# Jabez Branch Monitoring Report
# Pre-Restoration Conditions - Year 3 (2019)


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## 1.0 Introduction

In 2017, the Maryland Department of Natural Resources' (DNR) Resource Assessment Service (RAS) and Coastal Resources, Inc. (CRI) were tasked with conducting baseline biological and geomorphic monitoring of Jabez Branch and its tributary (*herein* Jabez 3) to measure the response of restoration efforts within the Jabez 3 watershed. Maryland Department of Transportation State Highway Administration (MDOT SHA) and Anne Arundel County are evaluating new stormwater management best management practices (BMPs) and stream restoration opportunities in the Jabez 3 drainage area to treat a portion of the uncontrolled runoff. Per Maryland Department of the Environment (MDE) designated use class guidelines (MDE, 2018), instream activities due to restoration construction cannot take place between October 1 and April 30.

Prior sampling found Jabez 3 to be in a degraded biological and physical condition. In the spring of 2017 (Year 1), DNR, MDOT SHA, and CRI established seven monitoring sites in the Jabez Branch watershed to measure the response of stream biota, physical habitat, and geomorphic stability to the potential restoration and stormwater management BMPs. Three years of pre-restoration monitoring have been completed to establish baseline conditions in the Jabez watershed. Post restoration monitoring is also planned and will provide insight into the stream's response to altered hydrology. Results and analysis from the three years of pre-restoration monitoring are presented in this report.

## 2.0 Background Information

### 2.1 Site Description

Jabez Branch is located in the Severn River watershed (MDE 8-Digit 02131002) in north-central Anne Arundel County, Maryland (**Figure 1**). The Severn River watershed is located in Maryland's Western Coastal Plain physiographic province (Reager and Cleaves, 2008). Jabez Branch is a second order stream that flows into Severn Run downstream of the study area. Jabez 3, the easternmost tributary to Jabez Branch, is a first order stream. Jabez Branch and its tributaries are classified as Use-Class III (Nontidal Cold Water) by MDE. The downstream portion of the Jabez Branch watershed is located within Severn Run Natural Environmental Area (NEA), which is owned and managed by DNR and is primarily forested. All seven study sites are located in the Severn Run NEA. The headwaters of Jabez Branch flow through residential developments and the interchange of Interstate 97 (I-97) and Maryland Routes 32 (MD 32) and 3 (**Figure 2**).

The drainage area to SEVE-201-X, the downstream most study site, is 5.29 square miles. The drainage area to SEVE-102-X, the downstream most restoration site, is 1.19 square miles. The percentage of impervious surface is similar in both catchments, with 16% in SEVE-102 and 12% in SEVE-201-X (Chesapeake Conservancy, 2016; see **Appendix A,** Figure 1). The predominant land use in the Jabez Branch watershed is low density residential, which makes up approximately 30% of the drainage area (MDP, 2010; **Appendix A**, Figure 2). This is followed by mixed forest at 22% and large lot subdivision (forest) at 13% (MDP, 2010). In the Jabez 3 watershed, low density residential is also the most common land use at 40%, with mixed forest as the second most prevalent at 15% (MDP, 2010). Notably, transportation land use makes up 13% of the drainage area of Jabez 3, while comprising less than 6% of the Jabez Branch watershed overall (MDP, 2010).

**Figure 1. Vicinity Map**

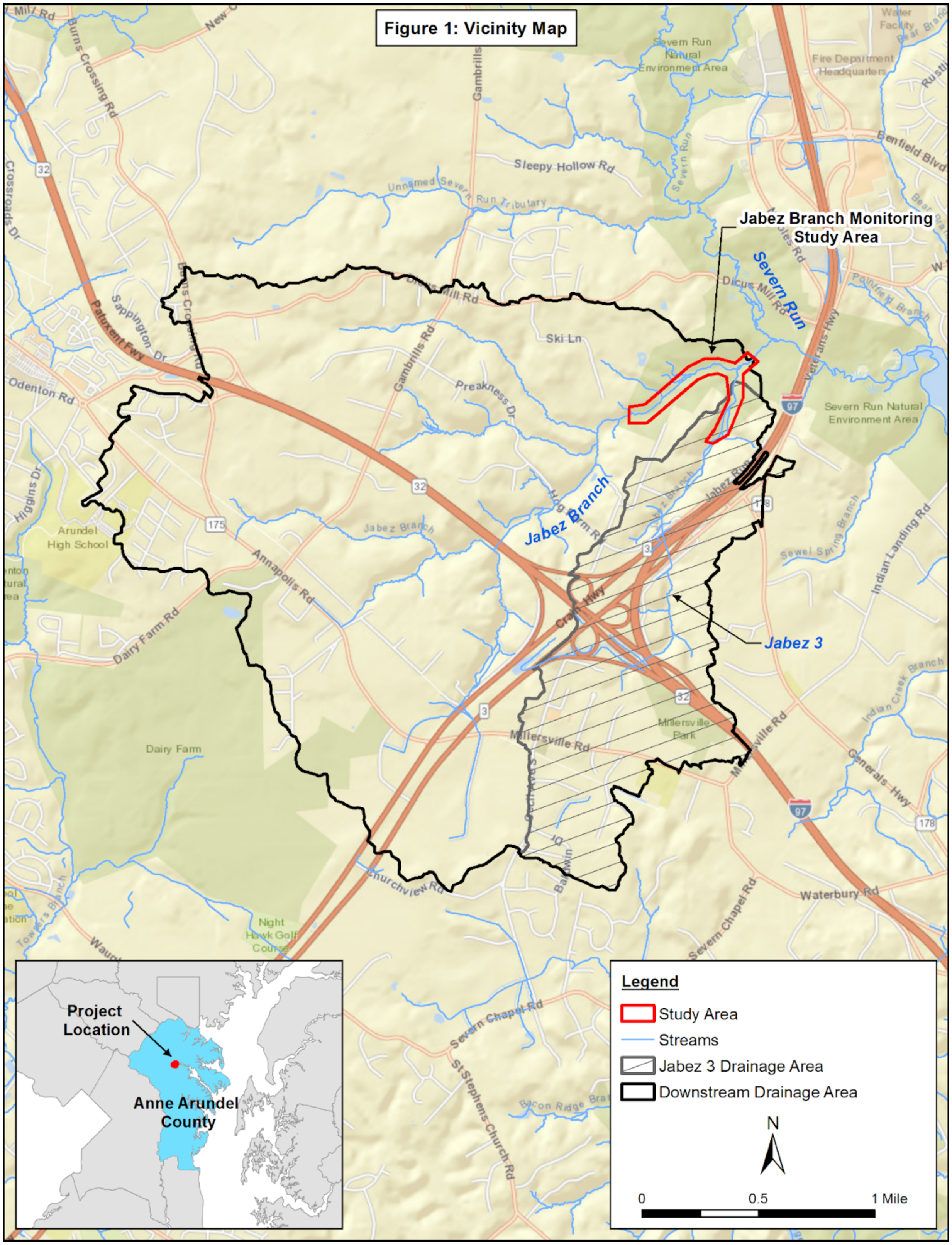
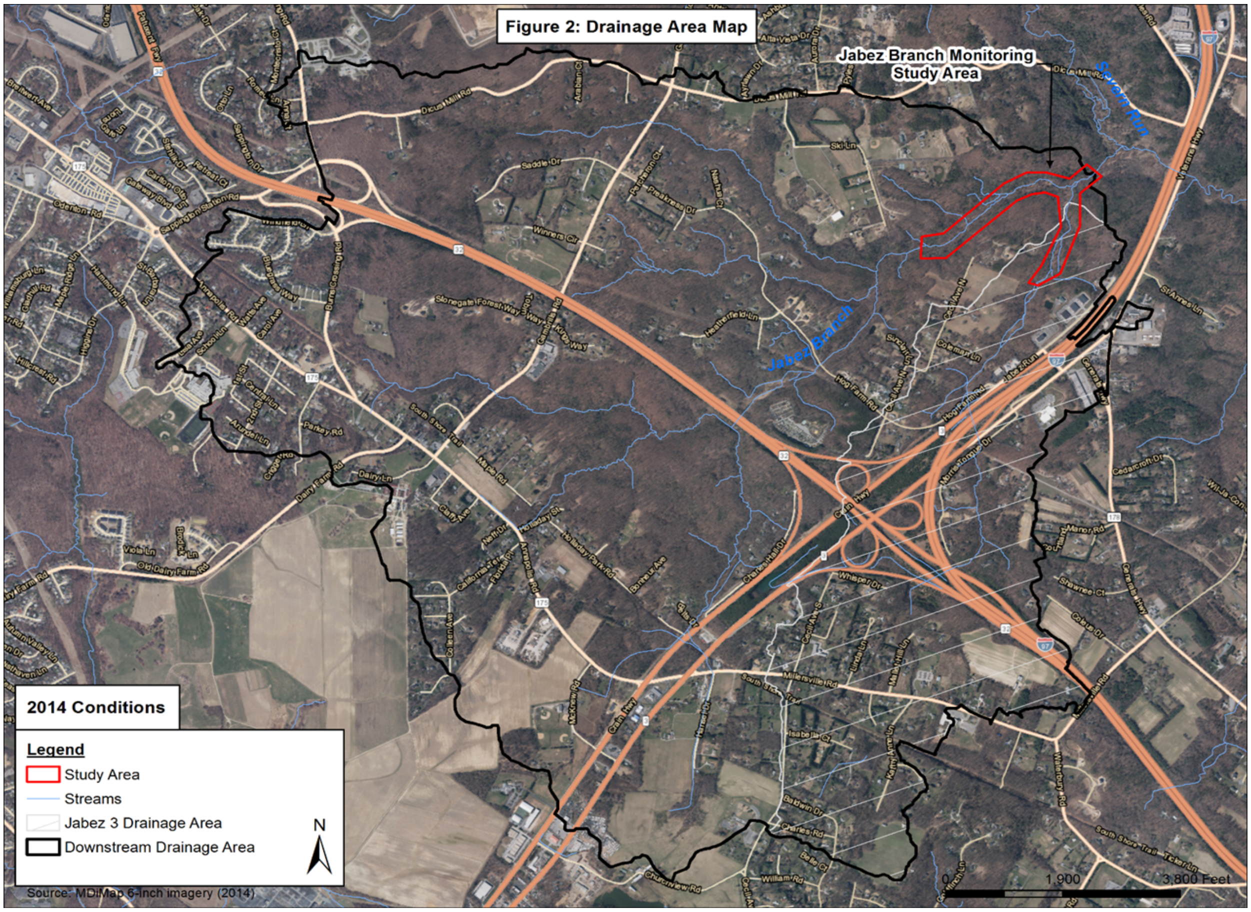


**Figure 2. Drainage Area Map**




## 2.2 History of Development

Topographic maps from five nonconsecutive years between 1894 and 1979 show how development in the Jabez Branch watershed progressed over time. By 1894, several moderately trafficked roads had already been constructed including Annapolis Road (MD 175), Dicus Mill Road, Veterans Highway (MD 178), and Crain Highway (MD 3) (see **Appendix B**, Figure 1). Between 1894 and 1907, scattered housing was constructed between Odenton and Millersville, as were the roads that connected those houses to the main highways (see **Appendix B**, Figures 1 and 2). Between 1907 and 1946, the U.S. Naval Academy purchased land to build a dairy near Gambrills. Clusters of houses were constructed along MD 175 in Millersville and Gambrills and Route 301 (which later became part of Crain Highway) was constructed between Route 178 and MD 175 (see **Appendix B**, Figures 2 and 3). While no major roadways were constructed in the area between 1946 and 1957, Arundel High School was built and more housing developed near existing roadways (see **Appendix B**, Figures 3 and 4). Between 1957 and 1970, construction began on the Patuxent Freeway (MD 32), and southbound lanes were added to Crain Highway. Between 1970 and 1979, I-97 was constructed and connected to MD 32 and MD 3 (see **Appendix B**, Figures 5 and 6). The development in the Jabez Branch subwatershed throughout the

1900s is presumed to have led to the degradation of Jabez 3 due to the increase in impervious surface area and resulting increase in the volume of surface runoff (Schueler et al., 2009).

### 2.3 Previous Studies

Biological assessments conducted as part of RAS's Maryland Biological Stream Survey (MBSS) in the Jabez Branch watershed date back to 1997. In Jabez 3, this monitoring was conducted during 1997 near its confluence with Jabez Branch. Indices of biotic integrity (IBIs) for both fish and benthic macroinvertebrate communities reflected degraded stream health. In 2003, monitoring was conducted in Jabez Branch upstream and downstream of its confluence with Jabez 3, as well as upstream of MD 32. While the fish index of biotic integrity (FIBI) scores at these three sites reflected a degraded community, the benthic macroinvertebrate index of biotic integrity (BIBI) scores were indicative of a healthy community. Additionally, Brook Trout were collected at the site upstream of MD 32. Streams with even minor urbanization in their drainages (>4% impervious land cover) do not typically support Brook Trout (Stranko et al., 2008). The recent presence of Brook Trout and high BIBI scores suggest that the upstream reaches of Jabez Branch may still be relatively undisturbed and healthy.

Additional biological assessments of Jabez Branch have been conducted by DNR's Fishing and Boating Services (FABS). These monitoring efforts were conducted every two to five years and are used to calculate trout density (number of fish per kilometer). Monitoring has confirmed the presence of multiple year classes of Brook Trout, indicating natural reproduction. Brook Trout density in Jabez Branch was low, ranging from approximately 17 to 92 trout per kilometer (Staley, M. 2018. Personal Communication). In 2018, sampling by FABS found two adult Brook Trout, including one individual in the study area on the control reach approximately 100 meters upstream of the confluence with Jabez 3. No young-of-the-year (YOY) individuals were collected during 2018 sampling.

In April 2015, Stantec and GPI prepared an Existing Conditions Evaluation of the Jabez 3 watershed (2015a). The evaluation included a visual inspection of the erosion and instability within the Jabez mainstem and tributaries, as well as an inspection of the surrounding BMPs, impervious surfaces, and pollutant loads (Stantec and GPI, 2015a). Areas in need of restoration were identified and appropriate restoration measures were discussed. The Existing Conditions Evaluation found that Jabez 3 contained reaches with highly variable conditions. Some reaches were in relatively stable condition due to the fact that catchments draining to them did not contain considerable impervious area. However, reaches that drained catchments with larger proportions of impervious area were severely degraded.

In September 2015, Stantec and GPI presented the Proposed Conditions Evaluation & Restoration Plan for the Jabez 3 watershed (2015b). This report built on the findings of the Existing Conditions Evaluation and recommended that mitigation efforts include 3,776 feet of stream restoration in two highly degraded reaches as well as several new or retrofitted BMPs and two areas of proposed forest plantings.

## 3.0 Methodology

Monitoring data has been collected by CRI and RAS staff during scheduled site visits over the first three years of pre-restoration monitoring starting in 2017. The monitoring activities included:

- Spring biological stream assessments (benthic macroinvertebrate sampling, habitat, water chemistry, temperature logger deployment)

- Summer biological stream assessments (fish sampling, habitat, temperature monitoring, dissolved oxygen monitoring)
- Geomorphic survey (cross sections, longitudinal profile, bed material characterization)
- BEHI (Bank Erosion Hazard Index) and NBS (Near Bank Stress)
- Monitoring photos
- Post-storm visit

Most site visits include taking photos and recording observations that document site conditions. Other site visits may include maintenance of data loggers and biological sampling. The schedule of monitoring visits for 2019 and the activities performed during each visit are summarized in **Table 1**.

**Table 1. Timeline of 2019 Site Visits**

| Dates | Monitoring Activities Performed |
|---|---|
| March 11 – April 8 | Benthic Macroinvertebrate Sampling, Spring Habitat Assessment, Temperature Logger Deployment, Water Chemistry |
| June 6 - June 7 | Electrofishing Survey and Summer Habitat Assessment |
| June 28 - November 18 | Dissolved Oxygen Monitoring |
| Aug 3rd- Aug 9th | Geomorphic Survey, Photo Monitoring, BEHI, NBS |
| Oct 28th | Post Storm Visit |

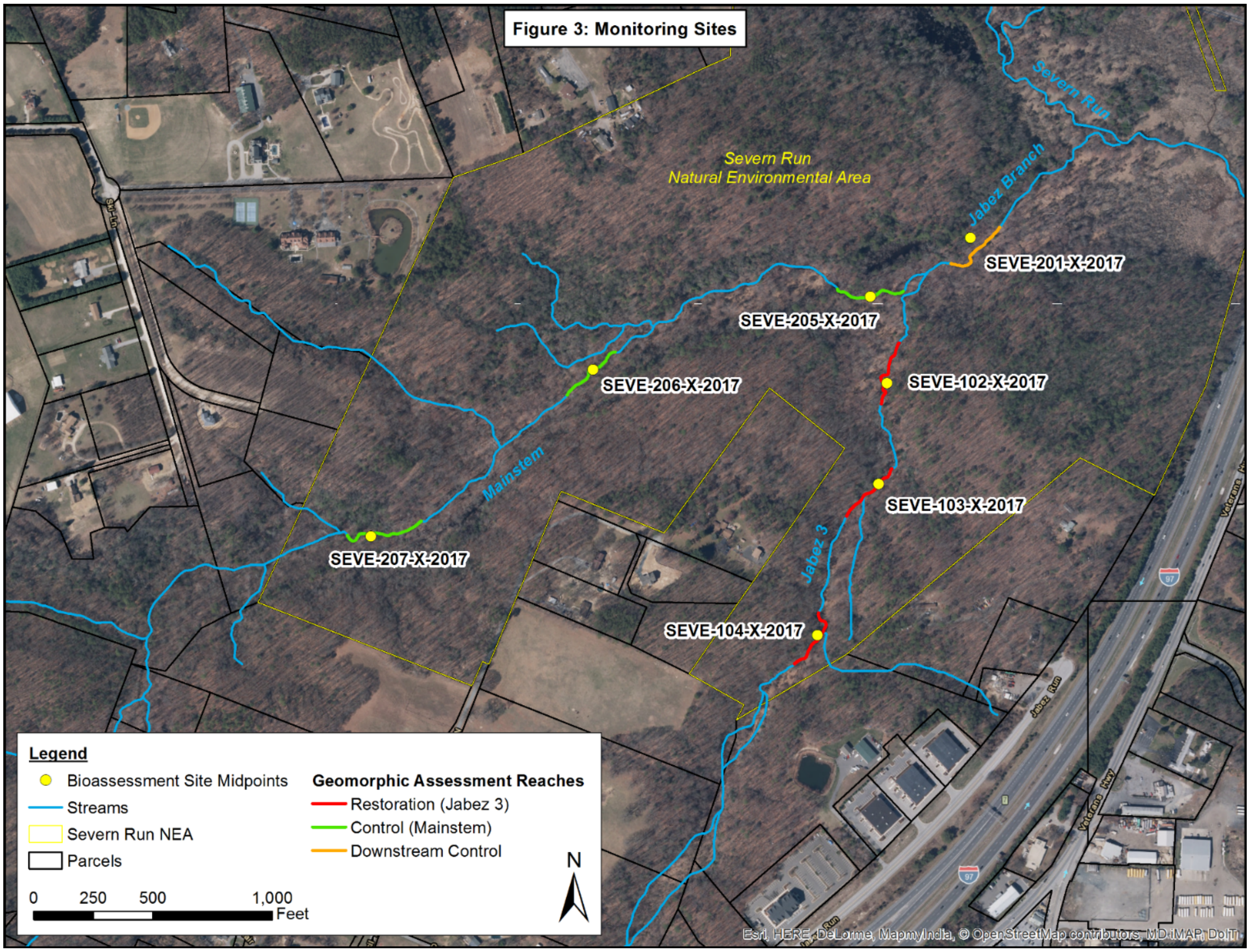
### 3.1 Site Selection

In the spring of 2017, RAS established seven monitoring sites in the Jabez Branch watershed to measure the response of stream restoration and BMPs on biota (Appendix G) and physical habitat. Pre-restoration data were collected from these seven sites to establish baseline conditions. Three sites (SEVE-102-X, SEVE-103-X, SEVE-104-X) were within the Jabez 3 restoration reach, three were paired control sites (SEVE-205-X, SEVE-206-X, SEVE-207-X) upstream of the confluence on Jabez Branch, and one was a control site (SEVE-201-X) located downstream of the control and restoration reach confluence. See site locations in **Figure 3**.

Additionally, sites sampled as part of the MBSS sentinel site network (Saville et al., 2014) were used to compare conditions at the restoration and control sites in the Jabez Branch watershed with those of reference conditions. MBSS sentinel sites were sampled annually and independent from the Jabez Branch study. Three reference sites were selected based on biological and geological similarities, physiographic province, as well as on their relative proximity to Jabez Branch (PRMT-177-S, UT Reeder Run; PTOB-002-S, Hoghole Run; and MATT-102-S, UT Mattawoman Creek). These sites differ from Jabez Branch in that none of them support Brook Trout. Permission to access the PTOB-002-S reference site was lost following the spring benthic sample in 2018 and was not reinstated for 2019 sampling. Consequently, PTOB-002-S was dropped as a reference site and data are no longer included in this report.

Throughout Maryland, a Brook Trout population existing in a Coastal Plain stream is a condition unique to Jabez Branch. Consequently, finding reference sites with similar thermal regimes was difficult. To provide a more appropriate comparison on thermal conditions, temperature data from a range of cold water Coastal Plain streams (n=24) and streams supporting Brook Trout (n=436) were used as reference conditions. Reference site data were selected using MDE's criteria for non-impaired cold water streams (Use-Class III (-P)). These criteria are outlined further in **Section 3.2.5**.

**Figure 3. Monitoring Sites**




## 3.2 Biological Stream Assessments

Baseline (i.e., pre-restoration) data were collected from the restoration and control sites to determine if biological communities at restoration sites would respond consistent with the restoration objectives. Data collected included benthic macroinvertebrates, fish, water temperature, dissolved oxygen concentration (2018, 2019), physical habitat, and water chemistry. Indices of biotic integrity (IBIs) were calculated for fish (FIBI) and benthic macroinvertebrates (BIBI) at each site using metrics indicative of stream health (Southerland et al. 2008). Results are combined into a scaled IBI score, ranging from 1.0 to 5.0, with an applied narrative ranking (**Table 2**).

**Table 2. Maryland Biological Stream Survey IBI scoring and narrative ranking**

| IBI Score | Narrative Ranking |
|---|---|
| 4.0 – 5.0 | Good |
| 3.0 – 3.99 | Fair |
| 1.0 – 2.99 | Poor |

Due to the close proximity of the three restoration and three paired control sites (**Figure 3**) only one temperature logger was deployed on each reach. All data were collected using MBSS protocols (Stranko et al. 2014). The United States Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBP) for low gradient streams (Barbour et al. 1999) were used to collect additional physical habitat data at the seven Jabez Branch sites. Brief descriptions of each parameter follows.

### 3.2.1 Benthic Macroinvertebrates

Benthic macroinvertebrates were collected at the seven Jabez Branch sites during March or April from 2017 to 2019. Reference site benthic macroinvertebrate samples were also collected during the spring index period (March 1 – April 30). Sampling was conducted using a 540 µm mesh D-shaped net within 20, 0.09 $m^2$ sub-samples of proportionally available optimal habitat. The 20 sub-samples were combined into one composite sample and sent to DNR's field laboratory where a minimum of 100 organisms were randomly selected and identified to genus, or lowest practical taxonomic level. While more in depth lab methodology is available in Boward and Friedman (2011), general understanding of the sorting and identification process is important to some analyses included in this report. Each site's composite sample is homogeneously distributed in a sorting tray made up of 100 grids. Organisms are identified from randomly selected grids until the targeted number of organisms has been reached. All grids are picked to completion, normally resulting in the identification of more than the targeted number of organisms. Organisms which were damaged or unidentifiable were excluded from BIBI calculations. BIBIs were calculated based on these data using metrics specific to Coastal Plain streams. Raw values found for each metric (**Table 3**) were scored 1, 3, or 5 (1 being worst, 5 being best), summed, and then averaged to obtain the final BIBI score.

**Table 3. Coastal Plain Benthic Macroinvertebrate IBI scoring metrics developed by Southerland et al. (2008)**

| | Thresholds | | |
|---|---|---|---|
| **Benthic IBIs (Metric)** | **5** | **3** | **1** |
| Number of Taxa | ≥ 22 | 14 – 21 | < 14 |
| Number of EPT Taxa | ≥ 5 | 2 – 4 | < 2 |
| Number of Ephemeroptera Taxa | ≥ 2 | 1 – 1 | < 1 |
| Percent Intolerant Urban | ≥ 28 | 10 – 27.99 | < 10 |
| Percent Ephemeroptera | ≥ 11 | 0.8 – 10.99 | < 0.8 |
| Number of Scraper Taxa | ≥ 2 | 1 – 1 | < 1 |
| Percent Climbers | ≥ 8 | 0.9 – 7.99 | < 0.9 |

In addition to the minimum of 100 individuals already identified for the BIBI calculation, at least 100 more macroinvertebrate individuals from each Jabez study site's benthic sample were randomly selected and identified to genus, or lowest taxonomic level. Most of the samples contained > 200 organisms due to the processing of complete grids, but herein we refer to these samples with 100 additional individuals as 200-count macroinvertebrate data. Identification of the additional individuals were not used in BIBI calculations, but helped further describe the benthic macroinvertebrate community by providing insight into patterns of richness and evenness. In some cases, fewer than 100 individuals were present in the entire sample. In these cases the maximum number of individuals were used for BIBI calculation and these data were excluded from the 200 count macroinvertebrate analysis.

While organisms that were unidentifiable to genus level were excluded from BIBI calculations, these organisms were lumped or split into a higher or lower taxonomic level during further macroinvertebrate community analysis. Organisms were only “lumped” into one taxon in instances where there were no other organisms from that genus identified. When multiple taxa from the same genus were present, organisms were “split” proportionately amongst these taxa. The majority of organisms which were lumped or split were in the *Chironomidae* family and accounted for 2.6% percent of individuals overall.

To describe patterns in the macroinvertebrate communities across sites and years, Shannon-Weiner Diversity and Pielou’s Evenness Indices were calculated. Sites from the control and restoration reaches were analyzed by year and placed into six groups (C2017, C2018, C2019, R2017, R2018, and R2019). The Shannon-Wiener Diversity Index was selected because it includes an evenness index and because it accounts for the possibility of taxa being present which were not detected during sampling (Maurer and McGill 2011). The Shannon-Wiener Diversity index is also commonly used, thus facilitating comparability between studies. The Shannon-Wiener Index scores range from 0 to 5, where 0 indicates low richness and evenness and 5 indicates high richness and complete uniformity of organisms across all taxa. Pielou’s Evenness Index is a component of the Shannon-Wiener Diversity index which describes variability in relative abundance among taxa on a scale from 0 to 1, where 0 indicates dominance by one taxon and 1 indicates equal abundance across taxa (Maurer and McGill 2011).

The same groups used for the Shannon-Wiener Index and Pielou’s Evenness Index were used in non-metric multidimensional scaling (NMDS). In this analysis, count data were used to determine the likeness of the R2017, R2018, R2019, C2017, C2018, and C2019 groups. Package vegan, 2.5-3 (Oksanen et al. 2018) was used to conduct this analysis in Program R 3.5.1 (R Core Team 2018). In addition to plotting the NMDS, 95% confidence interval ellipses were plotted for each of the six groups to show any overlap between groups and years.

A subset of metrics used in the BIBI were calculated and summarized annually for each site with the 200-count macroinvertebrate data. These metrics included percent composition and taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa because these organisms are generally associated with stream health and considered intolerant of anthropogenic stressors. Percent of individuals intolerant of urbanization and percent of individuals in the *Chironomidae* family were also included in analysis. Percent individuals intolerant of urbanization is another metric which describes how each site has been affected by development and other anthropogenic stressors. Percent composition of *Chrionomidae* was included because in most cases, the dominant taxa at restoration sites were in the *Chironomidae* family. A shift in dominant taxa following restoration may signify a change in habitat availability and subsequent macroinvertebrate composition.

Additionally, observed taxa richness and average number of individuals per grid were calculated to provide some insight into macroinvertebrate density and abundance. Average number of individuals per grid was calculated under the assumption that organisms were homogeneously distributed across the sorting tray using the equation $\frac{T^i}{P} = I$, where $T^i$ is the total number of individuals identified, $P$ is the number of grids picked, and $I$ is the average number of individuals per grid.

### 3.2.2 Fish Communities

Fish community data were collected from all study and reference sites during the summer index period (June 1 – September 30). Two-pass electrofishing surveys were conducted after the sites were blocked on the upstream and downstream ends with 6 millimeter mesh nets. Closure of the site allows for a more accurate census of the fish population. Fish collected from each electrofishing pass were identified to species, counted, weighed in aggregate, and released downstream of the survey area. FIBI scores were calculated with these data using metrics specific to Coastal Plain streams. Values observed for each metric **(Table 4)** were scored 1, 3, or 5 (1 being worst, 5 being best), summed, and then averaged to obtain the FIBI score.

**Table 4. Coastal Plain Fish IBI scoring metrics developed by Southerland et al. (2008)**

| | Thresholds | | |
|---|---|---|---|
| **Fish IBIs (Metric)** | **5** | **3** | **1** |
| Abundance per square meter | ≥ 0.72 | 0.45 – 0.71 | < 0.45 |
| Number of Benthic Species | ≥ 0.22 | 0.01 – 0.21 | 0 |
| Percent Tolerant | ≤ 68 | > 68 – 97 | > 97 |
| Percent Generalists, Omnivores, Invertivores | ≤ 92 | > 92 – < 100 | 100 |
| Percent Round-bodied Suckers | ≥ 2 | < 2 – > 0 | 0 |
| Percent Abundance Dominant Taxa | ≤ 40 | > 40 – 69 | > 69 |

### 3.2.3 Physical Habitat

Physical habitat was assessed at each study site because physical habitat scores and IBI scores are positively correlated. Habitat was assessed during the summer index period using seven metrics to represent different aspects of habitat quality (i.e., instream habitat, epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, riffle/run quality, riffle embeddedness, and shaded area). Physical habitat parameters were scored on a 0 (worst) to 20 (best) scale; embeddedness and shading were recorded as a percentage. Depth, wetted width, and discharge measurements were also made at each site to help quantify stream habitat. Riparian buffer widths, area of eroded stream banks, and severity of island/point bar deposition were also visually estimated. While erosion and deposition were evaluated during biological sampling, the geomorphic assessment quantified these processes in greater detail.

Additionally, Rapid Bioassessment Protocols (RBP) were used to further assess the available physical habitat at the seven sites in the Jabez Branch watershed in 2017. While some of the metrics (i.e., epifaunal substrate, cover, pool variability, and sediment deposition) were similar to those used in the MBSS protocols, additional metrics (i.e., pool substrate, channel flow status, channel alteration, sinuosity, bank stability, vegetative protection, and riparian zone width) were also used to assess physical habitat. RBP habitat measurements were also scored on a 0 (worst) to 20 (best) scale. Rankings for both habitat assessments are Poor (0-5), Marginal (6-10), Sub-Optimal (11-15), and Optimal (16-20). RBP data were not collected during 2018 or 2019 sampling.

#### 3.2.4 Water Chemistry

A grab water sample was collected from each study site during the spring index period and sent to the University of Maryland Center for Environmental Science Appalachian Laboratory for analysis. Parameters measured included: pH, acid neutralizing capacity (ANC), sulfate ($SO_4$), nitrate ($NO_3$), nitrite ($NO_2$), ammonia ($NH_4$), total nitrogen (TN), ortho-phosphate ($PO_4$), total phosphorus (TP), chloride (Cl), conductivity (µS/cm), bicarbonate ($HCO_3$), bromide (Br), sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), total ammonia ($NH_3$), and dissolved organic carbon (DOC). Analytical methods and QA/QC procedures employed by Appalachian Laboratory to ensure data quality are available in Kline (2018).

#### 3.2.5 Continuous Temperature

Continuous water and air temperature data were collected at three of the seven sites in the Jabez Branch watershed. Deploying one water temperature logger per reach (restoration, paired control, and downstream control) was sufficient because the restoration and paired control sites were in close proximity (**Figure 3**) and would presumably have little variation in temperature.  Each logger recorded water temperature every 20 minutes from June 1 – August 31.  After downloading, raw data undergo a quality control check per Maryland's Quality Assurance Document for Temperature Monitoring (MDNR, accessed 2017) to ensure accuracy of data and that water loggers did not become buried or de-watered during deployment.  Data used in this report were summarized into average daily temperature and summary statistics (**Appendix G**).

Reference temperature regimes for cold water Coastal Plain and Brook Trout supporting streams were developed from temperature data at previously monitored MBSS sites (through 2019). The criteria to select the sites within cold water Coastal Plain group followed MDE's criteria for non-impaired cold water streams (Use-Class III (-P)) (MDE 2013). Temperature data from MBSS sites with brook trout present ($n \geq 1$) were included in the brook trout group. Temperature data from sites meeting the Coastal Plain and Brook Trout criteria (**Table 5**) were compared to data collected in Jabez Branch study reaches (**Appendix G**).

**Table 5. Temperature Statistics for Non-impaired Cold Water Streams**

| Temperature Statistic (n=84,950 measurements) | Empirically Derived Value |
|---|---|
| Percent time >20ºC | 10.9% |
| Mean Temperature (ºC) | 17.3 |
| 90th Percentile Temperature (ºC) | 20.1 |

#### 3.2.6 Dissolved Oxygen

Onset HOBO Dissolved Oxygen Data Loggers (U26-001) were deployed during the summer of 2018 to establish baseline dissolved oxygen conditions and determine if dissolved oxygen is a stressor on macroinvertebrate or fish communities in the Jabez Branch watershed. One logger was deployed in the restoration reach at SEVE-103-X and a second logger was deployed in the adjacent control reach at

SEVE-206-X. Loggers were deployed in concrete and PVC housings to protect the units and ensure they were located in flowing water. Funding to support the purchase of these two loggers along with their deployment, maintenance, and data analysis, was obtained from DNR's Chesapeake and Coastal Service (CCS) through a monitoring agreement for monitoring restoration projects with funds from the Chesapeake and Atlantic Coastal Bays Trust Fund. Results are reported to provide context to other data collected in the Jabez Branch project.

Dissolved oxygen loggers recorded temperature (°C) and oxygen concentration (mg/L) every 60 minutes. RAS staff visited the study site either weekly or bi-weekly to remove algal growth from the sensor's membrane, download data, field calibrate, or remove sediment deposited on the logger. As burial of sensors was a constant and unavoidable issue, large portions of data were unreliable. QC of data was conducted using field notes (i.e. buried at time of visit), *in-situ* dissolved oxygen readings, and temperature data (daily fluctuation in temperature is generally less when buried in sediment). Inconsistencies in the dissolved oxygen data caused by dewatering and burial prevented daily summary statistics (mean, max, min concentrations) to be calculated. Instead, portions of reliable dissolved oxygen data are presented to show "normal" dissolved oxygen conditions and daily undulations.

As a result of difficulties collecting continuous dissolved oxygen data in 2018, new protocols were adopted in 2019. To determine whether dissolved oxygen is a stressor to biota, biweekly spot checks were conducted on the restoration and control reaches. During these spot checks, in-situ dissolved oxygen concentrations in 3 riffles and 3 pools were measured on each reach. As a supplement to the biweekly spot checks, dissolved oxygen concentration profiles were conducted seasonally (summer and fall) in the restoration reach to determine the homogeneity of oxygen concentrations. Methods used to profile the Jabez Branch restoration reach were similar to those used by Smithsonian Environmental Research Center (SERC) and US Environmental Protection Agency (USEPA). The 600 foot profile began at the confluence with the control reach and ended just upstream of the SEVE-104-X site. Dissolved oxygen concentration (mg/L), dissolved oxygen percent saturation, specific conductivity (us/cm), temperature (°C), and habitat type (riffle or pool) were recorded at each of the 50 stations. Stations were spaced every 12 feet to evenly divide the reach.

## 3.3 Geomorphic Assessments

The third year of baseline geomorphic assessment was completed in August 2019. The longitudinal profile and two cross sections, established at each of the seven monitoring reaches in 2017, were re-surveyed. The cross sections and longitudinal profile were compared to previous measurements to evaluate and track any changes in pattern, dimension, and profile of the stream channel during the three year monitoring period. The field data collection activities were based on data collection methods described in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et al., 1994). Field data were entered in the Reference Reach spreadsheet STREAM module 4.3L (Mecklenburg, 2006) for analysis. All references to left or right are facing downstream. Site maps and monitoring photos are included in **Appendix C**. **Appendix D** includes results of the geomorphic assessments grouped by site, including longitudinal profile and cross section graphs and bed material particle size distributions. BANCS assessment data and calculations can be found in **Appendix E**.

### 3.3.1 Hydrology and Discharge

Before geomorphic fieldwork commenced, estimated bankfull discharges in cubic feet per second (cfs) and dimensions were calculated for each site using preliminary drainage areas obtained from Stream

Stats 4.0 (USGS, 2017). The US Fish and Wildlife Service regional curve for the Western Coastal Plain was chosen due to the physiographic province, and because the Jabez sites fit within the ranges of drainage area sizes and percent imperviousness of sites used for the development of the curve (McCandless, 2003). Fixed Region Regression (FRR) Equations for the Western Coastal Plain Region were also consulted (MHP, 2016). These sources were used to verify bankfull indicators identified during the geomorphic assessment fieldwork (see **Table 6** below). Drainage areas were refined after fieldwork was completed based on the actual locations of cross sections.

**Table 6. Discharge Estimates for 2019**

| Site | Western Coastal Plain | | |
|---|---|---|---|
| | McCandless (2003) | Fixed Region Regression (MHP, 2016) | |
| | $Q_{bkf}$ (cfs) | $Q_{1.25}$ (cfs) | $Q_{1.5}$ (cfs) |
| SEVE-104-X | 34<br>(30 - 38) | 75<br>(45 - 104) | 100<br>(63 - 136) |
| SEVE-103-X | 35<br>(31 - 39) | 76<br>(47 - 106) | 102<br>(67 - 140) |
| SEVE-102-X | 35<br>(31 - 40) | 77<br>(47 - 107) | 103<br>(65 - 140) |
| SEVE-207-X | 82<br>(73 - 92) | 139<br>(85 - 194) | 183<br>(117 - 250) |
| SEVE-206-X | 86<br>(76 - 95) | 143<br>(87 - 198) | 188<br>(119 - 256) |
| SEVE-205-X | 87<br>(77 - 97) | 141<br>(86 - 196) | 185<br>(118 - 253) |
| SEVE-201-X | 106<br>(94 - 118) | 179<br>(109 - 249) | 235<br>(150 - 321) |

The USGS operates a stream gage on Jabez Branch upstream of MD 32 (#01589795, South Fork Jabez Branch at Millersville, MD). The drainage area to the gage is 1.0 square mile. Gage data may be extrapolated to ungaged sites upstream or downstream on the same stream within 0.5 to 1.5 times the drainage area (MHP, 2016). Though the restoration (Jabez 3) sites have a similar sized drainage area, they are on a different branch of the stream. The drainage areas to the control and downstream control sites are outside the range of sizes that may be extrapolated. However, flood frequencies calculated for this gage by the Maryland Hydrology Panel were still used as a reference when calibrating bankfull discharge at the Jabez Branch monitoring sites (MHP, 2016). For the 1.0 square mile drainage area at the stream gage, the $Q_{1.5}$ was 53 cfs and the $Q_2$ was 83 cfs (MHP, 2016).

### 3.3.2 Longitudinal Profile

The longitudinal profile includes survey of the bed features within the channel, water surface, bankfull, and low top of bank and was used to characterize the slope and morphology of the stream channel through the study area. A rebar pin was installed at the top of bank to mark the upstream end of each longitudinal profile. The longitudinal profile was surveyed upstream to downstream with the tape laid in the center of the channel. Longitudinal profiles at each site were approximately 300 linear feet, or longer as needed to tie into riffle bed features, and overlapped with the 75-m-long biological monitoring reaches as much as possible. Longitudinal profile graphs are included in **Appendix D**.

### 3.3.3 Cross Sections

Two cross sections (abbreviated as XS) were established within each of the seven monitoring reaches and were surveyed from left to right, facing downstream. Cross sections were established in riffles when possible, or in the crossover between meanders. Cross sections were monumented with rebar during the baseline (2017) assessment, and will be re-surveyed each year. End pins were placed far enough from the top of bank to capture the floodplain conditions and avoid loss of the pins due to bank erosion. The cross section survey is used to determine bankfull channel characteristics and will be used to compare changes in cross sectional area over time, which may be due to channel degradation or aggradation or lateral adjustments. Due to the difficulty in identifying bankfull in degraded reaches, cross sectional area at the top of bank will also be compared each year. At least four photographs were taken of each cross section, included both banks and facing the cross section from upstream and downstream. Cross section graphs are included in **Appendix D**.

### 3.3.4 Bed Material Characterization

The channel substrate analysis included conducting modified Wolman pebble counts and collecting bar samples in each study reach following protocols described by Rosgen (1996) and Bunte and Abt (2001). Pebble counts were conducted at each cross section to characterize the stream substrate. One bar sample was collected in each reach and wet sieved to determine the sediment size distribution of mobile sediment in the channel. Bed material data were used in the analysis of hydraulic variables and will be used to identify any trends in the composition of the substrate over time. Particle size distribution graphs are included in **Appendix D**.

### 3.3.5 Photographic Monitoring

Visual inspection and site photographs were recorded at every cross section and at various points along each reach. Photos were taken in locations that best represented the overall condition of the channel and in locations of interest that may be likely to change over time. Photo locations were recorded using a handheld GPS unit. Photo monitoring (abbreviated as PM) stations established during 2017 represent the baseline conditions, and photos will be repeated from the same location in subsequent years. These photos will be used to monitor change in channel conditions over time, including bed and bank stability, changes in pattern or bed features, or signs of excessive sedimentation. Photos follow each site map in **Appendix C**.

### 3.3.6 BEHI/BANCS

The Bank Assessment of Non-Point Source Consequences of Sediment (BANCS) model was used to map the locations and characteristics of eroded banks and develop a baseline estimate of erosion rates in 2017 (Rosgen, 2001 and 2009). The BANCS model consists of two commonly used bank erodibility estimation tools to predict stream bank erosion for discrete sections of streambank; the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) methods. BEHI and NBS analyses were performed on all eroding stream banks within the extent as the longitudinal profile for the control and downstream control reaches, and along the entirety of the restoration reach within Severn Run NEA.

A handheld GPS unit was used to record the location of the upstream and downstream ends of each eroding bank, and the length was measured by placing a measuring tape down the middle of the channel. Eroding banks were given an ID to link the BEHI form to the GPS data in the format of "ES.001," and numbered chronologically. The BEHI for each eroding bank was calculated using the following characteristics: the ratio of bank height to bankfull height, the ratio of root depth to bank height, root density, surface protection, bank angle, and bank material adjustments. The total score derived from these parameters was associated with a category rating, ranging from Very Low to Extreme. NBS predicts the amount of energy distributed to a streambank, which can accelerate erosion. NBS method #1 was used, which estimates the NBS based on channel pattern and depositional features. NBS method #1 ratings range from Low to Extreme.

A bank erosion rating curve to assign an erosion rate (feet/year), based on the BEHI and NBS ratings, to each eroding bank. The US Fish and Wildlife Bank Erosion curve for Hickey Run was used for this assessment (Berg et al., 2014). Subsequently, the annual sediment load (tons/year) expected for each bank was determined based on the bank area. Sediment load per foot of bank (tons/year/foot) was used to stratify the results into five categories using the Jenks natural breaks classification method in ArcMap 10.5. The 5 categories, from lowest to highest rate in tons/year/foot, were: 0-0.113, 0.113-0.228, 0.228-0.359, 0.359-0.576, and 0.576-2.397. Sections of banks with deposition or without any evidence of erosions were marked as No Erosion.

Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**. The 2018 BANCS field data were overlaid with the initial 2017 where applicable for comparison of all changes. The BANCS assessment will be repeated each year to evaluate changes in the extent and severity of erosion over the course of the monitoring period.

#### 3.3.7 Post-Storm Visit

Post-storm visits will occur once each monitoring year following a significant storm event (Q1YR or greater). Photographic documentation of the site was performed during this visit and included notes based on visual observations of flow characteristics, any pattern of erosion or deposition, and any other observations that document site conditions and/or problems. A summary of observations and photos are included in this annual monitoring report (**Appendix F**). A discharge of 11 cfs or greater at USGS Stream Gage 01589795 (South Fork Jabez Branch at Millersville, MD) will trigger a post-storm monitoring visit. In 2019, the USGS gage recorded 4 events (as of 10/30/2019) where discharge was at or exceeding 11 cfs, compared to 12 events in 2018 and 4 events in 2017. Post-storm photo monitoring is included in **Appendix F**.

### 3.4 Assessing Results

Results in this report constitute the three years of scheduled pre-restoration monitoring. All biological, physical habitat, chemistry, continuous temperature, and geomorphic data will be examined after the implementation of restoration efforts (such as stream restoration and stormwater management BMPs) to identify potential changes coincident with restoration actions. For many water quality variables, threshold values indicative of high quality or impaired streams are available from the literature or from Maryland Water Quality Criteria (COMAR 26.08.02). Thresholds associated with Brook Trout suitability and survival are also available from the literature. Rosgen stream types (1996) and cross sectional parameters, such as entrenchment ratio, will be used to characterize the relative stability or instability of the geomorphic assessment reaches. In subsequent years, cross section and longitudinal profile graphs will be overlaid in order to assess changes in cross sectional area, areas of erosion and deposition, and slope. Bed material composition and the extent and severity of erosion will also be compared year to year.

## 4.0 Results

Results from the first three years of baseline monitoring are grouped by stream reach and presented by site. Restoration sites are presented first, followed by control sites, and finally the downstream control site. Within the restoration and control groups, upstream sites are discussed before downstream sites.

### 4.1 Restoration Sites (Jabez 3)

Fish communities at sites SEVE-104-X, SEVE-103-X, and SEVE-102-X were in Poor condition. Benthic macroinvertebrate IBI scores ranked either Poor or Fair. Additionally, no macroinvertebrate samples from the restoration reach in 2018, or at SEVE-104-X in 2019 contained over 100 individuals. While scores are generally calculated on samples with > 100 individuals, IBIs from the restoration reach were still accepted. Low macroinvertebrate density in 2018 may have been due to high flows and increased sedimentation resulting from a high precipitation year. Note that macroinvertebrate metrics included in this section reflect only the data used in BIBI calculations and not the additional organisms identified for the community level analysis in **Section 4.5**. Degraded biological conditions were consistent with the Instream Habitat and Epifaunal Substrate scores, which were Poor or Marginal.

In general, Jabez 3 had more severe BEHI ratings than the Jabez Branch mainstem, as would be expected due to its more degraded condition. Forty-five percent of the total stream length assessed was experiencing erosion. Sixty-one percent of the erosion occurred on the left bank, and 39% occurred on the right. Of the eroded areas, 3% earned a BEHI rating of Extreme, 13% was rated as Very High, 60% was rated as High, 23% was rated as Moderate, and 1% was rated as Low. A total of 24% of the eroded length was in the two highest erosion rate categories. Overall, the extent of erosion in Jabez 3 increased slightly from 2017 (40% to 45%). Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

The bed material of Jabez 3 was primarily sand, with infrequent gravel riffles. The Rosgen stream types determined by the riffle cross sections throughout the restoration sites were unstable F and G type channels.

#### 4.1.1 SEVE-104-X

SEVE-104-X was the furthest upstream site on Jabez 3. The stream is characterized by a deeply entrenched channel that was completely disconnected from the floodplain, and steep, eroded banks composed of dense clay.

The drainage area of SEVE-104-X is 1.12 square miles. Impervious area covers 16% of the drainage area. The major land uses in the drainage area are as follows: low-density residential (41.9%), transportation (13.7%), mixed forest (12.5%), cropland (8.4%), open urban land (7.2%), and large lot subdivision/forest (7.0%). Approximately 37% of the drainage area is comprised of C and D soils, which have moderately high to high runoff potential, respectively (NRCS, 2007).

#### 4.1.1.1 *Biological Assessment Results*

IBI scores and metrics for all restoration and reference sites are summarized in **Appendix G.** IBI scores specific to SEVE-104-X for all years of monitoring are in **Table 7** below.

**Table 7. Pre-restoration IBI scores for SEVE-104-X**

| Index of Biotic Integrity | 2017 | 2018 | 2019 |
|---|---|---|---|
| FIBI | 1.33 | 1.33 | 2.0 |
| BIBI | 2.43 | 1.86* | 2.43* |

*BIBI based on < 100 individuals

BIBI scores at SEVE-104-X were Poor in all three years of pre-restoration monitoring. Only 18 individuals were collected in the 2018 benthic sample. Taxa richness fluctuated from 7 to 28 taxa across all years. SEVE-104-X supported two species of fish, American Eel (*Anguilla rostrata*) and Blacknose Dace (*Rhinichthys atratulus*) in 2017. Two additional fish species were collected in both 2018 and 2019, Pumpkinseed (*Lepomis gibbosus*) and White Sucker *(Catostomus commersoni*) in 2018, and Tessellated Darter *(Etheostoma olmstedi*) and Eastern Mudminnow (*Umbra pygmaea*) in 2019. FIBI scores were Poor in all pre-restoration years.

Scores from the RBP and MBSS physical habitat assessment reflected degraded conditions from 2017 to 2019 **(Table 8**). Little epifaunal habitat or fish cover were available in the site, which may have contributed to the low IBI scores. Continuous water temperature for the restoration reach is included in **Appendix G** and water chemistry results are summarized in **Table 9.**

**Table 8. MBSS physical habitat assessment and RBP scores at SEVE-104-X**

| Parameter (MBSS physical habitat assessment) | 2017 | 2018 | 2019 |
|---|---|---|---|
| Instream habitat (0-20) | 3 | 3 | 5 |
| Epifaunal substrate (0-20) | 2 | 2 | 6 |
| Velocity/Depth Diversity (0-20) | 6 | 6 | 7 |
| Pool/Glide/Eddy Quality (0-20) | 2 | 5 | 6 |
| Pool/Glide/Eddy Extent (m) | 8 | 10 | 30 |
| Riffle Quality (0-20) | 3 | 6 | 11 |
| Riffle/Run Extent (m) | 67 | 70 | 45 |
| Embeddedness (%) | 100 | 100 | 45 |
| Shading (%) | 80 | 85 | 70 |
| **Parameter (RBP)** | **2017** | **2018** | **2019** |
| Epifaunal Substrate/Available Cover (0-20) | 2 | - | - |
| Pool Substrate Characterization (0-20) | 3 | - | - |
| Pool Variability (0-20) | 2 | - | - |
| Sediment Deposition (0-20) | 1 | - | - |
| Channel Flow Status (0-20) | 6 | - | - |
| Channel Alteration (0-20) | 16 | - | - |
| Channel Sinuosity (0-20) | 4 | - | - |
| Bank Stability (0-20) | 3 | - | - |
| Vegetative Protection (0-20) | 3 | - | - |
| Riparian Vegetative Zone Width (0-20) | 20 | - | - |

*RBP not collected in 2018, 2019

**Table 9. Water chemistry results at SEVE-104-X**

| Parameter | 2017 | 2018 | 2019 |
|---|---|---|---|
| Closed pH | 6.94 | 7.05 | 6.92 |
| Spec. Conductance (µS/cm) | 536.7 | 551.60 | 441.0 |
| Acid Neutralizing Capacity (µeq/L) | 499.9 | 539.60 | 413.7 |
| Dissolved Organic Carbon (mg/L) | 0.92 | 0.77 | 1.261 |
| Chloride (mg/l) | 140.08 | 135.65 | 112.03 |
| Bicarbonate (mg/L) | 0.01 | - | - |
| Bromide (mg/L) | 0.05 | 0.05 | 0.04 |
| Sulfate (mg/L) | 9.26 | 10.99 | 12.69 |
| Sodium (mg/L) | 111.7 | 80.13 | 66.05 |
| Potassium (mg/L) | 3.11 | 3.29 | 2.99 |
| Magnesium (mg/L) | 6.53 | 6.171 | 4.65 |
| Calcium (mg/L) | 14.66 | 15.30 | 11.31 |
| Total Nitrogen (mg/L) | 1.02 | 1.07 | 1.50 |
| Total Ammonia Nitrogen (mg/L) | 0.08 | 0.10 | 0.06 |
| Nitrite-N (mg/L) | 0 | 0.00 | 0.01 |
| Nitrate-N (mg/L) | 0.83 | 0.92 | 1.45 |
| Total Phosphorus (mg/L) | 0.03 | 0.00 | 0.02 |
| Orthophosphate (mg/L) | 0 | 0.00 | 0.00 |
| Copper (µg/L) | - | 0.29 | 0.45 |
| Zinc (µg/L) | - | 14.49 | 21.84 |

#### 4.1.1.2 *Geomorphology Results*

A map of the geomorphic assessment reach showing longitudinal profile extent, cross section locations, and photo monitoring stations is included in **Appendix C**. Monitoring photos follow the site map in the appendix.

A 300 foot longitudinal profile and two cross sections were surveyed at this reach. In 2017 both cross sections were located in riffle/run, while in 2018 Cross Section 1 was located in a pool and Cross Section 2 was located in a riffle/run. Both cross sections were located downstream of an eroding tributary that entered the right bank at longitudinal profile station 0+54 (see PM-2 upstream in **Appendix G**). The tributary consists of a series of active headcuts that extended into the floodplain almost to the toe of the valley wall. The source of flow to the tributary was a high-density polyethylene (HDPE) pipe that conveyed flow to the valley floor from the adjacent private property. At the time of the 2018 site visit, the pipe had broken approximately 30 feet up the slope from the valley floor and was severely eroding the valley wall. Aerial imagery indicates that the source of the outfall is likely the pond on the property at 1518 Jabez Run. During the 2019 visit, the pipe had been temporarily repaired. Station 2+80 on the longitudinal profile corresponded with the downstream end of the biological assessment station (0 m). The water surface slope was slightly less steep in 2019 at 0.52% (0.66% in 2017, and 0.59% in 2018). This was likely due to continued aggradation and grade control (remnant debris jam and riffle) near the downstream extent of the longitudinal profile. Sinuosity was measured by dividing channel length by valley length, and was 1.3 during all survey years. The longitudinal profile graph is included in **Appendix D**.

Most of the reach formed a long riffle/run with the only other discernible bed features caused by large woody debris jams that were holding grade in the downstream meander and creating scour pools. The reach consisted of approximately 63% riffles/runs and 29% pools. More pool features were observed in 2019 than in previous monitoring years. This may be due to the grade control at the downstream extent of the reach as well as the lack of sand in the stream channel compared to previous years. Pool to pool spacing was measured between the same locations on each pool (e.g. top of pool to top of pool). **Table 10** and **Table 11** summarize the characteristics of the riffles and pools respectively.

**Table 10. SEVE-104-X Summary of Riffle Lengths and Slopes**

| | Length (ft) | | | Slope (%) | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 31.8 | 28.6 | 21.3 | 2.7 | 2.0 | 0.7 |
| **Minimum** | 2.4 | 2.0 | 5.0 | 0.4 | 0.2 | 0.1 |
| **Maximum** | 81.7 | 74.0 | 51.2 | 10.6 | 8.5 | 1.8 |

**Table 11. SEVE-104-X Summary of Pool Lengths and Slopes**

| | Length (ft) | | | Max Depth (ft) | | | Slope (%) | | | Pool to Pool Spacing (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 14.4 | 5.4 | 8.2 | 0.51 | 0.76 | 0.72 | 1.1 | 0.7 | 0.2 | N/A | 35.7 | 45.6 |
| **Minimum** | 14.4 | 2.0 | 4.0 | 0.51 | 0.56 | 0.41 | 1.1 | 0.0 | 0.0 | N/A | 6.0 | 28.0 |
| **Maximum** | 14.4 | 9.0 | 19.0 | 0.51 | 0.97 | 0.96 | 1.1 | 2.7 | 0.5 | N/A | 129.0 | 67.0 |

Most bed features were made of unstable, unconsolidated sand, allowing the bed to be very mobile and features indistinct. In 2019, there was a considerable decrease of sand within the channel and the clay stream bottom was exposed. The D50 of both riffle pebble counts and the bar sample was sand. Some small gravel was also present. **Table 12** and **Table 13** summarize the characteristics of the streambed material. Particle size distribution graphs are included in **Appendix D**.

**Table 12. SEVE-104-X Pebble Count Data**

| Riffle Cross Sections | | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Pebble Count Particle Size (mm)** | D16 | 0.18 | 0.08 | 0.06 | 0.24 | 0.06 | 0.06 |
| | D35 | 0.29 | 0.18 | 0.10 | 0.38 | 0.29 | 0.06 |
| | D50 | 0.35 | 0.25 | 0.30 | 0.58 | 0.40 | 0.09 |
| | D65 | 0.42 | 0.37 | 0.81 | 1.60 | 0.60 | 0.36 |
| | D84 | 0.65 | 0.68 | 2.20 | 6.60 | 1.60 | 1.2 |
| | D95 | 1.90 | 1.50 | 6.00 | 8.60 | 12.00 | 11.00 |
| **Pebble Count Substrate Type (%)** | Silt/Clay (0 - 0.062 mm) | 10% | 15% | 33% | 4% | 20% | 49% |
| | Sand (0.052 - 2 mm) | 86% | 82% | 50% | 62% | 67% | 41% |
| | Gravel (2 - 64 mm) | 5% | 3% | 17% | 34% | 13% | 9% |
| | Cobble (64 - 256 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Boulder (256 - 4096 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Bedrock | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 13. SEVE-104-X Bar Sample Data**

| Percentile | Particle Size (mm) | | |
|---|---|---|---|
| | 2017 | 2018 | 2019 |
| D16 | <2 | <2 | <2 |
| D35 | <2 | <2 | <2 |
| D50 | <2 | <2 | 3.0 |
| D84 | 5.4 | 12.0 | 23.0 |
| D95 | 16.0 | 42.0 | 61.0 |
| D100 | 51.0 | 64.0 | 100.0 |

The bankfull cross sectional area for SEVE-104-X was fairly consistent at both cross sections and was comparable to the cross sectional area estimated by the regional curve in both 2017 and 2018. In 2019, the channel downcut into the clay stream bed causing the bankfull channel to narrow slightly and therefore the area decreased at both cross-sections. Therefore, the area predicted by the regional curve was used to help estimate bankfull. Both cross sections showed an entrenched channel (entrenchment ratios of 1.3 and 1.4) with low (<12) width-depth ratios. These factors, combined with the D50 of sand and slope less than 2%, indicate the Rosgen channel type G5c. Slumping of the top soil layer continues to occur at each cross-section. **Table 14** shows the summary of hydraulic variables at Cross Sections 1 and 2 in this reach. Cross section graphs and photos are included in **Appendix D**.

**Table 14. SEVE-104-X Summary of Bankfull Dimensions**

| Parameter | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| Top of Bank Cross Sectional Area ($ft^2$) | 113.4 | 113.2 | 124.0 | 150.8 | 147.9 | 164.1 |
| Top of Bank Width (ft) | 18.4 | 18.5 | 20.8 | 21.9 | 22.5 | 24.4 |
| Bankfull Cross Sectional Area ($ft^2$) | 10.7 | 11.2 | 9.6 | 10.3 | 10.5 | 7.9 |
| Bankfull Width (ft) | 10.2 | 9.4 | 9.0 | 10.7 | 11.1 | 9.4 |
| Bankfull Mean Depth (ft) | 1.0 | 1.2 | 1.1 | 1.0 | 0.9 | 0.8 |
| Width/Depth Ratio | 9.7 | 7.8 | 8.5 | 11.1 | 11.7 | 11.2 |
| Velocity at Bankfull (ft/s) | 4.9 | 4.9 | 6.1 | 4.7 | 4.4 | 5.4 |
| Discharge at Bankfull (cfs) | 52.5 | 55.2 | 58.4 | 48.7 | 45.8 | 42.3 |
| Entrenchment Ratio | 1.2 | 1.2 | 1.3 | 1.4 | 1.3 | 1.4 |
| Width of Flood Prone Area (ft) | 12.8 | 11.3 | 11.3 | 15.4 | 14.4 | 13.6 |
| Threshold Grain Size (mm) | 19.0 | 19.0 | 15.0 | 18.0 | 16.0 | 12.0 |
| Channel Slope (%) | 0.66 | 0.59 | 0.52 | 0.66 | 0.59 | 0.52 |
| Rosgen Classification | G5c | G5c | G5c | G5c | G5c | G5c |

SEVE-104-X had the highest percentage of erosion among the restoration sites, with 76% of the total length experiencing erosion. Of the banks experiencing erosion, 87% earned a BEHI rating of High (down from 92% in 2018), and 13% were rated as Moderate. Eroding banks ranged from 3 to 8 feet in height. No banks in this reach were within the two highest erosion rate categories. Erosion rates ranged between 0.05 to 0.319 tons/year/foot. Notable changes in erosion at SEVE-104 were due to bank undercuts and the failing of top soil layers throughout the reach. Most of the banks in this reach are currently downcut to dense clay. Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

### 4.1.2 SEVE-103-X

SEVE-103-X was the middle site on Jabez 3. The stream in this location was incised, though with frequent bars and benches that may provide local floodplain access. The upstream end of the reach was against the left valley wall, and had bank erosion into dense clay. The stream meanders toward the center of the valley in the middle to downstream end of the reach.

The drainage area of SEVE-103-X is 1.16 square miles. Impervious area covers 16% of the drainage area. The major land uses in the drainage area are as follows: low-density residential (40.5%), mixed forest (13.9%), transportation (13.5%), cropland (8.1%), large lot subdivision/forest (7.1%), and open urban land (6.9%). Approximately 37% of the drainage area is comprised of C and D soils, which have moderately high to high runoff potential, respectively (NRCS, 2007).

#### 4.1.2.1 *Biological Stream Assessment Results*

IBI scores specific to SEVE-103-X for both years of monitoring are in **Table 15** below.

**Table 15. Pre-restoration IBI scores for SEVE-103-X**

| Index of Biotic Integrity | 2017 | 2018 | 2019 |
|---|---|---|---|
| FIBI | 2.67 | 1.33 | 2.00 |
| BIBI | 3.00 | 2.14* | 2.43 |

*BIBI based on < 100 individuals

BIBI scores were either Fair or Poor in all three years of pre-restoration monitoring. Macroinvertebrate density was low in 2018, with only 71 individuals collected. Taxa richness decreased from 36 to 20 taxa between 2017 and 2018, but returned to 36 in 2019. Only three taxa have belonged to an EPT order across the three years of pre-restoration monitoring. FIBI scores were Poor in all years of monitoring. SEVE-103-X supported five fish species in 2017, including American Eel, Blacknose Dace, Eastern Mudminnow, Bluegill (*Lepomis macrochirus*), and Tessellated Darter. Pumpkinseed were collected in 2018 and no new taxa were collected during the 2019 sampling.

Scores from both of the habitat assessments reflected degraded conditions for all years. Little epifaunal and fish habitat (reflected in the instream habitat score) was available, which may have contributed to the low IBI scores. Habitat scores were slightly higher in 2019. Continuous water temperature and dissolved oxygen data for the restoration reach is included in **Appendix G**. Physical Habitat and water chemistry data are summarized in **Table 16** and **Table 17**, respectively

**Table 16. MBSS physical habitat assessment and RBP scores at SEVE-103-X**

| Parameter (MBSS physical habitat assessment) | 2017 | 2018 | 2019 |
|---|---|---|---|
| Instream habitat (0-20) | 6 | 3 | 7 |
| Epifaunal substrate (0-20) | 3 | 3 | 10 |
| Velocity/Depth Diversity (0-20) | 4 | 6 | 7 |
| Pool/Glide/Eddy Quality (0-20) | 2 | 5 | 7 |
| Pool/Glide/Eddy Extent (m) | 3 | 10 | 38 |
| Riffle Quality (0-20) | 12 | 10 | 11 |
| Riffle/Run Extent (m) | 72 | 75 | 37 |
| Embeddedness (%) | 100 | 100 | 50 |
| Shading (%) | 75 | 85 | 70 |
| **Parameter (RBP)** | **2017** | **2018** | **2019** |
| Epifaunal Substrate/Available Cover (0-20) | 3 | - | - |
| Pool Substrate Characterization (0-20) | 6 | - | - |
| Pool Variability (0-20) | 2 | - | - |
| Sediment Deposition (0-20) | 3 | - | - |
| Channel Flow Status (0-20) | 11 | - | - |
| Channel Alteration (0-20) | 20 | - | - |
| Channel Sinuosity (0-20) | 10 | - | - |
| Bank Stability (0-20) | 9 | - | - |
| Vegetative Protection (0-20) | 9 | - | - |
| Riparian Vegetative Zone Width (0-20) | 20 | - | - |

*RBP not collected in 2018, 2019

**Table 17. Water chemistry results at SEVE-103-X**

| Parameter | 2017 | 2018 | 2019 |
|---|---|---|---|
| Closed pH | 6.93 | 7.01 | 6.79 |
| Spec. Conductance (µS/cm) | 499.80 | 524.70 | 405.3 |
| Acid Neutralizing Capacity (µeq/L) | 448.60 | 484.50 | 358.7 |
| Dissolved Organic Carbon (mg/L) | 0.90 | 0.74 | 1.27 |
| Chloride (mg/l) | 132.71 | 133.00 | 105.09 |
| Bicarbonate (mg/L) | 0.01 | - | - |
| Bromide (mg/L) | 0.05 | 0.05 | 0.03 |
| Sulfate (mg/L) | 9.12 | 10.62 | 12.16 |
| Sodium (mg/L) | 108.50 | 85.63 | 63.76 |
| Potassium (mg/L) | 2.96 | 3.16 | 2.73 |
| Magnesium (mg/L) | 6.27 | 6.09 | 4.29 |
| Calcium (mg/L) | 13.74 | 14.00 | 10.13 |
| Total Nitrogen (mg/L) | 0.97 | 1.09 | 1.50 |
| Total Ammonia Nitrogen (mg/L) | 0.08 | 0.09 | 0.06 |
| Nitrite-N (mg/L) | 0.00 | 0.00 | 0.01 |
| Nitrate-N (mg/L) | 0.81 | 0.89 | 1.38 |
| Total Phosphorus (mg/L) | 0.01 | 0.00 | 0.02 |
| Orthophosphate (mg/L) | 0.00 | 0.00 | 0.00 |
| Copper (µg/L) | - | 0.25 | 0.59 |
| Zinc (µg/L) | - | 13.74 | 20.82 |

#### 4.1.2.2 *Geomorphology Results*

A map of the geomorphic assessment reach showing longitudinal profile extent, cross section locations, and photo monitoring stations is included in **Appendix C**. Monitoring photos follow the site map in the appendix.

A 300 foot longitudinal profile was surveyed at SEVE-103-X. Two cross sections were surveyed; Cross Section 1 was a riffle/run in loose sand, and Cross Section 2 was a gravel riffle in 2019. A small tributary enters the right bank between the cross sections. The downstream ends of the longitudinal profile and bio-assessment reaches lined up. The average water surface slope was 0.58% in 2019 (0.60% in 2017 and 0.58% in 2018). Sinuosity was measured by dividing channel length by valley length, and was 1.1 during all survey years. Most of the profile at SEVE-103-X degraded slightly in 2019 and prominent instream features shifted. The riffle at Station 1+58 extended 13 feet downstream compared to 28 feet in 2018 and 9 feet in 2017. The longitudinal profile graph is included in **Appendix D**.

SEVE-103-X had several short gravel riffles, but was dominated by unconsolidated sand that could be classified as riffle/run. The reach consisted of 60% riffles and 40% pools in 2019, comparable to proportions in 2018. Pool to pool spacing was measured between the same locations on each pool (e.g. top of pool to top of pool). **Table 18** and **Table 19** summarize the characteristics of the riffles and pools respectively.

**Table 18. SEVE-103-X Summary of Riffle Lengths and Slopes**

| | Length (ft) | | | Slope (%) | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 22.0 | 15.8 | 8.0 | 1.5 | 0.7 | 1.6 |
| **Minimum** | 1.8 | 2.8 | 4.0 | 0.2 | 0.0 | 0.1 |
| **Maximum** | 79.5 | 40.2 | 13.0 | 2.8 | 2.1 | 3.2 |

**Table 19. SEVE-103-X Summary of Pool Lengths and Slopes**

| | Length (ft) | | | Max Depth (ft) | | | Slope (%) | | | Pool to Pool Spacing (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 5.3 | 7.4 | 4.7 | 0.7 | 0.90 | 0.80 | 0.6 | 0.4 | 0.2 | 27.7 | 31.5 | 37.7 |
| **Minimum** | 2.8 | 4.3 | 3.5 | 0.5 | 0.64 | 0.69 | 0.0 | 0.0 | 0.0 | 5.7 | 16.0 | 21.5 |
| **Maximum** | 9.8 | 12.5 | 8.5 | 0.9 | 1.04 | 1.01 | 2.5 | 1.3 | 0.9 | 52.8 | 62.5 | 66.0 |

The bed material mostly consisted of unstable, loose sand. A few riffles containing gravel were providing grade control in the reach. Cross Section 1 was dominated by sand, and the D50 was 0.49 mm in 2019. Cross Section 2 was coarser and had a D50 of 10 mm in 2019. Overall, the reach was dominated by sand with some fine/medium gravel as indicated by the D50 of the bar sample (3.7 mm in 2019) and Cross Section 2. Cross Section 1 was largely unchanged from 2017, while Cross Section 2 has seen a shift from gravel dominated material in 2017 to an even distribution of gravel and sand in 2018 then back to gravel in 2019. **Table 20** and **Table 21** summarize the characteristics of the streambed material. Particle size distribution graphs are included in **Appendix D**.

**Table 20. SEVE-103-X Pebble Count Data**

| | | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| Pebble Count Particle Size (mm) | D16 | 0.3 | 0.28 | 0.16 | 6.3 | 0.30 | 1.30 |
| | D35 | 0.41 | 0.55 | 0.25 | 12.0 | 1.00 | 8.10 |
| | D50 | 0.58 | 0.86 | 0.49 | 17.0 | 1.80 | 10.00 |
| | D65 | 1.1 | 1.50 | 4.1 | 23.0 | 5.30 | 14.00 |
| | D84 | 8.1 | 5.20 | 8.2 | 30.0 | 12.00 | 25.00 |
| | D95 | 22.0 | 11.00 | 11.0 | 45.0 | 26.00 | 38.00 |
| Pebble Count Substrate Type (%) | Silt/Clay (0 - 0.062 mm) | 2% | 3% | 4% | 0% | 2% | 0% |
| | Sand (0.052 - 2 mm) | 73% | 70% | 59% | 8% | 51% | 26% |
| | Gravel (2 - 64 mm) | 24% | 27% | 37% | 92% | 47% | 74% |
| | Cobble (64 - 256 mm) | 1% | 0% | 0% | 0% | 0% | 0% |
| | Boulder (256 - 4096 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Bedrock | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 21. SEVE-103-X Bar Sample Data**

| Percentile | Particle Size (mm) | | |
|---|---|---|---|
| | 2017 | 2018 | 2019 |
| D16 | <2 | <2 | <2 |
| D35 | <2 | <2 | <2 |
| D50 | <2 | 5.6 | 3.7 |
| D84 | 4.6 | 31.0 | 25.0 |
| D95 | 17.0 | 55.0 | 47.0 |
| D100 | 94.0 | 100.0 | 64.0 |

At SEVE-103-X, the bankfull cross sectional areas were close to the regional curve estimate of 11.5 square feet (McCandless, 2003). Cross Section 1 differs from the regional curve because of the undercut area on the left side of the channel, but is offset by new deposition on the right bank bench. Both cross sections were entrenched to moderately entrenched (entrenchment ratio > 1.4) with width-depth ratios >12 (+/- 2.0). Sinuosity was low (1.1), but this parameter can vary by +/- 0.2 units (Rosgen, 1996). These factors and the bed material discussed above indicate a Rosgen classification of F5 and F4. Dimensions at Cross Section 1 have been fairly consistent from 2017 to 2019 with only slight variance year to year. Cross Section 2 experienced erosion between bankfull and top of bank which caused the top of bank cross sectional area to increase from 2018. **Table 22** shows the summary of hydraulic variables at Cross Sections 1 and 2 in this reach. Cross section graphs and photos are included in **Appendix D**.

**Table 22. SEVE-103-X Summary of Bankfull Dimensions**

| Parameter<br>Riffle Cross Sections | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| Top of Bank Cross Sectional Area ($ft^2$) | 100.5 | 98.3 | 94.7 | 26.6 | 23.8 | 29.9 |
| Top of Bank Width (ft) | 26.5 | 26.6 | 25.4 | 16.4 | 14.4 | 16.7 |
| Bankfull Cross Sectional Area ($ft^2$) | 13.1 | 14.1 | 12.7 | 11.5 | 11.8 | 10.8 |
| Bankfull Width (ft) | 13.2 | 13.3 | 13.5 | 13.0 | 11.8 | 12.1 |
| Bankfull Mean Depth (ft) | 1.0 | 1.1 | 0.9 | 0.9 | 1.0 | 0.9 |
| Width/Depth Ratio | 13.3 | 12.5 | 14.3 | 14.6 | 11.8 | 13.5 |
| Velocity at Bankfull (ft/s) | 4.4 | 4.5 | 4.9 | 4.2 | 4.3 | 4.8 |
| Discharge at Bankfull (cfs) | 57.1 | 63.1 | 62.1 | 48.0 | 51.2 | 51.6 |
| Entrenchment Ratio | 1.4 | 1.5 | 1.3 | 1.4 | 1.5 | 1.4 |
| Width of Flood Prone Area (ft) | 18.4 | 19.4 | 17.6 | 17.9 | 17.6 | 16.4 |
| Threshold Grain Size (mm) | 17.0 | 18.0 | 16.0 | 16.0 | 17.0 | 16.0 |
| Channel Slope (%) | 0.60 | 0.58 | 0.58 | 0.60 | 0.58 | 0.58 |
| Rosgen Classification | F5 | F5 | F5 | F5 | F5 | F4 |

SEVE-103-X was experiencing erosion on 37% of the total site length, a decrease from 46% in 2018. Of the eroded areas, 57% earned a BEHI rating of High, and 43% was rated as Moderate. The banks were actively eroding throughout the reach except where depositional features were present. White and red clay were prevalent in the eroded banks along the left valley wall. Eroding banks ranged from 2 to 5 feet in height. No banks in this reach were within the highest erosion rate category. Erosion rates ranged from 0.057 to 0.513 tons/year/foot. Erosion extent increased at SEVE-103-X from 2017 to 2018 (37% to 46%), then decreased in 2019 (46% to 37%). The percentage of erosion with a BEHI rating of High continued to decrease from 2017 (83% in 2017, 58% in 2018, 57% in 2019) as Moderate BEHI continued to increase (17% in 2017, 42% in 2018, 43% in 2019) likely due to the increase in erosion extent within the reach. Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

### 4.1.3 SEVE-102-X

SEVE-102-X is the furthest site downstream on Jabez 3, several hundred feet upstream of the confluence with the mainstem. The stream was mostly located along the right side of the valley in this location, with steep eroded banks of clay where the stream was eroding into the valley wall. Sand deposition on top of the right bank in the upstream end of the reach indicated that flows have at least local access to the floodplain during some storm events.

The drainage area of SEVE-102-X is 1.19 square miles. Impervious area covers 16% of the drainage area. The major land uses in the drainage area are as follows: low-density residential (39.7%), mixed forest (15.0%), transportation (13.2%), cropland (7.9%), large lot subdivision/forest (7.8%), and open urban land (6.8%). Approximately 36% of the drainage area is comprised of C and D soils, which have moderately high to high runoff potential, respectively (NRCS, 2007).

#### 4.1.3.1 *Biological Stream Assessment Results*

IBI scores specific to SEVE-102-X for all years of monitoring are in **Table 23** below.

**Table 23. Pre-restoration IBI scores for SEVE-102-X**

| Index of Biotic Integrity | 2017 | 2018 | 2019 |
|---|---|---|---|
| FIBI | 2.00 | 2.00 | 2.33 |
| BIBI | 2.71 | 2.14* | 2.71 |

*BIBI based on < 100 individuals

FIBI and BIBI scores were Poor in all three years of pre-restoration monitoring. Similarly to the other restoration sites, fewer macroinvertebrate taxa and individuals were present in the 2018 sample at SEVE-102-X. The number of taxa belonging to Ephemeroptera, Plecoptera, or Tricoptera (EPT) orders ranged from one to four in the three years of pre restoration monitoring. Fish species collected included American Eel, Blacknose Dace, and Eastern Mudminnow in 2017. Tessellated Darter and Pumpkinseed were collected in 2019. Scores from the RBP and physical habitat assessment reflected degraded conditions. Little epifaunal habitat or fish cover was available, which may have contributed to the low IBI scores and macroinvertebrate density.

Continuous water temperature for the restoration reach is included in **Appendix G**. Physical habitat results are located in **Table 24** and water chemistry results in **Table 25**.

**Table 24. MBSS physical habitat assessment and RBP scores at SEVE-102-X**

| Parameter (MBSS physical habitat assessment) | 2017 | 2018 | 2019 |
|---|---|---|---|
| Instream habitat (0-20) | 10 | 5 | 6 |
| Epifaunal substrate (0-20) | 3 | 4 | 6 |
| Velocity/Depth Diversity (0-20) | 3 | 6 | 7 |
| Pool/Glide/Eddy Quality (0-20) | 6 | 6 | 7 |
| Pool/Glide/Eddy Extent (m) | 2 | 8 | 42 |
| Riffle Quality (0-20) | 7 | 6 | 7 |
| Riffle/Run Extent (m) | 73 | 75 | 37 |
| Embeddedness (%) | 95 | 90 | 60 |
| Shading (%) | 85 | 65 | 70 |
| **Parameter (RBP)** | **2017** | **2018** | **2019** |
| Epifaunal Substrate/Available Cover (0-20) | 3 | - | - |
| Pool Substrate Characterization (0-20) | 6 | - | - |
| Pool Variability (0-20) | 2 | - | - |
| Sediment Deposition (0-20) | 2 | - | - |
| Channel Flow Status (0-20) | 6 | - | - |
| Channel Alteration (0-20) | 16 | - | - |
| Channel Sinuosity (0-20) | 13 | - | - |
| Bank Stability (0-20) | 3 | - | - |
| Vegetative Protection (0-20) | 16 | - | - |
| Riparian Vegetative Zone Width (0-20) | 20 | - | - |

*RBP not collected in 2018, 2019

**Table 25. Water chemistry results at SEVE-102-X**

| Parameter | 2017 | 2018 | 2019 |
|---|---|---|---|
| Closed pH | 7.02 | 7.13 | 6.82 |
| Spec. Conductance (µS/cm) | 501.60 | 527.99 | 398.90 |
| Acid Neutralizing Capacity (µeq/L) | 410.30 | 441.80 | 356.70 |
| Dissolved Organic Carbon (mg/L) | 0.95 | 0.81 | 1.33 |
| Chloride (mg/l) | 133.48 | 135.67 | 104.97 |
| Bicarbonate (mg/L) | 0.01 | - | - |
| Bromide (mg/L) | 0.05 | 0.05 | 0.03 |
| Sulfate (mg/L) | 8.87 | 10.33 | 12.06 |
| Sodium (mg/L) | 102.20 | 96.62 | 62.58 |
| Potassium (mg/L) | 2.91 | 3.09 | 2.71 |
| Magnesium (mg/L) | 6.16 | 5.82 | 4.28 |
| Calcium (mg/L) | 12.89 | 13.53 | 10.09 |
| Total Nitrogen (mg/L) | 0.98 | 1.14 | 1.44 |
| Total Ammonia Nitrogen (mg/L) | 0.07 | 0.08 | 0.06 |
| Nitrite-N (mg/L) | 0.00 | 0.00 | 0.01 |
| Nitrate-N (mg/L) | 0.83 | 0.95 | 1.34 |
| Total Phosphorus (mg/L) | 0.01 | 0.00 | 0.01 |
| Orthophosphate (mg/L) | 0.00 | 0.00 | 0.00 |
| Copper (µg/L) | - | 0.25 | 0.51 |
| Zinc (µg/L) | - | 14.31 | 20.89 |

#### 4.1.3.2 *Geomorphology Results*

A map of the geomorphic assessment reach showing longitudinal profile extent, cross section locations, and photo monitoring stations is included in **Appendix C**. Monitoring photos follow the site map in the appendix.

A 299 foot longitudinal profile and two riffle cross sections were surveyed at this reach. Station 0 on the longitudinal profile corresponded with the upstream end of the biological assessment station (75 m). The average water surface slope was 0.62% in 2019. Sinuosity was measured by dividing channel length by valley length, and was 1.1 in all years. The longitudinal profile graph is included in **Appendix D**.

Few pools existed in SEVE-102-X in 2019, and only occurred in scour areas around large woody debris and root wads. The slope of the water surface was steep through these scour pools. The reach consisted of 78% riffles and 22% pools. Pool to pool spacing was measured between the same locations on each pool (e.g. top of pool to top of pool). **Table 26** and **Table 27** summarize the characteristics of the riffles and pools respectively.

**Table 26. SEVE-102-X Summary of Riffle Lengths and Slopes**

| | Length (ft) | | | Slope (%) | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 13.4 | 26.3 | 17.3 | 0.8 | 0.5 | 0.9 |
| **Minimum** | 3.0 | 9.0 | 5.0 | 0.0 | 0.1 | 0.0 |
| **Maximum** | 35.3 | 58.0 | 53.0 | 4.0 | 0.7 | 1.5 |

**Table 27. SEVE-102-X Summary of Pool Lengths and Slopes**

| | Length (ft) | | | Max Depth (ft) | | | Slope (%) | | | Pool to Pool Spacing (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 5.5 | 8.2 | 8.4 | 0.7 | 0.7 | 0.7 | 1.8 | 1.1 | 0.3 | 28.0 | 40.8 | 64.2 |
| **Minimum** | 3 | 3.0 | 6.5 | 0.6 | 0.4 | 0.6 | 0.6 | 0.0 | 0.0 | 28.0 | 5.6 | 33.0 |
| **Maximum** | 8 | 16.0 | 10.5 | 0.8 | 1.4 | 1.0 | 3.0 | 3.9 | 0.6 | 28.0 | 77.2 | 85.5 |

Much of the bed material in SEVE-102-X consisted of loose sand which is likely mobile during most storm events. The bed had aggraded as much as a foot in areas of this reach from 2017 to 2018. In 2019, the bed degraded slightly in the upstream portion of the reach and almost a foot in the downstream portion. White and purple clay was prevalent in the eroded right bank in the downstream end of the reach. The cross sections were located in gravel riffles in 2017, and therefore both had D50s in the fine gravel category. In 2018, the cross-sections were located in riffles of loose sand. In 2019, Cross Section 2 had a D50 representative of medium gravel while Cross Section 1 was sand. Both cross sections were located in riffles in 2019. Cross Section 2 is located in the downstream portion of the reach that has degraded since 2018. The bar sample had a D50 of sand in 2019 (<2 mm), which is representative of the overwhelmingly dominant sand substrate in the reach. **Table 28** and **Table 29** summarize the characteristics of the streambed material in SEVE-102-X. Particle size distribution graphs are included in **Appendix D**.

**Table 28. SEVE-102-X Pebble Count Data**

| | | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Pebble Count Particle Size (mm)** | D16 | 1.0 | 0.26 | 0.13 | 0.35 | 0.21 | 0.30 |
| | D35 | 5.2 | 0.39 | 0.23 | 2.1 | 0.32 | 8.60 |
| | D50 | 8.0 | 0.54 | 0.63 | 6.9 | 0.41 | 14.00 |
| | D65 | 12.0 | 0.96 | 4.70 | 11.0 | 0.55 | 19.00 |
| | D84 | 24.0 | 8.70 | 22.00 | 19.0 | 4.10 | 28.00 |
| | D95 | 31.0 | 20.00 | 34.00 | 30.0 | 16.0 | 42.00 |
| **Pebble Count Substrate Type (%)** | Silt/Clay (0 - 0.062 mm) | 1% | 0% | 0% | 1% | 6% | 7% |
| | Sand (0.052 - 2 mm) | 19% | 70% | 59% | 33% | 75% | 19% |
| | Gravel (2 - 64 mm) | 80% | 30% | 41% | 66% | 19% | 74% |
| | Cobble (64 - 256 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Boulder (256 - 4096 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Bedrock | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 29. SEVE-102-X Bar Sample Data**

| Percentile | Particle Size (mm) | | |
|---|---|---|---|
| | 2017 | 2018 | 2019 |
| D16 | <2 | <2 | <2 |
| D35 | <2 | <2 | <2 |
| D50 | <2 | <2 | <2 |
| D84 | 5.3 | <2 | 15.0 |
| D95 | 19.0 | 8.0 | 37.0 |
| D100 | 34.0 | 64.0 | 64.0 |

For SEVE-102-X in 2019, the cross sectional area was slightly lower at XS-1 than at XS-2, and XS-2 was slightly higher than the regional curve estimate, which was 11.6 square feet (McCandless, 2003). Bankfull indicators in this reach included depositional low benches within the downcut channel. Both cross sections were entrenched to moderately entrenched (ratios of 1.3 and 1.5), but this parameter can vary by +/- 0.2 units (Rosgen, 1996). Based on the high width-depth ratios (17.3 and 14.5), this reach fits into the unstable F channel type. Sinuosity was low (1.1) for an F stream type, but this parameter can also vary by +/- 0.2 units (Rosgen, 1996). **Table 30** shows the summary of hydraulic variables at Cross Sections 1 and 2 in this reach. Cross section graphs and photos are included in **Appendix D**.

**Table 30. SEVE-102-X Summary of Bankfull Dimensions**

| Parameter | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| Top of Bank Cross Sectional Area (ft²) | 101.6 | 103.3 | 97.3 | 64.4 | 58.1 | 66.4 |
| Top of Bank Width (ft) | 28.8 | 27.1 | 26.9 | 21.3 | 24.1 | 22.4 |
| Bankfull Cross Sectional Area (ft²) | 12.1 | 11.6 | 9.9 | 13.2 | 13.9 | 12.6 |
| Bankfull Width (ft) | 13.4 | 13.7 | 13.1 | 12.4 | 14.5 | 13.5 |
| Bankfull Mean Depth (ft) | 0.9 | 0.8 | 0.8 | 1.1 | 1.0 | 0.9 |
| Width/Depth Ratio | 14.8 | 16.1 | 17.3 | 11.6 | 15.1 | 14.5 |
| Velocity at Bankfull (ft/s) | 4.2 | 4.0 | 3.3 | 4.6 | 4.4 | 3.9 |
| Discharge at Bankfull (cfs) | 50.8 | 46.6 | 33.1 | 61.2 | 60.6 | 49.0 |
| Entrenchment Ratio | 1.5 | 1.6 | 1.5 | 1.4 | 1.3 | 1.3 |
| Width of Flood Prone Area (ft) | 20.6 | 21.7 | 20.1 | 17.1 | 19.3 | 17.4 |
| Threshold Grain Size (mm) | 15.0 | 14.0 | 13.0 | 17.0 | 16.0 | 16.0 |
| Channel Slope (%) | 0.57 | 0.57 | 0.59 | 0.57 | 0.57 | 0.59 |
| Rosgen Classification | F5 | F5 | F5 | F5 | F5 | F4 |

SEVE-102-X was the only reach in Jabez 3 that had a bank with an erosion rate in the highest category (Extreme). Thirty-nine (39%) percent of the reach was experiencing erosion. Of the eroded areas, 9% earned a BEHI rating of Very High, 37% was rated as High, 44% was rated as Moderate, and 10% was rated as Low. Eroding banks ranged from 3 to 10 feet in height. The majority (52%) of eroding banks fell within the middle category for erosion rates (0.160 to 0.308 tons/year/foot). Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

## 4.2 Control Sites (Jabez Branch Mainstem)

The Jabez Branch mainstem sites upstream of the confluence with Jabez 3 included SEVE-207-X, SEVE-206-X, and SEVE-205-X. An old embankment runs down the valley of the mainstem, crossing the stream just upstream of SEVE-205-X. The Maryland Inventory of Historic Properties record number AA-2318 indicates that the old embankment was part of the Potomac and Aquia Creek Railroad, which was graded in the 1860s but ties or tracks were never laid because the company went bankrupt (MIHP, 2003). It was later planned to be part of the Drum Point Railroad, but that also was never completed. In the present day, large trees are growing on the embankment. In some locations, drainage patterns have been altered due to the embankment.

Fish communities at the Jabez Branch mainstem sites lacked diversity and FIBI scores were Poor. Low FIBI scores were consistent with fish cover scores in the habitat assessment, which ranged from Poor to Marginal. Epifaunal substrate scores were Marginal, but the majority of BIBI scores were Good. Additionally, at least 4 EPT taxa were present at each of the control sites.

The BANCS assessment was completed throughout the length of each geomorphic assessment reach. Results within each reach are discussed in more detail in the following sections. Sixty percent (60%) of the total length of the three control sites was experiencing erosion in 2019, an increase from 2017 and 2018 (52% and 55%, respectively). Fifty-four percent (54%) of the erosion occurred on the left banks, and forty-six percent (46%) occurred on the right. Four percent (4%) of the eroded area earned a BEHI rating of Very High, 58% was rated as High, 37% was rated as Moderate, and 4% was rated as Low. Eroding banks were about equally split between the middle three categories of erosion rates (21%, 39%, and 34%), except for 7% that fell into the lowest category. No banks were in the highest erosion rate category of Extreme.

The bed material at the control sites was a mix of sand and small gravel. Throughout the control reaches, the stream appeared to have only localized (intermittent) access to the floodplain. All control reaches exhibited the unstable Rosgen stream type Gc at the riffle cross sections (the “c” modifier indicates a slope less than 2%).

### 4.2.1 SEVE-207-X

SEVE-207-X was the furthest site upstream on the Jabez Branch mainstem. It was located in approximately the same location as Anne Arundel County Round 2 biological assessment site R2-09-10 (Crunkleton et al., 2011). The old embankment runs down the center of the valley in this location, along the right floodplain of SEVE-207-X. It separates a large, linear wetland complex from the stream. Several hundred feet downstream of SEVE-207-X, a pipe under the embankment conveys flow from the wetland to the mainstem.

The drainage area of SEVE-207-X is 3.75 square miles. Impervious area covers 12% of the drainage area. The major land uses in the drainage area are as follows: low-density residential (28.2%), mixed forest (22.5%), large lot subdivision/forest (13.0%), deciduous forest (8.6%), and cropland (8.0%). Approximately 28% of the drainage area is comprised of C and D soils, which have moderately high to high runoff potential, respectively (NRCS, 2007).

#### 4.2.1.1 *Biological Stream Assessment Results*

IBI scores specific to SEVE-207-X for all years of monitoring are in **Table 31** below.

**Table 31. Pre-restoration IBI scores for SEVE-207-X**

| Index of Biotic Integrity | 2017 | 2018 | 2019 |
|---|---|---|---|
| FIBI | 2.00 | 2.33 | 2.00 |
| BIBI | 4.43 | 4.14 | 4.43 |

BIBI scores were Good in all years of pre-restoration monitoring. The total number of macroinvertebrate taxa decreased over the three years from 39 to 30. The number of EPT taxa also decreased from 2017 to 2019. FIBI scores were Poor in all three years of pre-restoration monitoring. Six fish species were collected in pre-restoration monitoring, including American Eel, Blacknose Dace, Eastern Mudminnow, White Sucker, Bluegill, and Tessellated Darter.

Scores from both habitat assessments reflected moderately degraded physical habitat conditions. Continuous water temperature for the upstream control reach is included in **Appendix G**. Physical habitat and water chemistry results are located below in **Table 32** and **Table 33,** respectively.

**Table 32. MBSS physical habitat assessment and RBP scores at SEVE-207-X**

| Parameter (MBSS physical habitat assessment) | 2017 | 2018 | 2019 |
|---|---|---|---|
| Instream habitat (0-20) | 10 | 10 | 7 |
| Epifaunal substrate (0-20) | 8 | 11 | 8 |
| Velocity/Depth Diversity (0-20) | 8 | 11 | 11 |
| Pool/Glide/Eddy Quality (0-20) | 7 | 11 | 10 |
| Pool/Glide/Eddy Extent (m) | 35 | 31 | 52 |
| Riffle Quality (0-20) | 11 | 11 | 12 |
| Riffle/Run Extent (m) | 40 | 54 | 26 |
| Embeddedness (%) | 80 | 65 | 70 |
| Shading (%) | 85 | 80 | 80 |
| **Parameter (RBP)** | **2017** | **2018** | **2019** |
| Epifaunal Substrate/Available Cover (0-20) | 8 | - | - |
| Pool Substrate Characterization (0-20) | 9 | - | - |
| Pool Variability (0-20) | 7 | - | - |
| Sediment Deposition (0-20) | 6 | - | - |
| Channel Flow Status (0-20) | 9 | - | - |
| Channel Alteration (0-20) | 14 | - | - |
| Channel Sinuosity (0-20) | 7 | - | - |
| Bank Stability (0-20) | 4 | - | - |
| Vegetative Protection (0-20) | 14 | - | - |
| Riparian Vegetative Zone Width (0-20) | 18 | - | - |

*RBP not collected in 2018, 2019

**Table 33. Water chemistry results at SEVE-207-X**

| Parameter | 2017 | 2018 | 2019 |
|---|---|---|---|
| Closed pH | 6.82 | 6.62 | 6.72 |
| Spec. Conductance (µS/cm) | 213.10 | 209.40 | 173.90 |
| Acid Neutralizing Capacity (µeq/L) | 233.80 | 183.60 | 182.20 |
| Dissolved Organic Carbon (mg/L) | 3.70 | 3.89 | 3.01 |
| Chloride (mg/l) | 46.37 | 46.14 | 36.93 |
| Bicarbonate (mg/L) | 0.01 | - | - |
| Bromide (mg/L) | 0.03 | 0.02 | 0.02 |
| Sulfate (mg/L) | 6.96 | 7.73 | 9.40 |
| Sodium (mg/L) | 29.73 | 25.34 | 23.73 |
| Potassium (mg/L) | 1.92 | 1.86 | 1.82 |
| Magnesium (mg/L) | 3.45 | 3.10 | 2.68 |
| Calcium (mg/L) | 6.51 | 5.73 | 5.67 |
| Total Nitrogen (mg/L) | 1.19 | 1.33 | 1.26 |
| Total Ammonia Nitrogen (mg/L) | 0.05 | 0.05 | 0.04 |
| Nitrite-N (mg/L) | 0.00 | 0.00 | 0.01 |
| Nitrate-N (mg/L) | 0.94 | 1.13 | 1.15 |
| Total Phosphorus (mg/L) | 0.02 | 0.02 | 0.01 |
| Orthophosphate (mg/L) | 0.00 | 0.00 | 0.00 |
| Copper (µg/L) | - | 0.86 | 0.73 |
| Zinc (µg/L) | - | 7.33 | 8.50 |

#### 4.2.1.2 *Geomorphology Results*

A map of the geomorphic assessment reach showing longitudinal profile extent, cross section locations, and photo monitoring stations is included in **Appendix C**. Monitoring photos follow the site map in the appendix.

The longitudinal profile surveyed at SEVE-207-X was 368 feet long in order to tie into riffles at the upstream and downstream ends. Cross Section 1 and Cross Section 2 were both in riffles at the time of assessment in 2019. Cross Section 1 was a re-survey of Anne Arundel County site R2-09-10, which was established in 2011 (Crunkleton et al., 2011). During the resurvey in 2017, the right end pin could not be found, so a new pin was placed in the same approximate location. An overlay of the cross section surveys is included in **Appendix C**. The average water surface slope was 0.43%, a decrease from 0.50% in 2017. Sinuosity was measured by dividing channel length by valley length, and was 1.1. The longitudinal profile graph is included in **Appendix D**.

SEVE-207-X consisted of 26% riffles and 74% pools in 2019, similar to conditions in 2018. Pool to pool spacing was measured between the same locations on each pool (e.g. top of pool to top of pool). **Table 34** and **Table 35** summarize the characteristics of the riffles and pools respectively.

**Table 34. SEVE-207-X Summary of Riffle Lengths and Slopes**

| | Length (ft) | | | Slope (%) | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 8.8 | 3.7 | 9.4 | 1.9 | 0.1 | 1.5 |
| **Minimum** | 3.0 | 2.4 | 5.0 | 0.0 | 0.0 | 1.1 |
| **Maximum** | 26.5 | 4.8 | 20.0 | 6.3 | 0.2 | 2.4 |

**Table 35. SEVE-207-X Summary of Pool Lengths and Slopes**

| | Length (ft) | | | Max Depth (ft) | | | Slope (%) | | | Pool to Pool Spacing (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 23.6 | 14.2 | 18.4 | 1.30 | 1.10 | 1.4 | 0.1 | 0.7 | 0.2 | 41.0 | 31.6 | 38.2 |
| **Minimum** | 8.0 | 4.5 | 4.0 | 0.86 | 0.62 | 0.95 | 0.0 | 0.1 | 0.0 | 17.0 | 14.0 | 18.0 |
| **Maximum** | 75.0 | 25.2 | 54.0 | 2.14 | 1.65 | 2.26 | 0.6 | 1.8 | 0.7 | 111.0 | 51.0 | 72.0 |

The bed material in SEVE-207-X consisted mostly of fine/medium gravel and sand in 2019. The D50 at Cross Section 1 was 1.7 mm (very coarse sand) and the Cross Section 2 D50 was 8.8 mm (medium gravel). The D50 of the bar sample was fine gravel (3.3 mm). **Table 36** summarizes the characteristics of the stream bed material in SEVE-207-X. Particle size distribution graphs are included in **Appendix D**.

**Table 36. SEVE-207-X Summary of Bed Material Data**

| | | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Pebble Count Particle Size (mm)** | D16 | 1.4 | 1.1 | 0.34 | 1.7 | 0.46 | 1.40 |
| | D35 | 4.5 | 4.9 | 1.20 | 4.4 | 1.6 | 5.30 |
| | D50 | 6.5 | 7.0 | 1.70 | 6.8 | 4.1 | 8.80 |
| | D65 | 7.7 | 9.2 | 8.00 | 9.6 | 5.8 | 10.00 |
| | D84 | 12.0 | 16.0 | 11.00 | 15.0 | 8.7 | 14.00 |
| | D95 | 18.0 | 27.0 | 20.00 | 20.0 | 11.0 | 21.00 |
| **Pebble Count Substrate Type (%)** | Silt/Clay (0 - 0.062 mm) | 1% | 6% | 3% | 1% | 0% | 0% |
| | Sand (0.052 - 2 mm) | 19% | 19% | 53% | 16% | 37% | 30% |
| | Gravel (2 - 64 mm) | 80% | 75% | 44% | 83% | 63% | 70% |
| | Cobble (64 - 256 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Boulder (256 - 4096 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Bedrock | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 37. SEVE-207-X Bar Sample Data**

| | Particle Size (mm) | | |
|---|---|---|---|
| Percentile | 2017 | 2018 | 2019 |
| D16 | <2 | <2 | <2 |
| D35 | <2 | <2 | <2 |
| D50 | <2 | <2 | 3.3 |
| D84 | 7.6 | 7.0 | 20.0 |
| D95 | 16.0 | 21.0 | 37.0 |
| D100 | 36.0 | 31.5 | 64.0 |

At SEVE-207-X, the cross sectional areas were slightly lower than the regional curve estimate in all three years (26.1 square feet; McCandless, 2003). Eroding banks were common in this reach and depositional features were well below bankfull. The most consistent bankfull indicator was a slope break in the bank. Both cross sections indicate an entrenched channel, and width-depth ratios were low (<12). Sinuosity was low (1.1), but this parameter can vary by +/- 0.2 units. These parameters, the slope <2%, and bar sample D50 of very fine gravel, indicate a Rosgen stream type of G5c or G4c. Very little change in channel dimensions were evident at each cross section from 2017 to 2019 other than an increase of both undercuts at Cross Section 1 and minimal variations in bed features. **Table 38** shows the summary of hydraulic variables at Cross Sections 1 and 2 in this reach. Cross section graphs and photos are included in **Appendix D**.

**Table 38. SEVE-207-X Summary of Bankfull Dimensions**

| Parameter Riffle Cross Sections | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|
| | **2017** | **2018** | **2019** | **2017** | **2018** | **2019** |
| Top of Bank Cross Sectional Area ($ft^2$) | 78.6 | 78.7 | 81.3 | 68.8 | 69.1 | 72.6 |
| Top of Bank Width (ft) | 20.4 | 20.0 | 24.7 | 16.2 | 15.9 | 16.3 |
| Bankfull Cross Sectional Area ($ft^2$) | 24.5 | 25.6 | 24.0 | 21.3 | 22.3 | 24.7 |
| Bankfull Width (ft) | 14.6 | 15.1 | 16.5 | 12.1 | 12.1 | 12.5 |
| Bankfull Mean Depth (ft) | 1.7 | 1.7 | 1.5 | 1.8 | 1.8 | 2.0 |
| Width/Depth Ratio | 8.7 | 8.9 | 11.3 | 6.9 | 6.6 | 6.3 |
| Velocity at Bankfull (ft/s) | 5.0 | 5.1 | 5.0 | 5.4 | 5.1 | 5.9 |
| Discharge at Bankfull (cfs) | 122.2 | 129.7 | 119.4 | 114.9 | 114.3 | 145.2 |
| Entrenchment Ratio | 1.1 | 1.1 | 1.0 | 1.3 | 1.3 | 1.3 |
| Width of Flood Prone Area (ft) | 16.6 | 16.6 | 16.5 | 15.7 | 15.9 | 15.7 |
| Threshold Grain Size (mm) | 20.0 | 19.0 | 16.0 | 22.0 | 20.0 | 20.0 |
| Channel Slope (%) | 0.5 | 0.43 | 0.39 | 0.5 | 0.43 | 0.39 |
| Rosgen Classification | G5c | G5c | G5c | G5c | G5c | G4c |

Bank erosion continued to be prevalent throughout the reach, with approximately 57% of the banks in the reach eroding, same as 2017. Eroding banks ranged from 1.5 to 6.2 feet in height. Of the eroded banks, 47% earned a BEHI rating of High (43% in 2017), 46% was rated as Moderate (49% in 2017), and 7% was rated as Low (8% in 2017). No banks were rated as Very High or Extreme BEHI. Close to half (47%) of the eroding banks fell into the lowest erosion rate category (0.007 to 0.112 tons/year/foot). About a quarter of eroding banks were in the second lowest category (0.112 to 0.228 tons/year/foot), and the rest were split between the highest three categories, including one bank in the highest erosion rate category. Erosion rates in 2018 were fairly consistent to those observed in 2017. Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

### 4.2.2 SEVE-206-X

SEVE-206-X was the middle control site on the mainstem. The old embankment ran along the right floodplain near the toe of the valley wall in the vicinity of this site. No evidence of out of bank flow was noted at this site. The roots of large trees stabilized the near-vertical banks in some locations, while other banks were eroding.

The drainage area of Reach 206 is 3.97 square miles. Impervious area covers 12% of the drainage area. The major land uses in the drainage area are as follows: low-density residential (27.4%), mixed forest (22.6%), large lot subdivision/forest (14.4%), deciduous forest (8.7%), and cropland (8.2%). Approximately 27% of the drainage area is comprised of C and D soils, which have moderately high to high runoff potential, respectively (NRCS, 2007).

#### 4.2.2.1 *Biological Stream Assessment Results*

IBI scores specific to SEVE-206-X for all years of monitoring are in **Table 39** below.

**Table 39. Pre-restoration IBI scores for SEVE-206-X**

| Index of Biotic Integrity | 2017 | 2018 | 2019 |
|---|---|---|---|
| FIBI | 2.67 | 2.33 | 2.33 |
| BIBI | 4.14 | 4.14 | 4.43 |

BIBI scores at SEVE-206-X were Good in all years of pre-restoration monitoring. Macroinvertebrate richness was high, with a minimum of 30 benthic macroinvertebrate taxa present, at least six of which were EPT taxa. FIBI scores were Poor in all three years of the survey. Five fish species were collected each year and six species total, including American Eel, Blacknose Dace, White Sucker, Tessellated Darter, Eastern Mudminnow, and Pumpkinseed.

Scores from both of the habitat assessments reflected moderately degraded conditions. Continuous water temperature for the upstream control reach is included in **Appendix G**. Physical habitat and water chemistry results are located in **Table 40** and **Table 41**, respectively.

**Table 40. MBSS physical habitat assessment and RBP scores at SEVE-206-X**

| Parameter (MBSS physical habitat assessment) | 2017 | 2018 | 2019 |
|---|---|---|---|
| Instream habitat (0-20) | 5 | 4 | 9 |
| Epifaunal substrate (0-20) | 4 | 6 | 7 |
| Velocity/Depth Diversity (0-20) | 10 | 7 | 11 |
| Pool/Glide/Eddy Quality (0-20) | 10 | 6 | 11 |
| Pool/Glide/Eddy Extent (m) | 12 | 15 | 60 |
| Riffle Quality (0-20) | 12 | 7 | 11 |
| Riffle/Run Extent (m) | 65 | 65 | 15 |
| Embeddedness (%) | 95 | 100 | 75 |
| Shading (%) | 75 | 85 | 80 |
| **Parameter (RBP)** | **2017** | **2018** | **2019** |
| Epifaunal Substrate/Available Cover (0-20) | 4 | - | - |
| Pool Substrate Characterization (0-20) | 9 | - | - |
| Pool Variability (0-20) | 4 | - | - |
| Sediment Deposition (0-20) | 6 | - | - |
| Channel Flow Status (0-20) | 11 | - | - |
| Channel Alteration (0-20) | 20 | - | - |
| Channel Sinuosity (0-20) | 12 | - | - |
| Bank Stability (0-20) | 4 | - | - |
| Vegetative Protection (0-20) | 18 | - | - |
| Riparian Vegetative Zone Width (0-20) | 20 | - | - |

*RBP not collected in 2018, 2019

**Table 41. Water chemistry results at SEVE-206-X**

| Parameter | 2017 | 2018 | 2019 |
|---|---|---|---|
| Closed pH | 6.71 | 6.60 | 6.84 |
| Spec. Conductance (µS/cm) | 208.50 | 206.40 | 166.00 |
| Acid Neutralizing Capacity (µeq/L) | 224.60 | 171.80 | 169.50 |
| Dissolved Organic Carbon (mg/L) | 3.47 | 3.50 | 2.83 |
| Chloride (mg/l) | 44.70 | 49.30 | 34.19 |
| Bicarbonate (mg/L) | 0.00 | - | |
| Bromide (mg/L) | 0.03 | 0.02 | 0.02 |
| Sulfate (mg/L) | 7.32 | 7.88 | 9.74 |
| Sodium (mg/L) | 28.51 | 24.33 | 21.85 |
| Potassium (mg/L) | 1.93 | 1.83 | 1.75 |
| Magnesium (mg/L) | 3.27 | 3.07 | 2.61 |
| Calcium (mg/L) | 6.35 | 5.69 | 5.59 |
| Total Nitrogen (mg/L) | 1.30 | 1.42 | 1.30 |
| Total Ammonia Nitrogen (mg/L) | 0.06 | 0.05 | 0.04 |
| Nitrite-N (mg/L) | 0.00 | 0.00 | 0.01 |
| Nitrate-N (mg/L) | 1.05 | 1.21 | 1.21 |
| Total Phosphorus (mg/L) | 0.02 | 0.03 | 0.01 |
| Orthophosphate (mg/L) | 0.00 | 0.00 | 0.00 |
| Copper (µg/L) | - | 0.73 | 0.71 |
| Zinc (µg/L) | - | 7.36 | 8.87 |

#### 4.2.2.2 *Geomorphology Results*

A map of the geomorphic assessment reach showing longitudinal profile extent, cross section locations, and photo monitoring stations is included in **Appendix C**. Monitoring photos follow the site map in the appendix.

A 300 foot longitudinal profile was surveyed at SEVE-206-X. The middle of the bio-assessment site is just upstream of the middle of the geomorphic assessment reach. Two cross sections were surveyed in riffles. A large woody debris jam was present in the downstream end of the reach, and blocked the full width of the channel in 2017 but has since been cleared by high flow (see PM-3 upstream in **Appendix C**). The average water surface slope of the reach was 0.30%, a decrease from 0.46% in 2017. Sinuosity was measured by dividing channel length by valley length, and was 1.1. The longitudinal profile graph is included in **Appendix D**.

Scour around large woody debris created most of the pool features in SEVE-206-X. The reach consisted of 46% riffles and 54% pools, an increase in proportional pool features from 2017. Pool to pool spacing was measured between the same locations on each pool (e.g. top of pool to top of pool). **Table 42** and **Table 43** summarize the characteristics of the riffles and pools respectively.

**Table 42. SEVE-206-X Summary of Riffle Lengths and Slopes**

| | Length (ft) | | | Slope (%) | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 11.1 | 11.8 | 12.4 | 0.7 | 0.3 | 1.5 |
| **Minimum** | 3.0 | 3.0 | 5.0 | 0.0 | 0.0 | 1.1 |
| **Maximum** | 27.0 | 22.0 | 22.5 | 2.4 | 1.3 | 2.4 |

**Table 43. SEVE-206-X Summary of Pool Lengths and Slopes**

| | Length (ft) | | | Max Depth (ft) | | | Slope (%) | | | Pool to Pool Spacing (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 12.8 | 5.7 | 23.6 | 1.1 | 1.1 | 1.1 | 0.3 | 0.5 | 0.3 | 34.7 | 21.6 | 42.3 |
| **Minimum** | 4 | 1.5 | 13.5 | 0.76 | 0.73 | 0.68 | 0.0 | 0.0 | 0.0 | 23 | 12.0 | 22.5 |
| **Maximum** | 24.5 | 14.0 | 57.0 | 1.7 | 1.48 | 1.7 | 1.4 | 1.7 | 0.6 | 50 | 37.0 | 76.0 |

The bed material in SEVE-206-X consisted mainly of fine gravel and sand. The D50 at Cross Section 1 was very fine gravel and the D50 at Cross Section 2 was sand. Both cross sections exhibited increasing finer material compared to 2017. The D50 of the bar sample fell into the sand category and was representative of the overall bed material (<2 mm). **Table 44** and **Table 45** summarize the characteristics of the stream bed material at SEVE-206-X. Particle size distribution graphs are included in **Appendix D**.

**Table 44. SEVE-206-X Summary of Bed Material Data**

| | Riffle Cross Sections | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Pebble Count Particle Size (mm)** | D16 | 2.0 | 0.38 | 0.26 | 2.4 | 0.29 | 0.21 |
| | D35 | 3.6 | 0.92 | 0.48 | 6.1 | 0.79 | 0.60 |
| | D50 | 5.7 | 2.7 | 1.30 | 7.1 | 1.3 | 1.30 |
| | D65 | 6.8 | 5.1 | 3.60 | 8.5 | 3.4 | 3.60 |
| | D84 | 8.6 | 8.5 | 9.20 | 12.0 | 7.4 | 11.00 |
| | D95 | 12.0 | 12.0 | 15.00 | 17.0 | 12.0 | 19.00 |
| **Pebble Count Substrate Type (%)** | Silt/Clay (0 - 0.062 mm) | 2% | 1% | 11% | 3% | 15% | 13% |
| | Sand (0.052 - 2 mm) | 14% | 44% | 49% | 10% | 44% | 47% |
| | Gravel (2 - 64 mm) | 84% | 54% | 40% | 87% | 40% | 40% |
| | Cobble (64 - 256 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Boulder (256 - 4096 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Bedrock | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 45. SEVE-206-X Bar Sample Data**

| Percentile | Particle Size (mm) | | |
|---|---|---|---|
| | 2017 | 2018 | 2019 |
| D16 | <2 | <2 | <2 |
| D35 | <2 | <2 | <2 |
| D50 | <2 | <2 | 3.4 |
| D84 | 6.1 | 6.6 | 13.0 |
| D95 | 12.0 | 12.0 | 21.0 |
| D100 | 27.0 | 31.5 | 31.5 |

For SEVE-206-X, the cross sectional area was slightly lower at XS-1 than at XS-2, and both were slightly lower than the regional curve estimate, which was 27.1 square feet (McCandless, 2003). A slope break in the bank was the most consistent bankfull indicator, as most depositional bars were well below bankfull. Both cross sections showed an entrenched channel, with low width-depth ratios (<12). Sinuosity was low (1.1), but this parameter can vary by +/- 0.2 units (Rosgen, 1996). Based on these factors and the slope <2%, the channel fits into a G5c stream type. Channel dimensions saw little change from 2017. **Table 46** shows the summary of hydraulic variables at Cross Sections 1 and 2 in this reach. Cross section graphs and photos are included in **Appendix D**.

**Table 46. SEVE-206-X Summary of Bankfull Dimensions**

| Parameter<br>Riffle Cross Sections | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| Top of Bank Cross Sectional Area ($ft^2$) | 75.5 | 75.7 | 75.2 | 84.4 | 79.2 | 82.0 |
| Top of Bank Width (ft) | 21.2 | 21.2 | 20.4 | 24.1 | 23.9 | 23.6 |
| Bankfull Cross Sectional Area ($ft^2$) | 23.6 | 24.4 | 26.2 | 24.9 | 25.3 | 25.5 |
| Bankfull Width (ft) | 14.2 | 14.6 | 14.7 | 16.1 | 17.1 | 17.3 |
| Bankfull Mean Depth (ft) | 1.7 | 1.7 | 1.8 | 1.5 | 1.5 | 1.5 |
| Width/Depth Ratio | 8.5 | 8.7 | 8.2 | 10.4 | 11.5 | 11.7 |
| Velocity at Bankfull (ft/s) | 5.5 | 4.5 | 5.1 | 5.4 | 4.2 | 4.7 |
| Discharge at Bankfull (cfs) | 129.8 | 109.3 | 135.0 | 133.9 | 107.1 | 119.5 |
| Entrenchment Ratio | 1.3 | 1.2 | 1.2 | 1.4 | 1.3 | 1.3 |
| Width of Flood Prone Area (ft) | 18.0 | 17.5 | 18.1 | 22.3 | 22.6 | 22.9 |
| Threshold Grain Size (mm) | 21.0 | 14.0 | 15.0 | 20.0 | 13.0 | 13.0 |
| Channel Slope (%) | 0.46 | 0.30 | 0.30 | 0.46 | 0.30 | 0.30 |
| Rosgen Classification | G5c | G5c | G5c | G5c | G5c | G5c |

SEVE-206-X had the lowest percent of eroded banks of the three control sites, with 47% of the total length being eroded despite an increase from 40% in 2017. Of the eroded banks, 51% earned a BEHI rating of High (45% in 2017), and 49% was rated as Moderate (55% in 2017), with no other BEHI categories present. Eroded banks ranged from 1.5 to 5 feet in height. Erosion rates split evenly into the three lowest categories. Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

#### 4.2.3 SEVE-205-X

SEVE-205-X is the furthest downstream of the three control sites, and is located just upstream of the confluence with Jabez 3. The old embankment crosses the stream upstream of this site. Logs sticking vertically out of the streambed where the embankment crosses may have been bridge piers (see PM-1 downstream in **Appendix C**). Downstream of this site, a narrow strip of land separated the mainstem from Jabez 3 where the two channels ran parallel to each other before diverging again prior to the confluence approximately 30 meters further downstream.

The drainage area of Reach 205 is 4.07 square miles. Impervious area covers 11% of the drainage area. The major land uses in the drainage area are as follows: low-density residential (27.0%), mixed forest

(23.4%), large lot subdivision/forest (14.4%), deciduous forest (8.8%), and cropland (8.2%). Approximately 27% of the drainage area is comprised of C and D soils, which have moderately high to high runoff potential, respectively (NRCS, 2007).

#### 4.2.3.1 *Biological Stream Assessment Results*

IBI scores specific to SEVE-205-X are below in **Table 47**.

**Table 47. Pre-restoration IBI scores for SEVE-205-X**

| Index of Biotic Integrity | 2017 | 2018 | 2019 |
|---|---|---|---|
| FIBI | 2.67 | 2.33 | 2.33 |
| BIBI | 4.43 | 3.86 | 4.43 |

The BIBI score at SEVE-205-X was Good in 2017 and 2019, and fair in 2018. Macroinvertebrate taxa richness was lower than at any other control site. EPT taxa richness ranged from four to eight in the three years of pre-restoration monitoring. FIBI scores were consistently Poor during pre-restoration monitoring. SEVE-205-X supported four fish species in 2017 and 2018 and five species in 2019, including American Eel, Blacknose Dace, White Sucker, Tessellated Darter, and Eastern Mudminnow.

Scores from both of the habitat assessments reflected moderately degraded conditions. Continuous water temperature for the upstream control reach is included in **Appendix G**. Physical habitat and water chemistry results are summarized below in **Table 48** and **Table 49**, respectively.

**Table 48. MBSS physical habitat assessment and RBP scores at SEVE-205-X**

| Parameter (MBSS physical habitat assessment) | 2017 | 2018 | 2019 |
|---|---|---|---|
| Instream habitat (0-20) | 4 | 6 | 6 |
| Epifaunal substrate (0-20) | 5 | 6 | 4 |
| Velocity/Depth Diversity (0-20) | 10 | 11 | 7 |
| Pool/Glide/Eddy Quality (0-20) | 7 | 12 | 6 |
| Pool/Glide/Eddy Extent (m) | 22 | 16 | 25 |
| Riffle Quality (0-20) | 11 | 11 | 14 |
| Riffle/Run Extent (m) | 57 | 63 | 50 |
| Embeddedness (%) | 90 | 90 | 80 |
| Shading (%) | 80 | 70 | 75 |
| **Parameter (RBP)** | **2017** | **2018** | **2019** |
| Epifaunal Substrate/Available Cover (0-20) | 10 | - | - |
| Pool Substrate Characterization (0-20) | 14 | - | - |
| Pool Variability (0-20) | 14 | - | - |
| Sediment Deposition (0-20) | 2 | - | - |
| Channel Flow Status (0-20) | 8 | - | - |
| Channel Alteration (0-20) | 17 | - | - |
| Channel Sinuosity (0-20) | 13 | - | - |
| Bank Stability (0-20) | 4 | - | - |
| Vegetative Protection (0-20) | 15 | - | - |
| Riparian Vegetative Zone Width (0-20) | 19 | - | - |

*RBP not collected in 2018, 2019

**Table 49. Water chemistry results at SEVE-205-X**

| Parameter | 2017 | 2018 | 2019 |
|---|---|---|---|
| Closed pH | 6.87 | 6.60 | 6.79 |
| Spec. Conductance (µS/cm) | 209.50 | 201.30 | 167.50 |
| Acid Neutralizing Capacity (µeq/L) | 222.90 | 161.10 | 152.67 |
| Dissolved Organic Carbon (mg/L) | 3.23 | 3.27 | 3.12 |
| Chloride (mg/l) | 44.71 | 42.30 | 33.70 |
| Bicarbonate (mg/L) | 0.01 | - | - |
| Bromide (mg/L) | 0.03 | 0.02 | 0.02 |
| Sulfate (mg/L) | 7.56 | 8.08 | 10.65 |
| Sodium (mg/L) | 27.77 | 23.30 | 21.78 |
| Potassium (mg/L) | 1.95 | 1.85 | 1.70 |
| Magnesium (mg/L) | 3.35 | 3.16 | 2.77 |
| Calcium (mg/L) | 6.50 | 5.82 | 5.30 |
| Total Nitrogen (mg/L) | 1.26 | 1.41 | 1.46 |
| Total Ammonia Nitrogen (mg/L) | 0.06 | 0.06 | 0.02 |
| Nitrite-N (mg/L) | 0.00 | 0.00 | 0.01 |
| Nitrate-N (mg/L) | 1.02 | 1.22 | 1.31 |
| Total Phosphorus (mg/L) | 0.01 | 0.02 | 0.01 |
| Orthophosphate (mg/L) | 0.00 | 0.00 | 0.00 |
| Copper (µg/L) | - | 0.86 | 0.59 |
| Zinc (µg/L) | - | 7.57 | 7.56 |

#### 4.2.3.2 *Geomorphology Results*

A map of the geomorphic assessment reach showing longitudinal profile extent, cross section locations, and photo monitoring stations is included in **Appendix C**. Monitoring photos follow the site map in the appendix.

A 300 foot longitudinal profile was surveyed at SEVE-205-X. Station 0 on the longitudinal profile was located among the old bridge piers where the embankment crosses the stream, and slightly upstream of the upstream end of the biological assessment station (75 meters). On the left floodplain, there were wetlands along the valley wall that were separated from the stream by the embankment. The average water surface slope was 0.30%, a decrease from 0.34% in 2017. Sinuosity was measured by dividing channel length by valley length, and was 1.1. The longitudinal profile graph is included in **Appendix D**.

The reach consisted of 25% riffles and 75% pools, an increase in proportion of pool features from 2017. Pool to pool spacing was measured between the same locations on each pool (e.g. top of pool to top of pool). **Table 50** and **Table 51** summarize the characteristics of the riffles and pools respectively.

**Table 50. SEVE-205-X Summary of Riffle Lengths and Slopes**

| | Length (ft) | | | Slope (%) | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 9.9 | 6.0 | 10.3 | 0.8 | 0.5 | 0.3 |
| **Minimum** | 4.0 | 1.5 | 3.0 | 0.0 | 0.0 | 0.0 |
| **Maximum** | 23.0 | 12.6 | 19.0 | 1.5 | 1.3 | 1.0 |

**Table 51. SEVE-205-X Summary of Pool Lengths and Slopes**

| | Length (ft) | | | Max Depth (ft) | | | Slope (%) | | | Pool to Pool Spacing (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 13.5 | 23.0 | 13.7 | 1.2 | 1.3 | 1.3 | 0.1 | 0.4 | 0.3 | 36.7 | 40.4 | 55.6 |
| **Minimum** | 3.3 | 7.0 | 8 | 0.8 | 0.8 | 0.96 | 0.0 | 0.0 | 0.0 | 14 | 18.0 | 24 |
| **Maximum** | 26.5 | 53.4 | 26 | 1.44 | 2.28 | 1.7 | 0.5 | 1.4 | 0.4 | 64.5 | 65.9 | 84 |

The bed material was a mix of sand and gravel with some large woody debris in the channel. The D50s of both cross sections were 1 mm or less (sand) and decreased from 6 mm (fine gravel) in 2017. The D50 of the bar sample of sand (<2 mm) was representative of the proportion of sand in the reach. **Table 52** and **Table 53** summarize the characteristics of the stream bed material in this reach. Particle size distribution graphs are included in **Appendix D**.

**Table 52. SEVE-205-X Summary of Bed Material Data**

| | Riffle Cross Sections | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Pebble Count Particle Size (mm)** | D16 | 0.52 | 0.06 | 0.19 | 1.6 | 0.50 | 0.25 |
| | D35 | 2.9 | 0.45 | 0.40 | 4.5 | 0.75 | 0.35 |
| | D50 | 6.3 | 0.73 | 0.68 | 6.4 | 1.00 | 0.46 |
| | D65 | 7.8 | 1.40 | 1.00 | 7.4 | 1.50 | 0.62 |
| | D84 | 11.0 | 6.50 | 1.50 | 9.8 | 4.20 | 0.89 |
| | D95 | 14.0 | 11.0 | 1.90 | 14.0 | 8.80 | 1.50 |
| **Pebble Count Substrate Type (%)** | Silt/Clay (0 - 0.062 mm) | 3% | 20% | 3% | 0% | 0% | 0% |
| | Sand (0.052 - 2 mm) | 28% | 50% | 94% | 18% | 76% | 99% |
| | Gravel (2 - 64 mm) | 69% | 29% | 3% | 82% | 24% | 1% |
| | Cobble (64 - 256 mm) | 0% | 1% | 0% | 0% | 0% | 0% |
| | Boulder (256 - 4096 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Bedrock | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 53. SEVE-205-X Bar Sample Data**

| Percentile | Particle Size (mm) | | |
|---|---|---|---|
| | 2017 | 2018 | 2019 |
| D16 | <2 | <2 | <2 |
| D35 | <2 | <2 | <2 |
| D50 | <2 | <2 | 2.1 |
| D84 | 6.8 | 6.1 | 9.5 |
| D95 | 12.0 | 11.0 | 28.0 |
| D100 | 18.0 | 16.0 | 64.0 |

The cross sectional area at SEVE-205-X was fairly consistent at both cross sections and was slightly lower than the regional curve estimate, which was 27.6 square feet (McCandless, 2003). The bankfull indicators were primarily slope breaks on the banks. Sand deposition on top of the bank upstream of Cross Section 1 indicated that reach SEVE-207-X has floodplain access at high flows in some locations, despite the entrenchment ratios of 1.3 and 1.5 at the cross section locations. The width-depth ratios were low (<12), and sinuosity was also low (1.1), but this parameter can vary by +/- 0.2 units (Rosgen, 1996). These factors, in combination with sand as the dominant bed material, indicate a G5c stream type. Cross Section 1 saw an increase in both top of bank and bankfull cross sectional area in 2018 due to erosion of the right bank. Cross Section 2 was a decrease in top of bank cross sectional area because of deposition on the left bank while bankfull cross sectional area increased as scour and erosion occurred at the toe of the right bank. **Table 54** shows the summary of hydraulic variables at Cross Sections 1 and 2 in this reach. Cross section graphs and photos are included in **Appendix D**.

**Table 54. SEVE-205-X Summary of Bankfull Dimensions**

| Parameter<br>Riffle Cross Sections | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| Top of Bank Cross Sectional Area (ft²) | 58.4 | 61.7 | 55.1 | 63.1 | 60.2 | 56.8 |
| Top of Bank Width (ft) | 15.9 | 15.9 | 15.2 | 19.5 | 18.5 | 17.5 |
| Bankfull Cross Sectional Area (ft²) | 25.8 | 26.5 | 23.9 | 25.9 | 27.1 | 27.6 |
| Bankfull Width (ft) | 12.9 | 12.6 | 12.4 | 13.2 | 13.5 | 14.0 |
| Bankfull Mean Depth (ft) | 2.0 | 2.1 | 1.9 | 2.0 | 2.0 | 2.0 |
| Width/Depth Ratio | 6.4 | 6.0 | 6.4 | 6.8 | 6.7 | 7.1 |
| Velocity at Bankfull (ft/s) | 5.1 | 4.8 | 5.7 | 4.9 | 4.8 | 5.9 |
| Discharge at Bankfull (cfs) | 132.1 | 126.0 | 134.9 | 128.4 | 130.7 | 161.3 |
| Entrenchment Ratio | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 | 1.5 |
| Width of Flood Prone Area (ft) | 15.4 | 15.9 | 15.7 | 18.1 | 19.9 | 20.8 |
| Threshold Grain Size (mm) | 18.0 | 15.0 | 10.0 | 17.0 | 16.0 | 11.0 |
| Channel Slope (%) | 0.34 | 0.30 | 0.21 | 0.34 | 0.30 | 0.21 |
| Rosgen Classification | G5c | G5c | G5c | G5c | G5c | G5c |

SEVE-205-X was the only control reach that had a BEHI rating of Very High. Sixty-one percent of the total length monitored was experiencing erosion. Of the eroded banks, 14% earned a BEHI rating of Very High, 81% was rated as High, and 6% was rated as Moderate. Eroded banks ranged from 3 to 4.5 feet in height. Most eroded banks fell into the middle and second lowest erosion rate category. The narrow strip of land between the mainstem and Jabez 3 at the downstream end of this reach has eroded through and intermittently acts as the Jabez 3 confluence with the mainstem. Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

## 4.3 Downstream Control

### 4.3.1 SEVE-201-X

Site SEVE-201-X was located downstream of the confluence of Jabez 3 and the Jabez Branch mainstem. The drainage area of SEVE-201-X is 5.29 square miles. Impervious area covers 12% of the drainage area. The major land uses in the drainage area are as follows: low-density residential (29.7%), mixed forest (22.0%), large lot subdivision/forest (12.8%), cropland (8.1%), deciduous forest (6.8%), and transportation (5.6%). Approximately 29% of the drainage area is comprised of C and D soils, which have moderately high to high runoff potential, respectively (NRCS, 2007).

#### 4.3.1.1 *Biological Stream Assessment Results*

IBI scores specific to SEVE-201-X for all years of monitoring are in **Table 55** below.

**Table 55. Pre-restoration IBI scores for SEVE-201-X**

| Index of Biotic Integrity | 2017 | 2018 | 2019 |
|---|---|---|---|
| FIBI | 2.67 | 2.67 | 2.33 |
| BIBI | 5.00 | 4.14 | 4.71 |

BIBI scores at SEVE-201-X were Good in all three years of pre-restoration monitoring. Macroinvertebrate taxa richness ranged between 29 and 41 during the three years of pre-restoration monitoring. At least eight EPT taxa were present in all years of sampling. FIBI scores were Poor in 2017, 2018 and 2019. SEVE-201-X has supported seven fish species, including American Eel, Blacknose Dace, White Sucker, Tessellated Darter, Eastern Mudminnow, Bluegill, and Pumpkinseed. Note that macroinvertebrate metrics included in this section reflect only the data used in BIBI calculations and not the additional organisms identified for the community level analysis in **Section 4.5**.

Scores from both of the habitat assessments reflected intact instream conditions. Continuous water temperature for the downstream control reach is included in **Appendix G**. Physical habitat and water chemistry results are summarized in **Table 56** and **Table 57** below.

**Table 56. MBSS physical habitat assessment and RBP scores at SEVE-201-X**

| Parameter (MBSS physical habitat assessment) | 2017 | 2018 | 2019 |
|---|---|---|---|
| Instream habitat (0-20) | 12 | 7 | 7 |
| Epifaunal substrate (0-20) | 14 | 6 | 4 |
| Velocity/Depth Diversity (0-20) | 10 | 7 | 8 |
| Pool/Glide/Eddy Quality (0-20) | 10 | 9 | 8 |
| Pool/Glide/Eddy Extent (m) | 35 | 9 | 65 |
| Riffle Quality (0-20) | 11 | 11 | 12 |
| Riffle/Run Extent (m) | 40 | 75 | 10 |
| Embeddedness (%) | 95 | 85 | 75 |
| Shading (%) | 85 | 85 | 60 |
| **Parameter (RBP)** | **2017** | **2018** | **2019** |
| Epifaunal Substrate/Available Cover (0-20) | 7 | - | - |
| Pool Substrate Characterization (0-20) | 8 | - | - |
| Pool Variability (0-20) | 5 | - | - |
| Sediment Deposition (0-20) | 3 | - | - |
| Channel Flow Status (0-20) | 13 | - | - |
| Channel Alteration (0-20) | 20 | - | - |
| Channel Sinuosity (0-20) | 8 | - | - |
| Bank Stability (0-20) | 4 | - | - |
| Vegetative Protection (0-20) | 18 | - | - |
| Riparian Vegetative Zone Width (0-20) | 20 | - | - |

*RBP not collected in 2018, 2019

**Table 57. Water chemistry results at SEVE-201-X**

| Parameter | 2017 | 2018 | 2019 |
|---|---|---|---|
| Closed pH | 6.94 | 6.96 | 6.86 |
| Spec. Conductance (µS/cm) | 276.90 | 498.97 | 219.10 |
| Acid Neutralizing Capacity (µeq/L) | 241.10 | 361.70 | 194.10 |
| Dissolved Organic Carbon (mg/L) | 2.12 | 1.98 | 2.91 |
| Chloride (mg/l) | 67.57 | 131.46 | 47.49 |
| Bicarbonate (mg/L) | 0.01 | - | - |
| Bromide (mg/L) | 0.04 | 0.02 | 0.03 |
| Sulfate (mg/L) | 8.16 | 8.87 | 11.02 |
| Sodium (mg/L) | 38.41 | 76.75 | 29.46 |
| Potassium (mg/L) | 2.10 | 2.44 | 1.95 |
| Magnesium (mg/L) | 3.77 | 4.08 | 3.21 |
| Calcium (mg/L) | 7.61 | 11.50 | 6.17 |
| Total Nitrogen (mg/L) | 1.26 | 1.23 | 1.44 |
| Total Ammonia Nitrogen (mg/L) | 0.06 | 0.07 | 0.03 |
| Nitrite-N (mg/L) | 0.00 | 0.00 | 0.01 |
| Nitrate-N (mg/L) | 1.06 | 1.02 | 1.34 |
| Total Phosphorus (mg/L) | 0.01 | 0.05 | 0.01 |
| Orthophosphate (mg/L) | 0.00 | 0.00 | 0.00 |
| Copper (µg/L) | - | 0.71 | 0.51 |
| Zinc (µg/L) | - | 9.70 | 10.23 |

#### 4.3.1.2 *Geomorphology Results*

A map of the geomorphic assessment reach showing longitudinal profile extent, cross section locations, and photo monitoring stations is included in **Appendix C**. Monitoring photos follow the site map in the appendix.

A 300 foot longitudinal profile was surveyed at SEVE-201-X. In 2019, the two cross sections were surveyed, one in a riffle/run, and the other in a pool. An existing side channel along the right bank of the reach was higher than the baseflow water elevation, and therefore only conveyed flow during certain storm events. It branched off from the main channel at station 0+95 on the longitudinal profile (see PM-2 right bank in **Appendix C**) and rejoined it at station 1+90 (see PM-4 right bank). The SEVE-201-X average water surface slope was 0.35% in 2019, an increase from 0.28% in 2018 and decrease from 0.45% in 2017. Sinuosity was measured by dividing channel length by valley length, and was 1.2 throughout all monitoring years. The longitudinal profile graph is included in **Appendix D**.

Several woody debris jams continue to create more stable pool features in SEVE-201-X than any other reach. The reach consisted of 23% riffles and 77% pools in 2019, a substantial increase in proportion of pools from 2018 (49% riffle, 51% pool). Pool to pool spacing was measured between the same locations on each pool (e.g. top of pool to top of pool). **Table 58** and **Table 59** summarize the characteristics of the riffles and pools, respectively.

**Table 58. SEVE-201-X Summary of Riffle Lengths and Slopes**

| | Length (ft) | | | Slope (%) | | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 6.5 | 7.3 | 8.4 | 0.9 | 0.6 | 0.9 |
| **Minimum** | 3.3 | 4.5 | 1.0 | 0.0 | 0.0 | 0.0 |
| **Maximum** | 15.6 | 13.0 | 20.5 | 2.0 | 1.3 | 2.0 |

**Table 59. SEVE-201-X Summary of Pool Lengths and Slopes**

| | Length (ft) | | | Max Depth (ft) | | | Slope (%) | | | Pool to Pool Spacing (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Mean** | 12.1 | 8.3 | 32.9 | 1.3 | 1.1 | 1.1 | 0.4 | 0.4 | 0.3 | 27.5 | 30.6 | 45.6 |
| **Minimum** | 5.7 | 4.0 | 6.0 | 0.75 | 0.87 | 0.82 | 0.0 | 0.0 | 0.0 | 9.4 | 14.5 | 19.0 |
| **Maximum** | 25.3 | 18.0 | 2.0 | 2.72 | 1.4 | 1.47 | 1.2 | 0.8 | 1.0 | 76.2 | 91.0 | 106.5 |

Bed material was a mix of sand and some gravel in 2019. The D50 of Cross Section 1 was very coarse sand. The D50 of Cross Section 2 was fine gravel, which was coarser compared to 2018. Small gravel was much more prevalent in 2017 at both cross sections but has since been reduced by the influx of finer material. **Table 60** and **Table 61** summarize the characteristics of the stream bed material in SEVE-201-X. Particle size distribution graphs are included in **Appendix D**.

**Table 60. SEVE-201-X Summary of Bed Material Data**

| | Riffle Cross Sections | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|---|
| | | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| **Pebble Count Particle Size (mm)** | D16 | 2.1 | 0.15 | 0.28 | 0.44 | 0.13 | 0.36 |
| | D35 | 6.7 | 0.27 | 1.00 | 3.10 | 0.29 | 1.40 |
| | D50 | 9.0 | 0.36 | 1.70 | 7.00 | 0.43 | 4.20 |
| | D65 | 11.0 | 0.49 | 4.70 | 9.20 | 0.68 | 7.00 |
| | D84 | 16.0 | 1.20 | 9.50 | 18.00 | 1.60 | 13.00 |
| | D95 | 25.0 | 14.0 | 15.0 | 29.0 | 7.40 | 20.00 |
| **Pebble Count Substrate Type (%)** | Silt/Clay (0 - 0.062 mm) | 0% | 0% | 5% | 0% | 2% | 7% |
| | Sand (0.052 - 2 mm) | 15% | 91% | 50% | 32% | 85% | 38% |
| | Gravel (2 - 64 mm) | 85% | 9% | 45% | 68% | 13% | 55% |
| | Cobble (64 - 256 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Boulder (256 - 4096 mm) | 0% | 0% | 0% | 0% | 0% | 0% |
| | Bedrock | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 61. SEVE-201-X Bar Sample Data**

| | Particle Size (mm) | | |
|---|---|---|---|
| **Percentile** | 2017 | 2018 | 2019 |
| D16 | <2 | <2 | <2 |
| D35 | <2 | <2 | <2 |
| D50 | 2.5 | <2 | 2.4 |
| D84 | 7.4 | 2.0 | 12.0 |
| D95 | 16.0 | 16.0 | 32.0 |
| D100 | 34.0 | 64.0 | 64.0 |

Sand deposition on the floodplain in several locations indicated that the reach had access to the floodplain, though this may occur infrequently. Cross Section 1 was located slightly upstream of the biological assessment station 75m, and Cross Section 2 was slightly upstream of the biological assessment station's midpoint. For SEVE-201-X, the cross sectional area was slightly higher at Cross Section 1 than at Cross Section 2 for all assessments. In 2019, both cross sections were lower than the regional curve estimate, which was 33.2 square feet (McCandless, 2003). The bankfull indicators in this reach included slope breaks in the banks and scour lines. Upstream of Cross Section 2, the side channel would divert some water during high flows that would otherwise flow through XS-2, causing the bankfull to be slightly lower than at XS-1. Flood prone width at both cross sections was not out of bank in 2019, and therefore entrenchment ratios were lower than previous years (1.9 and 1.3). This was due to degradation across the stream bed throughout the reach. Width-depth ratios were low (<12). Substantial aggradation caused cross-sectional areas at both cross sections to increase in 2018. In 2019, a combination of deposition and degradation narrowing the bankfull channel continued to decrease bankfull cross sectional area.  Based on these factors, and D50s between sand and gravel, the reach was most indicative of a G5/4 Rosgen stream type. This is a change from previous years due to the degradation of the stream bed and subsequent decrease in entrenchment ratio. Cross Section 1 is classified as an E channel, but was in transition to a G channel at the time of the survey in 2019. **Table 62** shows the summary of hydraulic variables at Cross Sections 1 and 2 in this reach. Cross section graphs and photos are included in **Appendix D**.

**Table 62. SEVE-201-X Summary of Bankfull Dimensions**

| Parameter | XS-1 | | | XS-2 | | |
|---|---|---|---|---|---|---|
| Riffle Cross Sections | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| Top of Bank Cross Sectional Area ($ft^2$) | 64.1 | 59.9 | 60.6 | 49.2 | 38.7 | 48.4 |
| Top of Bank Width (ft) | 20.0 | 19.9 | 18.9 | 14.1 | 13.7 | 13.8 |
| Bankfull Cross Sectional Area ($ft^2$) | 30.4 | 35.1 | 30.0 | 27.3 | 28.5 | 24.8 |
| Bankfull Width (ft) | 17.0 | 18.2 | 17.0 | 12.9 | 12.8 | 12.4 |
| Bankfull Mean Depth (ft) | 1.8 | 1.9 | 1.8 | 2.1 | 2.2 | 2.0 |
| Width/Depth Ratio | 9.5 | 9.5 | 9.6 | 6.1 | 5.8 | 6.2 |
| Velocity at Bankfull (ft/s) | 4.6 | 4.8 | 5.6 | 4.9 | 4.7 | 5.8 |
| Discharge at Bankfull (cfs) | 140.6 | 166.8 | 168.6 | 132.9 | 134.8 | 142.8 |
| Entrenchment Ratio | 3.8 | 3.0 | 1.9 | 10.8 | 3.5 | 1.3 |
| Width of Flood Prone Area (ft) | 65.0 | 55.0 | 31.5 | 140.0 | 140.0 | 15.7 |
| Threshold Grain Size (mm) | 15.0 | 15.0 | 18.0 | 16.0 | 15.0 | 18.0 |
| Channel Slope (%) | 0.45 | 0.28 | 0.37 | 0.45 | 0.28 | 0.37 |
| Rosgen Classification | E4/5 | E5 | E5/4 (G5/4) | E4/5 | E5 | G4/5 |

Bank erosion was present in over half of this reach (57%) in 2019, and eroding banks ranged from 4 to 5 feet in height. Of the eroded banks, 40% was rated as High and 60% was rated as Moderate. Eroding banks were concentrated only in the three lowest erosion rate categories, with the majority in the middle category (0.308 – 0.640 tons/year/foot). Maps showing the distribution of erosion rates and BANCS field data and calculations are included in **Appendix E**.

### 4.4 Post-Storm Visit

A post-storm monitoring site visit was performed at the Jabez Branch site on October 28, 2019. On October 27, 2019 a discharge greater than 11 cfs (cubic feet per second) was recorded at USGS Stream

Gage 01589795 (South Fork Jabez Branch at Millersville, MD). The gage peaked at 21.7 cfs and remained above 11 cfs for approximately 45 minutes. Monitoring photos from 2017, 2018, and 2019 can be found in **Appendix F**.

Several changes to the stream channel were noted during the post-storm monitoring site visit; however, most of the channel appeared to have experienced only minor changes since the first monitoring year. Some shifting of sediment and changes to mid-channel bars were noted along with some minor bank erosion.

On the Jabez 3 tributary, site SEVE-104-X had developed a small headcut in the clay stream bed near the beginning of the longitudinal profile that was first noted during the 2019 geomorphic assessment. Since the August 2019 assessment, the downcutting at this location appeared to worsen (**Appendix F, PM-1 Downstream from Long Pro Start**). Just upstream of the site, the left valley wall is sliding down into the stream therefore forcing flow into the right bank which has undercut into the clay bank (**Appendix F**, **PM-1 Upstream from Long Pro Start**). At site SEVE-103-X, there were little to no changes observed outside of shifting substrate. At site SEVE-102-X, fresh sediment deposits were noticeable on point bars and downstream of instream woody debris, otherwise, no major changes had occurred.

On the mainstem of Jabez Branch, site SEVE-207-X had accumulated a debris jam that was building near the downstream end of the reach (**Appendix F, PM-6 Upstream from Long Pro End**). There was also a tree that had fallen across the channel at the upstream extent of the reach (**Appendix F, PM-1 Upstream from Long Pro Start**). At site SEVE-206-X, no major changes had occurred throughout the reach following the storm event. At site SEVE-205-X, depositional features had shifted throughout the reach. At site SEVE-201-X, loose sediment deposition was noticeable throughout the reach.

## 4.5 Dissolved Oxygen Monitoring

Dissolved oxygen monitoring in Jabez Branch began in 2018. Collection of reliable continuous dissolved oxygen data proved to be difficult during the summer months in 2018. The higher than normal amount of precipitation in 2018, high stream flows, and associated bed load resulted in continual sedimentation of the loggers at both sites in the Jabez Branch watershed. As a result of the dissolved oxygen loggers becoming dewatered and/or buried in sediment, large portions of the dissolved oxygen concentration data failed QA/QC. Consequently, an accurate and complete record of reliable instream dissolved oxygen concentrations from the summer of 2018 will not be available. **Figure 4** below illustrates the diurnal fluctuations in temperature and oxygen concentrations at SEVE-103-X during the most intact section of data.

Oxygen concentrations were lowest during the day when air temperatures were normally the highest. Inversely, dissolved oxygen concentrations were highest overnight when air temperatures were cooler and less respiration typically occurs. While the 11 days of data presented in the figure below are the most intact out of the five months of data collected, significant sedimentation still occurred. The sections of data where the dissolved oxygen concentration line is unreliable (i.e., noisy) signify at least partial burial of the probe. Periods of temperature data which express less fluctuation between minimum and maximum daily water temperatures are also evidence of sedimentation of the probes. This pattern was illustrated on 8/28, 8/31 – 9/2, and 9/7. Daily maximum air temperatures during this time period ranged from the mid 80's to the low 90's Fahrenheit. While there was no evidence of declining dissolved oxygen concentration in our data, daily high air temperatures throughout the summer reached higher than those during the period of time reported in **Figure 4**. Consequently, the possibility that dissolved oxygen concentrations declined during periods when our loggers were buried could not be ruled out in 2018.

**Figure 4. Variation in Temperature and Dissolved Oxygen Concentrations at SEVE-103-X in 2018.**

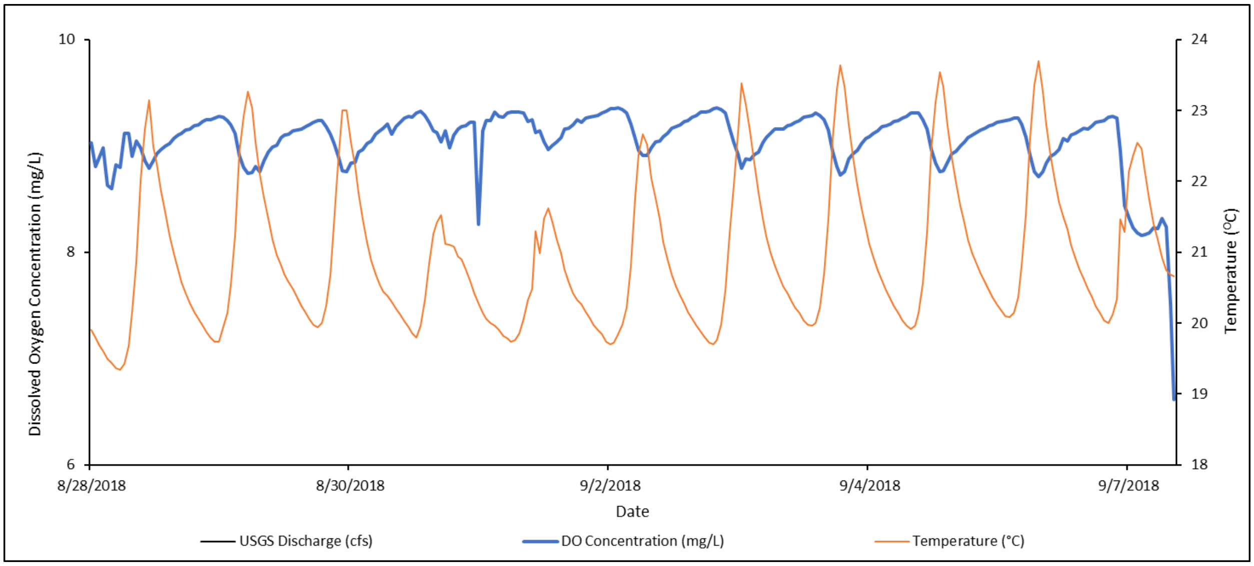
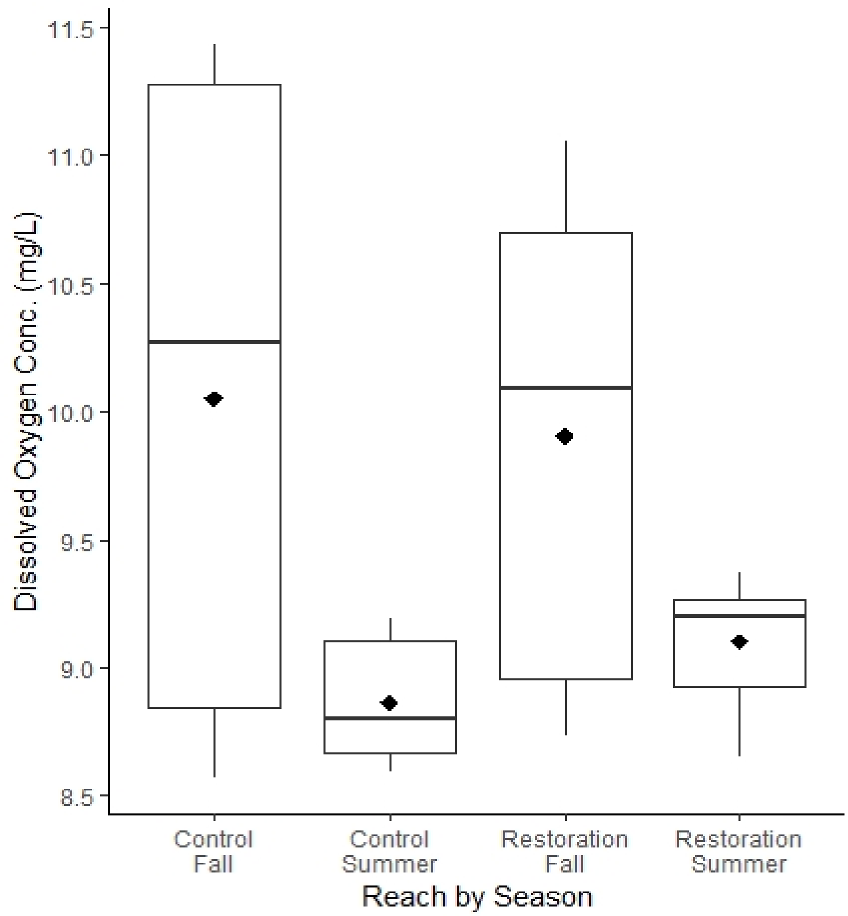


**Figure 5. Results of dissolved oxygen spotcheck data by reach and season. Note that symbols in boxplots show mean, median, range, and interquartile range.**




As a result of difficulties collecting continuous dissolved oxygen data in 2018, new protocols were adopted in 2019. Summary statistics of spot check data are above in **Figure 5**. Results from the biweekly spot check data expectedly reflect significantly higher dissolved oxygen concentrations in fall than in the summer. As there was no significant difference in dissolved oxygen concentrations between riffle and pool habitats in either the control or restoration reaches, these data were lumped together. Dissolved oxygen concentrations in the restoration reach were also very similar to those in the control reach. No concentrations below 8.5 mg/L were recorded during any sampling event in 2019, suggesting that dissolved oxygen conditions do not approach the 6.0 mg/L average daily threshold set in the Maryland Water Quality Criteria (COMAR 26.08.02) for Use Class-III streams in either the restoration or control reaches.

Results from the 2019 dissolved oxygen longitudinal profiles, as well as 2018 continuous dissolved oxygen graphics for both the restoration and control sites are included in **Appendix G** (Figure 3). Note that the continuous dissolved oxygen concentration data from 2018 have not been corrected and include data where dewatering and burial of the sensors is suspected.

### 4.6 Continuous Temperature

Continuous temperature monitoring has been conducted in the Jabez Branch watershed during the three years of pre-restoration monitoring. Again, high flows, channel alteration, and sedimentation have complicated continuous temperature data logging efforts. Temperature data from the restoration reach in 2019, as well as from all three stream reaches in 2018, failed the MBSS temperature data QA/QC process and were excluded from analysis. Summary statistics for Jabez Branch temperature data can be found in **Appendix G**.

Daily average stream temperatures observed in Jabez Branch did not exceed the thermal maximum for Brook Trout survival (24°C) (**Figures 6**), but commonly exceeded the 20°C threshold for reproducing trout streams during summer months. No temperature data  collected at Jabez Branch met MDE's criteria for Use-Class III streams. The range of temperatures in Jabez Branch were within the upper limits of temperatures experienced at MBSS sites where brook trout were collected (**Figure 7**), suggesting that thermal conditions within Jabez Branch may be at least marginally suitable for brook trout populations.

**Figure 6. Mean daily temperatures at Jabez Branch with trout thermal tolerances.**

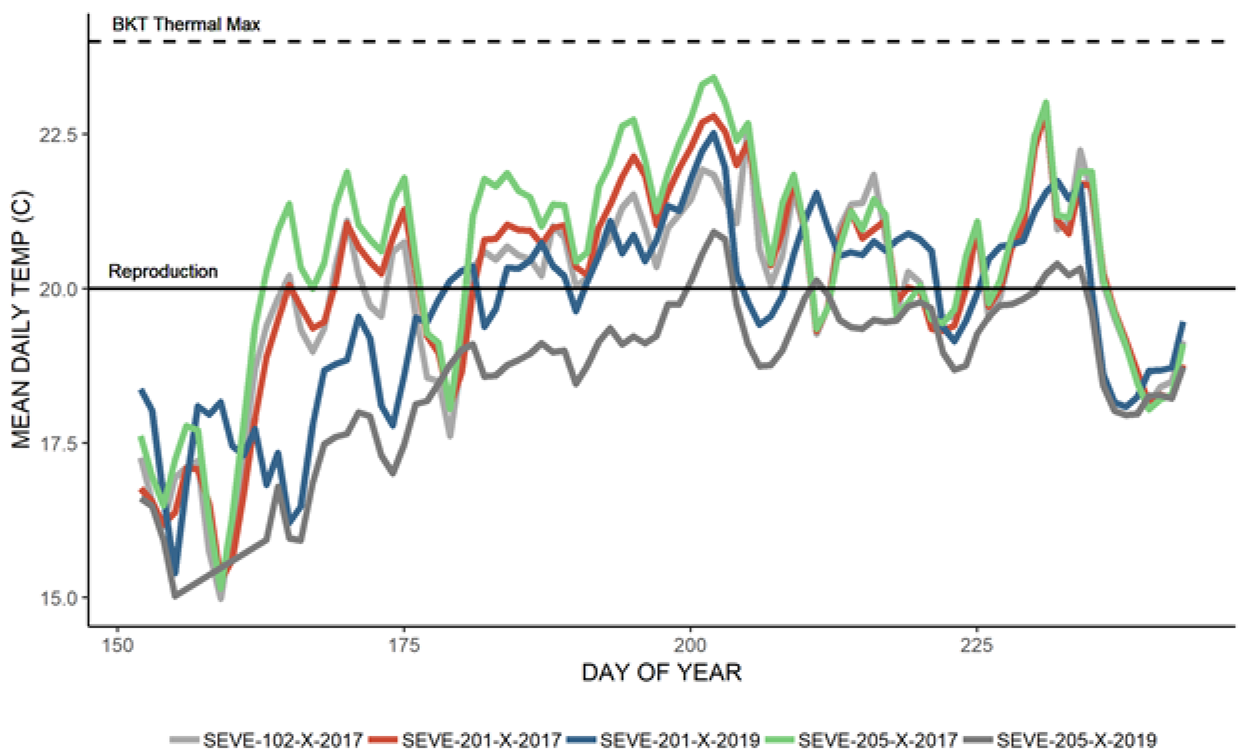
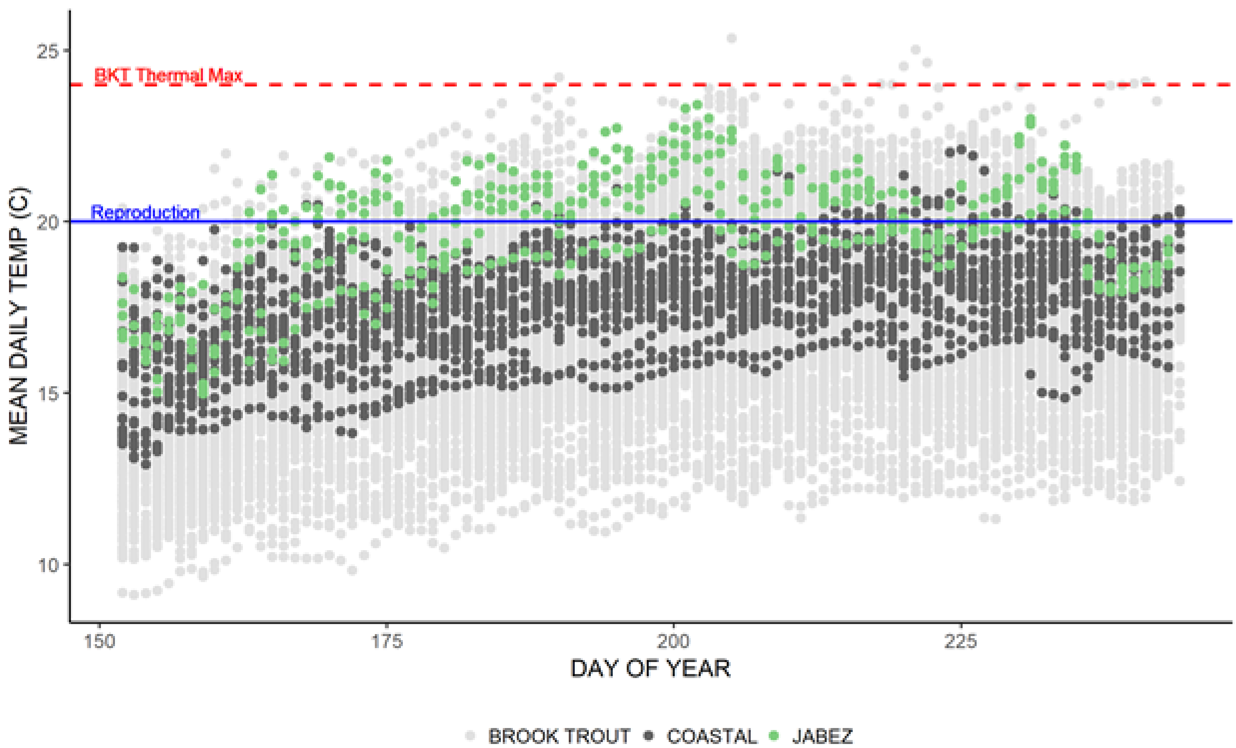


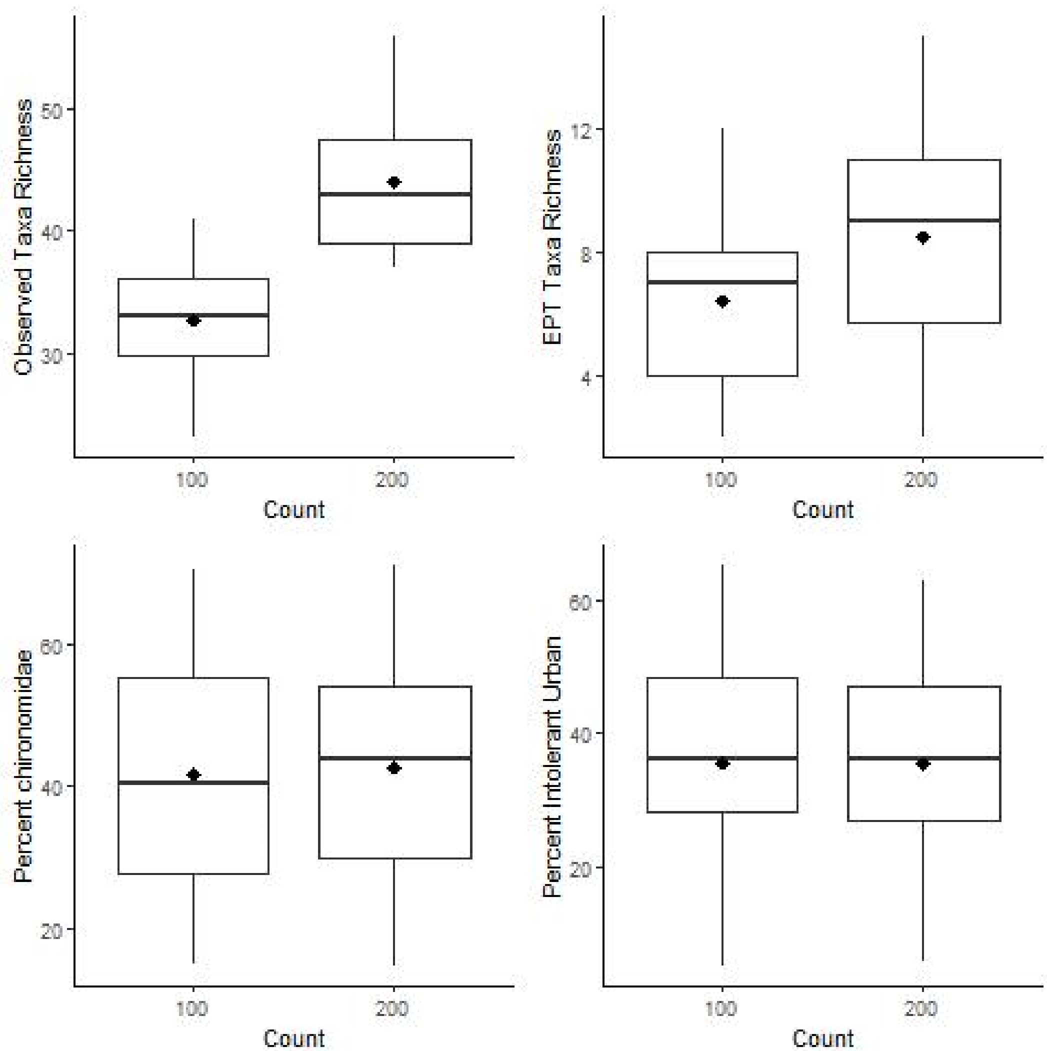
**Figure 7. Temperature ranges for MBSS coastal plain streams meeting MDE's Use-Class III criteria, MBSS brook trout streams, and Jabez Branch with trout thermal tolerances.**




## 4.7 Macroinvertebrate Community

Prior to analyzing macroinvertebrate community structure beyond the calculation of the benthic macroinvertebrate IBI, a two-tailed, paired t-test was conducted on IBI related metrics to determine any potential benefits of identifying 100 additional macroinvertebrates. Five samples were removed from this analysis (all from restoration reach) because identification of all macroinvertebrates still yielded an insufficient number of individuals ($n^{100} = n^{200}$). Observed taxa richness and EPT taxa richness were both significantly higher ($P < 0.05$) in the 200-count subsample and increased by an average of 11.3 and 2.1 taxa, respectively (**Figure 8**). Percentage of individuals intolerant of urbanization or in the *Chironomidae* family were virtually unchanged after identification of an additional 100 individuals, suggesting that the 100 count subsample may do an adequate job in assessing some community level trends. The identification of an additional 100 individuals did provide more resolution in terms of richness and allows for increased detection of rare or sensitive taxa. The increased ability to detect rare or sensitive taxa will be beneficial following restoration when these taxa may begin to recolonize the restoration reach.

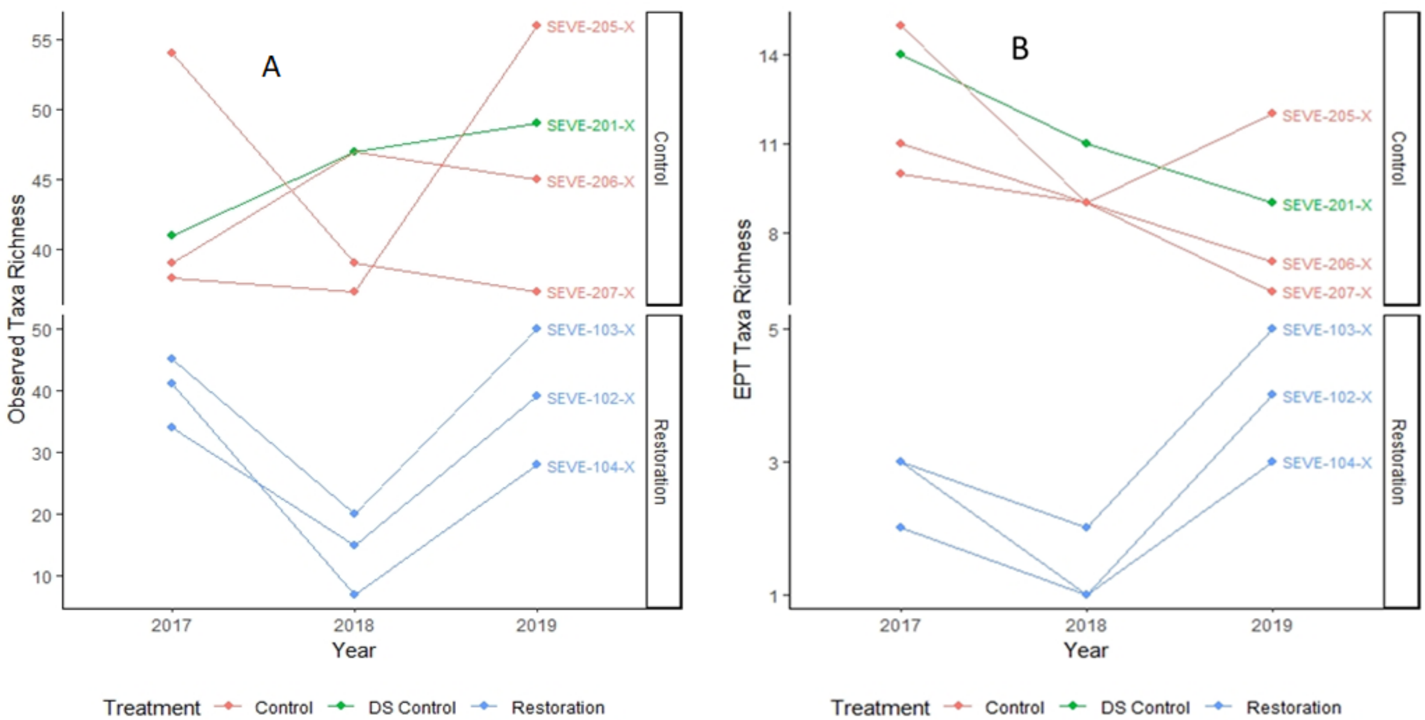
**Figure 8. Boxplots of relationships between 100 and 200 macroinvertebrate subsamples and metrics. Note that symbols in boxplots show mean, median, range, and interquartile range.**

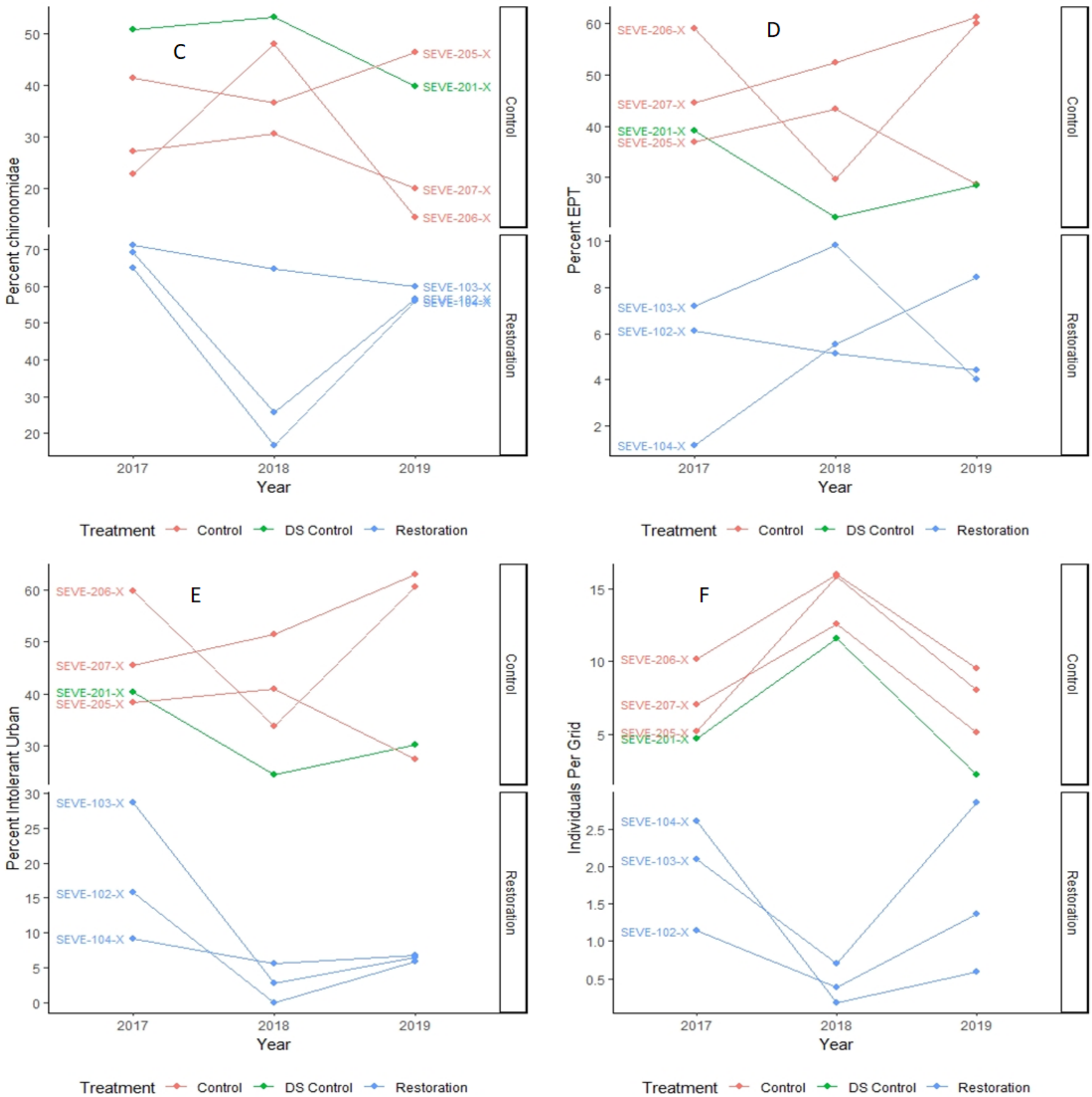



Results in this section are based on a target of at least 200 individuals of the benthic macroinvertebrate community. Not all samples in the restoration reach collected 200 individuals. In these instances, the maximum number of individuals collected were included in the analysis. Metrics reported below include observed taxa richness, EPT taxa richness, percent *Chironomidae*, percent EPT taxa, percent intolerant of urbanization, and mean number of individuals per grid. These metrics were included for pre-restoration data based on stratification between control and restoration sites. Average number of individuals per grid was included in the analyses to provide some insight into macroinvertebrate density and abundance.

Pre-restoration macroinvertebrate sampling from 2017 through 2019 included a total of 3889 individuals from 8 classes, 19 orders, 48 families, and 122 genera. Richness and percentage of sensitive taxa metrics were consistently higher in the control reach than in the restoration reach in all years of pre-restoration sampling (**Figure 9**, **B**, **D**, and **E**), while percent chironomidae (**Figure 9, C**) was consistently higher in the restoration reach. Higher than normal precipitation and stream flows presumably caused the anomalous values in 2018, particularly in the restoration reach where most metrics decreased. Richness and percentage data in 2019 was similar to that of 2017, suggesting a stabilization at restoration and control sites.

**Figure 9 (A-F). Trends in benthic macroinvertebrate communities across all sites in 2017 and 2018. Metrics include: (A) observed taxa richness, (B) observed EPT taxa richness, (C) percent taxa in the *Chironomidae* family, (D) percent EPT taxa, (E) percent of individuals intolerant of anthropogenic stressors (urbanization), and (F) mean number of individuals per grid picked.**






Results from the Shannon-Wiener Diversity Index, Pielou's Evenness Index, and the non-metric multidimensional scaling (NMDS) ordination are below in **Figure 10** and **Figure 11**. Results for these three analyses generally exhibited the same patterns. Diversity and evenness indices were more stable in the control reach, while these indices fluctuated at the restoration sites between years. Evenness has decreased over the three years of monitoring at the control sites likely due to the presence of a large number of *acerpenna*. The fluctuating results of these indices at restoration sites between 2017 and 2019 suggests that macroinvertebrate communities experienced a large amount of inter-annual variation likely in response to disturbance. Understanding this variation will facilitate interpretation of results when comparing pre- and post-restoration conditions.

The NMDS ordination (**Figure 11**) observes differences in community composition and relative abundances of taxa between the restoration and control reaches in the Jabez Branch watershed. The NMDS conducted on the first three years of pre-restoration data in Jabez Branch had a stress value of 0.1319. Since a stress value of zero represents no distortion of the data and a stress level > 0.2 is considered poor, there appears to be a strong level of relatedness among communities in the data.

Patterns observed in the biodiversity indices were consistent with the NMDS, as years 2017, 2018, and 2019 ordinated in different parts of component space in the restoration reach. Similarly to the biodiversity indices, restoration conditions in the ordination seemed to rebound in 2019. Data from 2017 to 2019 in the control reach ordinated closely, suggesting less inter-annual variation in macroinvertebrate taxa at these sites. The 2018 restoration reach sites ordinated furthest from the other 5 groups in component space, likely as a result of low relative abundance in these samples.

**Figure 10. Boxplots of the Shannon-Weiner Diversity Index (top) and Pielou's Evenness Index (bottom) calculated for 2017, 2018, and 2019 in the control (C2017, C2018, C2019) and restoration (R2017, R2018, R2019) reaches. Note that symbols in the boxplots show mean, median, range, interquartile range and outliers.**

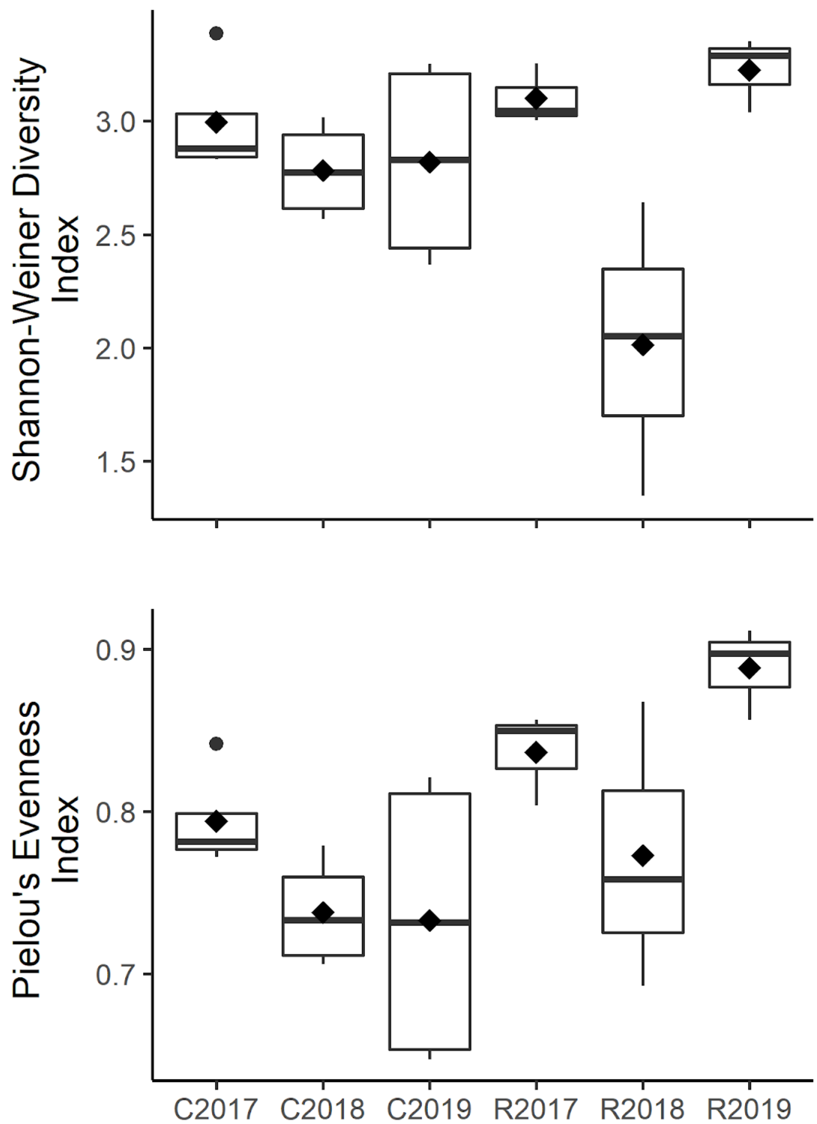
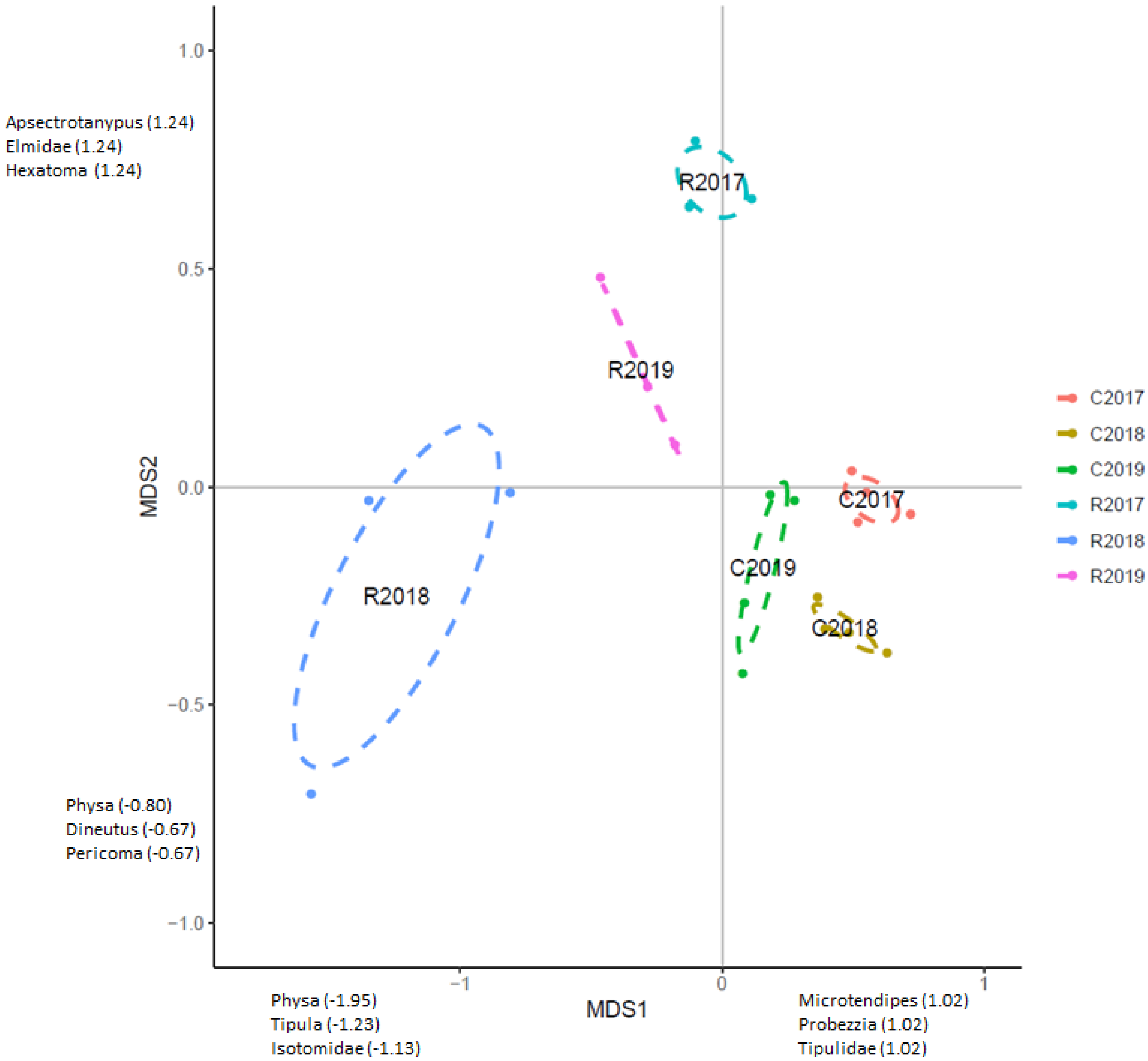


**Figure 11. Non-metric multidimensional scaling (NMDS) ordination of control (C2017, C2018, C2019) and restoration sites (R2017, R2018, and R2019) in 2017, 2018, and 2019. Ellipses drawn reflect the 95% confidence interval for each series.**




## 5.0 Discussion

The goal of water quality efforts in the Jabez 3 watershed is to reduce nutrient and sediment loads to the Chesapeake Bay and improve physical habitat, biological condition, and geomorphic stability. Restoration of streams with highly urbanized catchments has rarely resulted in improvements for benthic macroinvertebrate (Tullos et al. 2009) or fish (Violin et al. 2011; Stranko et al. 2012) communities. Alternatively, stream channel restoration has shown a significant positive influence on stream biota in some forested and agricultural streams (Tullos et al. 2009; Selego et al. 2012) and benthic macroinvertebrate richness and density estimates are greater in restored compared to unrestored stream reaches (Miller et al. 2010). Improving biologic condition or density in Jabez 3 may be possible if stormwater management facilities and restoration efforts improve habitat availability and address hydrologic issues within the watershed.

Based on the three years of pre-restoration monitoring, habitat quality and biological conditions are degraded in Jabez 3. Specifically, low instream habitat and epifaunal substrate scores reflected a lack of stable and heterogeneous habitat necessary to support fish or macroinvertebrate communities indicative of non-degraded conditions (Klauda et al. 1998). As the majority of habitat available at these sites consists of shallow, embedded riffles, creating additional pools and coarser riffle habitat could be beneficial to fish and macroinvertebrate communities. Physical habitat quality and biological condition at the control sites are less degraded than in the restoration reach. Differences in these conditions between study reaches may be a result of surrounding land use (Morgan and Cushman 2005) as the Jabez 3 watershed has nearly twice as much urban land cover as the upstream control watershed (**Appendix G**) and roughly 35% less forest cover (Homer et al. 2015). Urbanization in the Jabez 3 watershed may have also contributed to degraded water quality (Morgan et al. 2007). For example, conductivity, an indicator of biotic assemblages, was approximately twice as high in the restoration reach as the "critical value" established in Morgan et al. 2007, and about three times higher than in the control reach. However, despite having more development and less forest cover, summer temperatures in Jabez 3 were either cooler or suspected to be comparable (restoration data failed QC) to the control sites in the first three years of pre-restoration monitoring.

As low dissolved oxygen concentrations have shown adverse effects on survival and emergence of benthic macroinvertebrates (Nebeker 1972), loggers were deployed in 2018 to establish baseline dissolved oxygen conditions in the Jabez Branch watershed. Unfortunately, an above average precipitation year and coincident sedimentation of the dissolved oxygen loggers prevented collection of reliable data for the entire summer. No intact sections of data at the restoration or control sites showed any signs of large fluctuations or "crashes" in dissolved oxygen concentration. This was consistent with 2019 spot check and profile data in which dissolved oxygen concentrations were never below 8 mg/L. Continued post-restoration monitoring of dissolved oxygen concentration may provide a more complete assessment of pre and post-restoration oxygen conditions and help determine if oxygen concentrations are prohibitive of sensitive taxa colonization. While some water chemistry and physical habitat data reflect degraded conditions in the restoration reach, dissolved oxygen concentrations are not a stressor to biota. Thermal conditions also may not prohibit the colonization of sensitive or cold water obligate taxa as water temperatures are within the upper limits of streams which support brook trout.

The BIBI scores from the restoration and control sites exhibit a trend similar to the physical habitat data as they are positively correlated (Klauda et al. 1998). The majority of IBI scores for both fish and benthic macroinvertebrates in the restoration reach were in the Poor category. While FIBI scores were also generally poor in the control reach from 2017 to 2019, BIBI scores were similar to those of the two reference MBSS sentinel sites which ranked in the Good category. The intact benthic macroinvertebrate community in the control reach is important, as it could be a source population for recolonization of the restoration reach. Current physical habitat and water quality conditions likely prohibit recolonization, but these limitations may be overcome by restoration efforts.

Analysis of the 200-count subsample macroinvertebrate data provided patterns that were not evident in the BIBI scores alone, which relied on an approximate 100 count subsample. Interannual variation at the restoration sites was much higher than in the control sites. Variability was most pronounced in the number of individuals per grid picked at the restoration sites. As we were unable to calculate true density or abundance from our D-net data, individuals per grid picked were calculated as an estimate of density. The decrease in density observed at the restoration sites in 2018 and subsequent rebound in 2019 was consistent with other metrics analyzed (EPT taxa richness, percent intolerant of urbanization) and suggests that macroinvertebrate assemblages in this reach may be more susceptible to disturbance than those inhabiting the control reach. NMDS results also reflected high interannual variability in the restoration reach, while almost no variability occurred in the control reach. While the reported metrics show the main patterns in macroinvertebrate communities prior to restoration, it is important to note that patterns may change following restoration, necessitating the analysis of other metrics.

The results of the geomorphic assessment from the third year of pre-restoration monitoring continue to show degraded conditions in Jabez 3. All Jabez 3 study reaches exhibited unstable F and Gc stream types that indicate a disconnected floodplain and incised channel. Bank erosion was actively occurring on 47% of the entire Jabez 3 study reach. SEVE-104-X had the highest percentage of erosion within the geomorphic assessment area with 76% of the banks eroding. SEVE-103-X and SEVE-102-X both had less eroding banks with 37% and 39%, respectively. This continues to support a trend that erosion in Jabez 3 was more extensive further upstream from the Jabez Branch confluence. There continued to be some areas within Jabez 3 that exhibited signs of recovery such as the presence of vegetated low benches within the incised channel. These areas of recovery were more common in the downstream portions of the tributary.

The control reaches of mainstem Jabez Branch were less incised compared to Jabez 3 with some areas where out-of-bank flows were evident (deposition at top of banks) and floodplain access was intermittent. The channel was generally still entrenched and therefore most reaches exemplified a Gc stream type. Percent of eroded bank within the control sites increased the further upstream the site was (SEVE-205: 55%, SEVE-206 60%, SEVE-207: 65%). This trend was unique to the 2019 monitoring year and may be a result of degraded stream bed conditions with less depositional features causing more banks to be assessed for erosion.

The downstream control (SEVE-201/203-X) had better floodplain access than the other sites upstream on Jabez Branch. There was evidence of more frequent out-of-bank flows and the bank heights were slightly lower. The downstream control site had 57% eroded banks, but none of the banks fell into the two highest erosion rate categories indicating that banks in that reach were eroding at lower rates.

Observations during the third year of pre-restoration monitoring further support the unstable conditions within the Jabez Branch system. There were little to no stable riffles in any portion of the study reaches. As was the case with the 2017 and 2018 geomorphic assessments, in-stream features (riffle, run, pool, and glide) were not discernible at times. In many cases features have been displaced or have migrated within the channel due to the shifting sand and large bed loads. Specifically within Jabez 3, the overall trend of the study reach continued to be scouring of the stream bed further upstream while aggradation was more frequent downstream. In some areas of site SEVE-102-X, aggradation up to one foot had occurred from 2017 to 2018. During the 2019 survey, the aggradation was less frequent and most of the reach degraded closer to the 2017 bed elevations. Jabez 3 continued to be negatively impacted by a large number of headcuts and extremely incised outfall tributaries downstream of the I-97 crossing. The upstream portion of the Jabez 3 study reach was mostly made up of exposed clay bank due to the downcutting of a top soil layer that is extremely vulnerable to erosion and slumping.

The mainstem Jabez Branch was similar to Jabez 3 in that there was more aggradation further downstream. Site SEVE-201/203-X degraded 0.5ft - 1ft at both cross-sections and throughout the reach. Subsequently, bed elevations returned to levels similar to the 2017 survey. This site differed from the rest of the study reaches because it was the only one that did not entirely warrant a stream classification of an entrenched channel.

Given the instability throughout the entire Jabez Branch system, some geomorphic variables will vary greatly from year to year. In some cases, geomorphic variables will vary between every storm event that mobilizes the substrate causing degradation and aggradation at different locations throughout the project area.

2019 is the final year of pre-restoration monitoring at Jabez Branch. The baseline monitoring described in this report will be useful in tracking future restoration progress. Restoration efforts are tentatively planned in the coming years and thus the data from this report and the past two years will provide baseline data for comparison to post-restoration conditions.

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