	36.9791	-77.4964	Black Branch	4/26/18	Hopler, D.	20	Swamp	Altered	NO	NO
5ACABR000.64	36.6779	-77.4923	Caney Branch	4/11/18	Hopler, D.	4	Stream	Altered	NO	NO

Appendix G. AAC Macroinvertebrate Samples – FY 2018–2019

		Sampling Site		5AXSRE000.13	5ACOU001.40	5ABBS001.35
		Sampling Date		4/12/2018	5/3/2018	4/26/2018
Order	Family	Genus	Final ID	UNT Seacorrie Swamp	Council Swamp	Black Branch
Amphipoda	Gammaridae	Gammarus	Gammarus	22	132	13
Bivalvia	Sphaeriidae	Pisidium	Pisidium	3	12	0
Bivalvia	Sphaeriidae	Sphaerium	Sphaerium	0	1	0
Coleoptera	Dytiscidae	Hydroporus	Hydroporus	1	0	9
Coleoptera	Elmidae	Dubiraphia	Dubiraphia	2	0	0
Coleoptera	Elmidae	Macronychus	Macronychus glabratus	0	0	0
Coleoptera	Gyrinidae	Dineutes	Dineutus	0	0	0
Coleoptera	Gyrinidae	Gyrinus	Gyrinus	0	0	0
Coleoptera	Haliplidae	Peltodytes	Peltodytes	0	1	0
Coleoptera	Scirtidae	Scirtes	Scirtes	0	0	0
Collembola	Isotomidae		EXCLUDED	0	0	0
Decapoda	Cambaridae	Immature	Cambaridae	0	5	0
Decapoda	Palaemonidae	Palaemonetes	Palaemonetes	0	0	0
Diptera	Ceratopogonidae	Atrichopogon	Atrichopogon	0	2	2
Diptera	Ceratopogonidae	Palpomyia	Palpomyia	1	1	1
Diptera	Chaoboridae	Chaoborus	Chaoborus	0	0	0
Diptera	Chironomidae		Chironomidae (A)	54	18	37
Diptera	Ptychopteridae	Ptychoptera	Ptychoptera	0	0	0
Diptera	Simuliidae	Simulium	Simulium	3	0	0
Diptera	Tabanidae	Chrysops	Chrysops	0	0	1
Diptera	Tipulidae-Limonea subfamily	Immature/ Not identifiable	Tipulidae	2	0	0
Diptera	Tipulidae-Tipulinea subfamily	Tipula	Tipula	0	0	0
Ephemeroptera	Baetidae	Immature/ no gills	Baetidae	0	1	0
Ephemeroptera	Caenidae	Caenis	Caenis	0	0	0
Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella	2	0	0
Ephemeroptera	Leptophlebiidae	Leptophlebia	Leptophlebia	26	0	0
Gastropoda	Physidae	Physa	Physidae	0	1	0
Hemiptera	Corixidae	Trichocorixa	Trichocorixa	0	0	0
Hemiptera	Naucoridae	Pelocoris	Pelocoris	0	0	0
Hemiptera	Notonectidae	Notonecta	Notonecta	0	0	0
Hydracarina			Hydracarina	0	0	0
Isopoda	Asellidae	Caecidotea	Asellidae	2	19	2
Odonata	Calopterygidae	Calopteryx	Calopteryx	0	0	0
Odonata	Coenagrionidae	Enallagma	Enallagma	6	0	0
Odonata	Corduliidae/ Libellulidae immature		Libellulidae/ Cordullidae	0	2	1
Odonata	Lestidae	Lestes	Lestes	0	0	1
Odonata	Libellulidae	Libellula	Libellula	0	0	0
Odonata	Libellulidae	Pachydiplax	Pachydiplax longipennis	1	0	0
Odonata	Zygoptera immature		Zygoptera	0	0	2
Oligochaeta			Oligochaeta	0	7	13
Plecoptera	Perlidae	Perlesta	Perlesta	0	0	0
Trichoptera	Dipseudopsidae	Phylocentropus	Phylocentropus	1	0	0
Trichoptera	Limnephilidae	Ironoquia	Ironoquia	0	0	0
Trichoptera	Limnephilidae	Pycnopsyche	Pycnopsyche	0	0	0

		Sampling Site		5ADBS002.75	5AIVY001.37	5AJOE007.60
		Sampling Date		4/20/2018	4/13/2018	4/26/2018
Order	Family	Genus	Final ID	Dobie Swamp	Ivy Branch	Joseph Swamp
Amphipoda	Gammaridae	Gammarus	Gammarus	0	11	0
Bivalvia	Sphaeriidae	Pisidium	Pisidium	0	1	0
Bivalvia	Sphaeriidae	Sphaerium	Sphaerium	0	0	1
Coleoptera	Dytiscidae	Hydroporus	Hydroporus	0	1	1
Coleoptera	Elmidae	Dubiraphia	Dubiraphia	0	0	0
Coleoptera	Elmidae	Macronychus	Macronychus glabratus	0	0	0
Coleoptera	Gyrinidae	Dineutes	Dineutus	0	0	0
Coleoptera	Gyrinidae	Gyrinus	Gyrinus	0	0	0
Coleoptera	Haliplidae	Peltodytes	Peltodytes	0	1	0
Coleoptera	Scirtidae	Scirtes	Scirtes	0	0	0
Collembola	Isotomidae		EXCLUDED	0	0	0
Decapoda	Cambaridae	Immature	Cambaridae	1	0	0
Decapoda	Palaemonidae	Palaemonetes	Palaemonetes	0	0	0
Diptera	Ceratopogonidae	Atrichopogon	Atrichopogon	0	0	0
Diptera	Ceratopogonidae	Palpomyia	Palpomyia	28	0	10
Diptera	Chaoboridae	Chaoborus	Chaoborus	0	0	0
Diptera	Chironomidae		Chironomidae (A)	61	16	14
Diptera	Ptychopteridae	Ptychoptera	Ptychoptera	0	0	0
Diptera	Simuliidae	Simulium	Simulium	0	0	0
Diptera	Tabanidae	Chrysops	Chrysops	3	0	0
Diptera	Tipulidae-Limonea subfamily	Immature/ Not identifiable	Tipulidae	0	0	0
Diptera	Tipulidae-Tipulinea subfamily	Tipula	Tipula	0	0	0
Ephemeroptera	Baetidae	Immature/ no gills	Baetidae	0	0	0
Ephemeroptera	Caenidae	Caenis	Caenis	0	0	0
Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella	0	0	0
Ephemeroptera	Leptophlebiidae	Leptophlebia	Leptophlebia	0	0	0
Gastropoda	Physidae	Physa	Physidae	0	0	0
Hemiptera	Corixidae	Trichocorixa	Trichocorixa	0	0	0
Hemiptera	Naucoridae	Pelocoris	Pelocoris	0	0	0
Hemiptera	Notonectidae	Notonecta	Notonecta	0	0	0
Hydracarina			Hydracarina	0	0	2
Isopoda	Asellidae	Caecidotea	Asellidae	0	3	173
Odonata	Calopterygidae	Calopteryx	Calopteryx	0	0	0
Odonata	Coenagrionidae	Enallagma	Enallagma	0	0	0
Odonata	Corduliidae/ Libellulidae immature		Libellulidae/ Cordullidae	0	0	0
Odonata	Lestidae	Lestes	Lestes	0	0	1
Odonata	Libellulidae	Libellula	Libellula	0	0	0
Odonata	Libellulidae	Pachydiplax	Pachydiplax longipennis	2	0	0
Odonata	Zygoptera immature		Zygoptera	0	0	0
Oligochaeta			Oligochaeta	0	0	1
Plecoptera	Perlidae	Perlesta	Perlesta	0	0	0
Trichoptera	Dipseudopsidae	Phylocentropus	Phylocentropus	0	0	0
Trichoptera	Limnephilidae	Ironoquia	Ironoquia	0	0	0
Trichoptera	Limnephilidae	Pycnopsyche	Pycnopsyche	0	0	0

		Sampling Site		5AOTR000.88	5ASRE004.17	5ATRR008.25
		Sampling Date		4/20/2018	4/12/2018	5/1/2018
Order	Family	Genus	Final ID	Otterdam Swamp	Seacorrie Swamp	Tarrara Creek
Amphipoda	Gammaridae	Gammarus	Gammarus	60	0	2
Bivalvia	Sphaeriidae	Pisidium	Pisidium	0	0	6
Bivalvia	Sphaeriidae	Sphaerium	Sphaerium	0	0	0
Coleoptera	Dytiscidae	Hydroporus	Hydroporus	5	0	3
Coleoptera	Elmidae	Dubiraphia	Dubiraphia	0	0	0
Coleoptera	Elmidae	Macronychus	Macronychus glabratus	0	0	0
Coleoptera	Gyrinidae	Dineutes	Dineutus	0	0	2
Coleoptera	Gyrinidae	Gyrinus	Gyrinus	0	0	0
Coleoptera	Haliplidae	Peltodytes	Peltodytes	0	0	0
Coleoptera	Scirtidae	Scirtes	Scirtes	0	0	0
Collembola	Isotomidae		EXCLUDED	0	0	0
Decapoda	Cambaridae	Immature	Cambaridae	0	0	0
Decapoda	Palaemonidae	Palaemonetes	Palaemonetes	0	0	0
Diptera	Ceratopogonidae	Atrichopogon	Atrichopogon	0	0	3
Diptera	Ceratopogonidae	Palpomyia	Palpomyia	7	0	3
Diptera	Chaoboridae	Chaoborus	Chaoborus	0	0	1
Diptera	Chironomidae		Chironomidae (A)	56	1	117
Diptera	Ptychopteridae	Ptychoptera	Ptychoptera	0	0	0
Diptera	Simuliidae	Simulium	Simulium	0	0	0
Diptera	Tabanidae	Chrysops	Chrysops	0	0	0
Diptera	Tipulidae-Limonea subfamily	Immature/ Not identifiable	Tipulidae	0	0	0
Diptera	Tipulidae-Tipulinea subfamily	Tipula	Tipula	0	0	0
Ephemeroptera	Baetidae	Immature/ no gills	Baetidae	0	0	0
Ephemeroptera	Caenidae	Caenis	Caenis	2	0	8
Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella	0	0	0
Ephemeroptera	Leptophlebiidae	Leptophlebia	Leptophlebia	0	0	0
Gastropoda	Physidae	Physa	Physidae	0	0	2
Hemiptera	Corixidae	Trichocorixa	Trichocorixa	0	0	0
Hemiptera	Naucoridae	Pelocoris	Pelocoris	0	0	0
Hemiptera	Notonectidae	Notonecta	Notonecta	1	0	0
Hydracarina			Hydracarina	0	0	1
Isopoda	Asellidae	Caecidotea	Asellidae	55	0	42
Odonata	Calopterygidae	Calopteryx	Calopteryx	0	0	0
Odonata	Coenagrionidae	Enallagma	Enallagma	0	0	0
Odonata	Corduliidae/ Libellulidae immature		Libellulidae/ Cordullidae	8	1	3
Odonata	Lestidae	Lestes	Lestes	0	0	0
Odonata	Libellulidae	Libellula	Libellula	0	0	0
Odonata	Libellulidae	Pachydiplax	Pachydiplax longipennis	0	0	0
Odonata	Zygoptera immature		Zygoptera	0	0	0
Oligochaeta			Oligochaeta	7	0	7
Plecoptera	Perlidae	Perlesta	Perlesta	0	0	0
Trichoptera	Dipseudopsidae	Phylocentropus	Phylocentropus	0	0	0
Trichoptera	Limnephilidae	Ironoquia	Ironoquia	0	0	0
Trichoptera	Limnephilidae	Pycnopsyche	Pycnopsyche	0	0	0

		Sampling Site		5ACABR000.64	5AXDMR001.60	5AXNOT001.00
		Sampling Date		4/11/2018	5/1/2018	3/28/2018
Order	Family	Genus	Final ID	Caney Branch	UNT Darden Swamp	UNT Nottoway River 1
Amphipoda	Gammaridae	Gammarus	Gammarus	101	24	9
Bivalvia	Sphaeriidae	Pisidium	Pisidium	0	0	0
Bivalvia	Sphaeriidae	Sphaerium	Sphaerium	1	0	0
Coleoptera	Dytiscidae	Hydroporus	Hydroporus	0	0	0
Coleoptera	Elmidae	Dubiraphia	Dubiraphia	0	0	0
Coleoptera	Elmidae	Macronychus	Macronychus glabratus	1	0	0
Coleoptera	Gyrinidae	Dineutes	Dineutus	0	0	0
Coleoptera	Gyrinidae	Gyrinus	Gyrinus	0	0	0
Coleoptera	Haliplidae	Peltodytes	Peltodytes	0	0	0
Coleoptera	Scirtidae	Scirtes	Scirtes	0	3	0
Collembola	Isotomidae		EXCLUDED	15	0	0
Decapoda	Cambaridae	Immature	Cambaridae	1	0	0
Decapoda	Palaemonidae	Palaemonetes	Palaemonetes	0	4	0
Diptera	Ceratopogonidae	Atrichopogon	Atrichopogon	0	2	0
Diptera	Ceratopogonidae	Palpomyia	Palpomyia	9	3	1
Diptera	Chaoboridae	Chaoborus	Chaoborus	0	0	0
Diptera	Chironomidae		Chironomidae (A)	41	91	38
Diptera	Ptychopteridae	Ptychoptera	Ptychoptera	0	0	0
Diptera	Simuliidae	Simulium	Simulium	0	0	0
Diptera	Tabanidae	Chrysops	Chrysops	0	0	0
Diptera	Tipulidae-Limonea subfamily	Immature/ Not identifiable	Tipulidae	1	0	0
Diptera	Tipulidae-Tipulinea subfamily	Tipula	Tipula	1	0	0
Ephemeroptera	Baetidae	Immature/ no gills	Baetidae	0	0	0
Ephemeroptera	Caenidae	Caenis	Caenis	1	5	0
Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella	0	0	7
Ephemeroptera	Leptophlebiidae	Leptophlebia	Leptophlebia	1	0	0
Gastropoda	Physidae	Physa	Physidae	0	0	0
Hemiptera	Corixidae	Trichocorixa	Trichocorixa	0	0	0
Hemiptera	Naucoridae	Pelocoris	Pelocoris	0	2	2
Hemiptera	Notonectidae	Notonecta	Notonecta	0	0	0
Hydracarina			Hydracarina	0	2	0
Isopoda	Asellidae	Caecidotea	Asellidae	7	39	11
Odonata	Calopterygidae	Calopteryx	Calopteryx	0	0	0
Odonata	Coenagrionidae	Enallagma	Enallagma	0	6	1
Odonata	Corduliidae/ Libellulidae immature		Libellulidae/ Cordullidae	3	2	1
Odonata	Lestidae	Lestes	Lestes	0	0	0
Odonata	Libellulidae	Libellula	Libellula	1	0	1
Odonata	Libellulidae	Pachydiplax	Pachydiplax longipennis	0	0	1
Odonata	Zygoptera immature		Zygoptera	0	0	0
Oligochaeta			Oligochaeta	4	18	0
Plecoptera	Perlidae	Perlesta	Perlesta	0	0	0
Trichoptera	Dipseudopsidae	Phylocentropus	Phylocentropus	0	0	0
Trichoptera	Limnephilidae	Ironoquia	Ironoquia	0	0	0
Trichoptera	Limnephilidae	Pycnopsyche	Pycnopsyche	1	0	0

		Sampling Site		5AXNOTb000.45	5AXBRa001.08	5AXBRb000.20
		Sampling Date		3/28/2018	4/20/2018	5/3/2018
Order	Family	Genus	Final ID	UNT Nottoway River 2	UNT Blackwater River 2	UNT Blackwater River 3
Amphipoda	Gammaridae	Gammarus	Gammarus	7	30	8
Bivalvia	Sphaeriidae	Pisidium	Pisidium	0	0	0
Bivalvia	Sphaeriidae	Sphaerium	Sphaerium	0	0	0
Coleoptera	Dytiscidae	Hydroporus	Hydroporus	1	1	0
Coleoptera	Elmidae	Dubiraphia	Dubiraphia	0	0	0
Coleoptera	Elmidae	Macronychus	Macronychus glabratus	0	0	0
Coleoptera	Gyrinidae	Dineutes	Dineutus	0	0	0
Coleoptera	Gyrinidae	Gyrinus	Gyrinus	0	0	0
Coleoptera	Haliplidae	Peltodytes	Peltodytes	0	0	0
Coleoptera	Scirtidae	Scirtes	Scirtes	0	0	0
Collembola	Isotomidae		EXCLUDED	0	0	0
Decapoda	Cambaridae	Immature	Cambaridae	0	0	0
Decapoda	Palaemonidae	Palaemonetes	Palaemonetes	0	0	0
Diptera	Ceratopogonidae	Atrichopogon	Atrichopogon	0	0	0
Diptera	Ceratopogonidae	Palpomyia	Palpomyia	0	11	2
Diptera	Chaoboridae	Chaoborus	Chaoborus	0	0	0
Diptera	Chironomidae		Chironomidae (A)	62	43	125
Diptera	Ptychopteridae	Ptychoptera	Ptychoptera	0	1	0
Diptera	Simuliidae	Simulium	Simulium	0	0	0
Diptera	Tabanidae	Chrysops	Chrysops	0	0	0
Diptera	Tipulidae-Limonea subfamily	Immature/ Not identifiable	Tipulidae	0	0	0
Diptera	Tipulidae-Tipulinea subfamily	Tipula	Tipula	0	0	0
Ephemeroptera	Baetidae	Immature/ no gills	Baetidae	0	2	0
Ephemeroptera	Caenidae	Caenis	Caenis	0	1	0
Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella	0	0	0
Ephemeroptera	Leptophlebiidae	Leptophlebia	Leptophlebia	0	0	0
Gastropoda	Physidae	Physa	Physidae	0	0	4
Hemiptera	Corixidae	Trichocorixa	Trichocorixa	0	0	9
Hemiptera	Naucoridae	Pelocoris	Pelocoris	0	0	0
Hemiptera	Notonectidae	Notonecta	Notonecta	1	0	0
Hydracarina			Hydracarina	0	0	0
Isopoda	Asellidae	Caecidotea	Asellidae	122	104	0
Odonata	Calopterygidae	Calopteryx	Calopteryx	0	1	0
Odonata	Coenagrionidae	Enallagma	Enallagma	3	0	0
Odonata	Corduliidae/ Libellulidae immature		Libellulidae/ Cordullidae	0	0	0
Odonata	Lestidae	Lestes	Lestes	0	0	0
Odonata	Libellulidae	Libellula	Libellula	0	0	0
Odonata	Libellulidae	Pachydiplax	Pachydiplax longipennis	1	0	0
Odonata	Zygoptera immature		Zygoptera	0	0	0
Oligochaeta			Oligochaeta	4	9	52
Plecoptera	Perlidae	Perlesta	Perlesta	0	2	0
Trichoptera	Dipseudopsidae	Phylocentropus	Phylocentropus	0	0	0
Trichoptera	Limnephilidae	Ironoquia	Ironoquia	0	0	0
Trichoptera	Limnephilidae	Pycnopsyche	Pycnopsyche	0	0	0

		Sampling Site		5AXPPL000.11	5AWRN000.46
		Sampling Date		4/13/2018	4/11/2018
Order	Family	Genus	Final ID	UNT Poplar Swamp	Warren Swamp
Amphipoda	Gammaridae	Gammarus	Gammarus	9	25
Bivalvia	Sphaeriidae	Pisidium	Pisidium	0	2
Bivalvia	Sphaeriidae	Sphaerium	Sphaerium	0	1
Coleoptera	Dytiscidae	Hydroporus	Hydroporus	0	11
Coleoptera	Elmidae	Dubiraphia	Dubiraphia	0	0
Coleoptera	Elmidae	Macronychus	Macronychus glabratus	0	0
Coleoptera	Gyrinidae	Dineutes	Dineutus	0	0
Coleoptera	Gyrinidae	Gyrinus	Gyrinus	0	1
Coleoptera	Haliplidae	Peltodytes	Peltodytes	0	0
Coleoptera	Scirtidae	Scirtes	Scirtes	0	0
Collembola	Isotomidae		EXCLUDED	0	0
Decapoda	Cambaridae	Immature	Cambaridae	0	1
Decapoda	Palaemonidae	Palaemonetes	Palaemonetes	0	0
Diptera	Ceratopogonidae	Atrichopogon	Atrichopogon	1	0
Diptera	Ceratopogonidae	Palpomyia	Palpomyia	23	1
Diptera	Chaoboridae	Chaoborus	Chaoborus	0	0
Diptera	Chironomidae		Chironomidae (A)	106	21
Diptera	Ptychopteridae	Ptychoptera	Ptychoptera	0	0
Diptera	Simuliidae	Simulium	Simulium	0	0
Diptera	Tabanidae	Chrysops	Chrysops	0	1
Diptera	Tipulidae-Limonea subfamily	Immature/ Not identifiable	Tipulidae	0	0
Diptera	Tipulidae-Tipulinea subfamily	Tipula	Tipula	0	0
Ephemeroptera	Baetidae	Immature/ no gills	Baetidae	2	1
Ephemeroptera	Caenidae	Caenis	Caenis	14	1
Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella	0	0
Ephemeroptera	Leptophlebiidae	Leptophlebia	Leptophlebia	0	0
Gastropoda	Physidae	Physa	Physidae	0	0
Hemiptera	Corixidae	Trichocorixa	Trichocorixa	0	0
Hemiptera	Naucoridae	Pelocoris	Pelocoris	0	0
Hemiptera	Notonectidae	Notonecta	Notonecta	0	0
Hydracarina			Hydracarina	0	1
Isopoda	Asellidae	Caecidotea	Asellidae	47	123
Odonata	Calopterygidae	Calopteryx	Calopteryx	0	0
Odonata	Coenagrionidae	Enallagma	Enallagma	2	1
Odonata	Corduliidae/ Libellulidae immature		Libellulidae/ Cordullidae	0	0
Odonata	Lestidae	Lestes	Lestes	0	0
Odonata	Libellulidae	Libellula	Libellula	1	1
Odonata	Libellulidae	Pachydiplax	Pachydiplax longipennis	1	0
Odonata	Zygoptera immature		Zygoptera	0	0
Oligochaeta			Oligochaeta	1	9
Plecoptera	Perlidae	Perlesta	Perlesta	0	0
Trichoptera	Dipseudopsidae	Phylocentropus	Phylocentropus	0	0
Trichoptera	Limnephilidae	Ironoquia	Ironoquia	0	1
Trichoptera	Limnephilidae	Pycnopsyche	Pycnopsyche	0	0

Appendix H: Fish assemblage data.

Agency Site Code	Sampling Date	*Amia calva*	*Ameiurus natalis*	*Ameiurus nebulosus*	*Acantharchus pomotis*	*Anguilla rostrata*	*Aphredoderus sayanus*	*Chologaster cornuta*
5ABBS001.35	4/26/2018	0	0	0	1	0	0	0
5ACABR000.64	4/11/2018	0	0	0	0	0	0	0
5ACOU001.40	5/3/2018	0	2	0	0	0	14	0
5ADBS002.75	4/20/2018	0	1	0	3	0	3	0
5AIVY001.37	4/13/2018	0	0	0	2	0	2	0
5AIVY001.37	3/27/2019	0	1	0	4	0	7	0
5AJNH010.18	8/22/2007	0	0	0	3	0	3	0
5AJNH010.18	4/25/2019	0	0	0	0	0	0	0
5AJNH010.19	4/25/2019	0	0	0	0	0	0	0
5AJNH010.20	4/25/2019	0	0	0	0	0	0	0
5AJNH010.21	4/25/2019	0	0	0	0	0	0	0
5AJNH010.22	4/25/2019	0	0	0	0	0	7	0
5AJNH010.23	4/25/2019	0	0	0	2	0	0	0
5AJNH010.24	5/1/2019	0	0	0	0	0	0	0
5AJNH010.25	5/1/2019	0	0	0	0	0	0	0
5AJNH010.26	5/1/2019	0	1	0	0	0	0	0
5AJOE007.60	4/26/2018	0	0	0	0	0	2	1
5AMS000.40	5/13/2005	0	3	0	7	0	22	0
5AMS000.40	4/17/2019	0	0	0	1	1	10	0
5AOTR000.88	4/20/2018	0	0	2	0	0	1	3
5ASRE004.17	4/12/2018	0	0	0	4	0	1	0
5ATRR008.25	5/1/2018	0	0	0	1	2	1	0
5AWRN000.46	4/11/2018	0	0	0	0	0	0	0
5AWRN000.46	4/25/2019	0	0	0	1	0	3	0
5AXBRa001.08	4/20/2018	0	0	0	2	3	11	1
5AXBRa001.40	12/8/2004	0	4	0	1	0	11	0
5AXBRa001.40	4/17/2019	0	0	0	0	0	0	0
5AXBRb000.20	5/3/2018	0	0	0	0	0	0	0
5AXDMR001.60	5/1/2018	0	0	0	0	0	4	0
5AXJH000.31	3/25/2005	0	1	0	2	1	7	2
5AXJH000.31	4/17/2019	0	0	0	13	0	15	0
5AXJO000.10	8/7/2012	0	0	0	2	0	1	0
5AXJO000.10	4/17/2019	0	0	0	1	0	0	0
5AXNOT001.00	3/28/2018	0	0	0	1	0	0	0
5AXNOTb000.4	3/28/2018	0	0	0	0	0	0	0
5AXNOTc000.04	3/15/2013	0	0	0	0	0	12	0
5AXPPL000.11	4/13/2018	0	0	0	1	0	4	0
5AXSCKa001.82	6/10/2005	0	2	0	1	0	19	0
5AXSCKa001.82	4/25/2019	0	2	2	2	0	21	0
5AXSRE000.13	4/12/2018	0	7	0	8	0	4	0
5AXSRE000.13	3/27/2019	1	1	0	9	5	9	0

Agency Site Code	Sampling Date	*Centrarchus macropterus*	*Cyprinella analostana*	*Esox americanus*	*Enneacanthus obesus*	*Enneacanthus chaetodon*	*Enneacanthus gloriosus*
5ABBS001.35	4/26/2018	2	0	0	0	0	0
5ACABR000.64	4/11/2018	0	49	0	0	0	0
5ACOU001.40	5/3/2018	0	0	2	0	0	0
5ADBS002.75	4/20/2018	0	0	6	16	0	12
5AIVY001.37	4/13/2018	0	0	0	0	0	0
5AIVY001.37	3/27/2019	2	0	0	0	0	3
5AJNH010.18	8/22/2007	0	0	4	3	0	3
5AJNH010.18	4/25/2019	0	0	0	0	0	0
5AJNH010.19	4/25/2019	0	0	0	0	0	0
5AJNH010.20	4/25/2019	0	0	0	0	0	27
5AJNH010.21	4/25/2019	0	0	0	2	0	0
5AJNH010.22	4/25/2019	0	0	0	0	0	0
5AJNH010.23	4/25/2019	0	0	0	0	0	0
5AJNH010.24	5/1/2019	4	0	0	0	0	0
5AJNH010.25	5/1/2019	0	0	0	0	0	0
5AJNH010.26	5/1/2019	0	0	0	0	0	0
5AJOE007.60	4/26/2018	0	0	0	0	0	0
5AMS000.40	5/13/2005	5	0	1	0	0	16
5AMS000.40	4/17/2019	0	0	0	0	0	1
5AOTR000.88	4/20/2018	1	0	0	0	0	0
5ASRE004.17	4/12/2018	2	0	0	0	0	2
5ATRR008.25	5/1/2018	1	0	1	0	0	5
5AWRN000.46	4/11/2018	1	0	4	0	0	1
5AWRN000.46	4/25/2019	15	0	9	0	0	4
5AXBRa001.08	4/20/2018	1	0	4	0	0	11
5AXBRa001.40	12/8/2004	6	0	2	0	0	5
5AXBRa001.40	4/17/2019	0	0	1	0	0	0
5AXBRb000.20	5/3/2018	0	0	0	0	0	0
5AXDMR001.60	5/1/2018	1	0	0	0	0	0
5AXJH000.31	3/25/2005	6	0	3	0	0	1
5AXJH000.31	4/17/2019	7	0	8	0	0	1
5AXJO000.10	8/7/2012	62	0	1	0	3	4
5AXJO000.10	4/17/2019	0	0	0	0	1	7
5AXNOT001.00	3/28/2018	1	0	0	0	0	7
5AXNOTb000.4	3/28/2018	4	0	0	2	0	2
5AXNOTc000.04	3/15/2013	0	0	1	0	0	0
5AXPPL000.11	4/13/2018	3	0	1	6	0	0
5AXSCKa001.82	6/10/2005	1	0	1	0	0	0
5AXSCKa001.82	4/25/2019	1	0	0	0	0	20
5AXSRE000.13	4/12/2018	4	0	5	5	0	6
5AXSRE000.13	3/27/2019	5	0	4	3	0	17

Agency Site Code	Sampling Date	*Esox niger*	*Erimyzon oblongus*	*Erimyzon sucetta*	*Gambusia holbrooki*	*Lepomis gibbosus*	*Lepomis gulosus*	*Lepomis macrochirus*
5ABBS001.35	4/26/2018	0	0	0	0	0	0	0
5ACABR000.64	4/11/2018	0	0	0	0	0	0	0
5ACOU001.40	5/3/2018	0	0	0	0	0	0	0
5ADBS002.75	4/20/2018	0	0	0	0	0	0	0
5AIVY001.37	4/13/2018	0	0	0	0	0	0	1
5AIVY001.37	3/27/2019	0	0	0	0	0	0	0
5AJNH010.18	8/22/2007	4	6	0	9	0	1	6
5AJNH010.18	4/25/2019	0	0	0	31	0	0	0
5AJNH010.19	4/25/2019	2	0	0	0	0	0	0
5AJNH010.20	4/25/2019	0	0	0	0	0	0	0
5AJNH010.21	4/25/2019	0	0	0	0	0	0	0
5AJNH010.22	4/25/2019	0	0	0	0	0	0	0
5AJNH010.23	4/25/2019	0	0	0	0	0	0	0
5AJNH010.24	5/1/2019	0	0	0	0	0	0	0
5AJNH010.25	5/1/2019	0	1	0	0	0	0	0
5AJNH010.26	5/1/2019	0	0	0	0	0	0	0
5AJOE007.60	4/26/2018	0	0	0	0	0	0	0
5AMS000.40	5/13/2005	0	4	0	2	2	0	0
5AMS000.40	4/17/2019	0	0	0	0	0	0	0
5AOTR000.88	4/20/2018	0	0	0	0	0	0	3
5ASRE004.17	4/12/2018	0	1	0	0	0	0	0
5ATRR008.25	5/1/2018	0	1	0	11	1	1	5
5AWRN000.46	4/11/2018	0	3	0	1	0	0	0
5AWRN000.46	4/25/2019	0	4	0	0	1	0	1
5AXBRa001.08	4/20/2018	0	0	0	18	0	0	0
5AXBRa001.40	12/8/2004	0	0	0	0	12	3	2
5AXBRa001.40	4/17/2019	0	0	0	2	0	0	0
5AXBRb000.20	5/3/2018	0	0	0	45	0	0	0
5AXDMR001.60	5/1/2018	1	6	0	0	0	0	0
5AXJH000.31	3/25/2005	0	1	0	0	0	0	0
5AXJH000.31	4/17/2019	0	6	0	0	9	0	0
5AXJO000.10	8/7/2012	0	1	0	0	0	0	0
5AXJO000.10	4/17/2019	0	0	0	0	0	0	0
5AXNOT001.00	3/28/2018	0	0	0	1	0	0	0
5AXNOTb000.4	3/28/2018	0	0	1	0	0	0	0
5AXNOTc000.04	3/15/2013	0	0	0	0	0	0	0
5AXPPL000.11	4/13/2018	0	3	0	41	0	0	1
5AXSCKa001.82	6/10/2005	0	0	0	0	0	4	0
5AXSCKa001.82	4/25/2019	1	8	0	0	2	4	0
5AXSRE000.13	4/12/2018	0	2	0	0	0	0	0
5AXSRE000.13	3/27/2019	0	6	0	0	0	0	0

Agency Site Code	Sampling Date	*Micropterus salmoides*	*Notemigonus crysoleucas*	*Noturus gyrinus*	*Umbra pygmaea*
5ABBS001.35	4/26/2018	0	0	0	0
5ACABR000.64	4/11/2018	0	0	0	1
5ACOU001.40	5/3/2018	0	0	0	2
5ADBS002.75	4/20/2018	0	0	0	41
5AIVY001.37	4/13/2018	0	0	0	11
5AIVY001.37	3/27/2019	0	0	0	1
5AJNH010.18	8/22/2007	0	1	0	1
5AJNH010.18	4/25/2019	0	0	0	0
5AJNH010.19	4/25/2019	0	0	0	0
5AJNH010.20	4/25/2019	0	0	0	0
5AJNH010.21	4/25/2019	0	0	0	0
5AJNH010.22	4/25/2019	0	0	0	0
5AJNH010.23	4/25/2019	0	0	0	0
5AJNH010.24	5/1/2019	0	0	0	0
5AJNH010.25	5/1/2019	0	0	0	0
5AJNH010.26	5/1/2019	0	0	0	0
5AJOE007.60	4/26/2018	0	0	0	2
5AMS000.40	5/13/2005	0	0	0	8
5AMS000.40	4/17/2019	0	0	0	1
5AOTR000.88	4/20/2018	0	0	0	0
5ASRE004.17	4/12/2018	0	17	0	1
5ATRR008.25	5/1/2018	0	0	0	0
5AWRN000.46	4/11/2018	0	0	0	0
5AWRN000.46	4/25/2019	0	7	0	0
5AXBRa001.08	4/20/2018	0	2	0	9
5AXBRa001.40	12/8/2004	1	0	1	0
5AXBRa001.40	4/17/2019	0	0	0	2
5AXBRb000.20	5/3/2018	0	1	0	0
5AXDMR001.60	5/1/2018	0	4	0	0
5AXJH000.31	3/25/2005	0	0	0	0
5AXJH000.31	4/17/2019	0	0	0	0
5AXJO000.10	8/7/2012	0	0	0	0
5AXJO000.10	4/17/2019	0	0	0	0
5AXNOT001.00	3/28/2018	0	0	0	0
5AXNOTb000.4	3/28/2018	0	0	0	0
5AXNOTc000.04	3/15/2013	0	0	0	2
5AXPPL000.11	4/13/2018	0	0	0	0
5AXSCKa001.82	6/10/2005	0	0	0	1
5AXSCKa001.82	4/25/2019	0	2	0	1
5AXSRE000.13	4/12/2018	0	2	0	0
5AXSRE000.13	3/27/2019	0	27	0	0