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Hydromorphological Characterization of the Piney Creek Watershed of Raleigh County, West Virginia, a Tributary of the New River Gorge National Park

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Abstract: In this study, information was collected regarding the habitat condition, channel profile, and stream discharge of key waterways within the Piney Creek Watershed in vicinity of Beckley, Raleigh County, West Virginia. Piney Creek is a major tributary that flows into the New River within the New River Gorge National Park and Preserve. To establish robust and sustainable ongoing stream monitoring, West Virginia University Institute of Technology (WVU Tech), Beckley Sanitary Board (BSB) and Piney Creek Watershed Association (PCWA) partnered in conducting stream habitat assessments at key sites within the watershed utilizing the guidelines provided by the West Virginia Department of Environmental Protection's Save Our Streams initiative. Additionally, the organizations developed standard operating procedures for calculating flow and discharge utilizing low-cost, easy-to-perform float gauging methodology. In total, 21 sites from five named streams (Beaver Creek, Cranberry Creek, Little Whitestick Creek, Whitestick Creek, and Piney Creek) and seven unnamed streams were selected and assessed for channel width and depth, velocity, discharge, sediment deposition, embeddedness, bank stability, riparian buffer, and stream bed composition. Streambed composition and discharge showed variability among the subwatershed sites. Nine site habitat scores received overall habitat scores of "suboptimal", while ten were scored as "marginal" and two as "poor" stream habitat. Lack of riparian buffer was found to be the most frequent habitat score deficiency in the Piney Creek Watershed, with 18 out of the 42 total stream banks receiving a score of "poor" in this category. Characterization of the watershed is important for establishing baseline information as well as identifying important sites for future research and execution of improvement projects. This study defines an accessible research locale and model watershed.

Keywords: watershed; stream habitat; stormwater; pollution.

Introduction

As food production, industrialization, and energy requirements increase to sustain the growing world population, safeguarding water resources will continue to be an issue of concern in coming years. As urbanization has increased, a series of common impairments have been observed in watersheds globally. These common impairments have been termed "urban stream syndrome", a framework which attempts to highlight some similarities in watersheds impacted by development. Urban streams are commonly defined as any channel impacted by urban uses such as transportation, residential development, commercial activity, and by impervious surfaces such as parking lots (Booth *et al.*, 2016). According to Shaver *et al.* (2007) urban storm runoff can host a variety of harmful pollutants, including solids, pathogens, petroleum hydrocarbons, synthetic nutrients, and metals. A part of sustaining freshwater resources is the proper management of increased storm water and runoff associated with growing urban populations.

After comparing urban, pasture, unmanaged forest, and managed forest, Schoonover *et. al.* (2005) found that urban areas exhibited significantly elevated concentrations of pollutants in a wide range of parameters, including total dissolved solids, chloride, nitrate, sulfate, sodium, potassium, ammonium, and fecal coliforms. The authors found that as little as a 5%-increase in impervious surface areas, resulted in nearly threefold increase in key nutrient pollutants, including nitrates and phosphates, and a sevenfold elevation for fecal coliforms (Schoonover *et al.*, 2005). Furthermore, the National Water Quality Inventory Report to Congress from 1996, identified urban runoff as a leading agent of ocean shoreline and estuary impairment in the United States (US EPA, 2015). Though many similarities are found globally in the diverse urban stream syndrome watersheds, nuanced heterogeneity has been observed leading to a call for more detailed understanding of these differences at local levels (Booth *et al*, 2015)

The Piney Creek Watershed lies entirely within Raleigh County in southern West Virginia within the Central Appalachians ecoregion and drains an approximately 352 km^2 (136 mi^2) area within the Lower New River Watershed. The drainage system of the Piney Creek Watershed consists of a variety of rivers and sub-watersheds, which includes Batoff Creek, Beaver Creek, Bowyer Creek, Cranberry Creek, Laurel Creek, Little Beaver Creek, Little Whitestick Creek, Piney Creek, Soak Creek, and Whitestick Creek (*Piney Creek Watershed Plan*, 2012). These streams converge at Piney Creek and flow into the New River at the New River Gorge National Park and Preserve.

The West Virginia Department of Environmental Protection (WVDEP) performed stream water quality monitoring of the Piney Creek Watershed, from July 1, 2004 until June 30, 2005 to determine if there were specific pollutants that could impair water quality in the watershed using the West Virginia Water Quality Standards (West Virginia Department of Environmental Protection, 2008). All ten monitored streams within the Piney Creek watershed were shown to have pollutant impairment that could adversely affect human health or the environment. Fecal coliform bacteria impairment was found in 90-percent of those monitored streams (West Virginia Department of Environmental Protection, 2008). Iron and fecal coliform pollutants are the most pervasive impairments in West Virginia streams as greater than 12,800 km (8,000 stream-miles) are impaired according to the 2016 WVDEP report (West Virginia Department of Environmental Protection, 2016).

Piney Creek and its tributaries Cranberry Creek, Whitestick Creek, and Little Whitestick Creek were consequently identified as the four creeks with the greatest need for a reduction in fecal coliform bacteria and all four creeks were placed on the WV impairment list 303(d) (West Virginia Department of Environmental Protection, 2008). Therefore, the U.S. Environmental Protection Agency (US EPA) requires remediation within the city of Beckley to reduce the amount of pollution. In 2012, the Piney Creek Watershed Association developed a Watershed Plan to implement remediation to achieve required reductions to pollution impairments (*Piney Creek Watershed Plan*, 2012). To routinely record quantitative and qualitative data to focus and help assess effects of remediation projects on the Piney Creek watershed health, the Piney Creek Watershed Association, Beckley Sanitary Board, and West Virginia University Institute of Technology Department of Biology partnered to form the Piney Creek Water Monitoring Program in 2018 and developed an EPA approved Quality Assurance Project Plan for this monthly sampling endeavor.

The Piney Creek Water Monitoring Program recognized the need for a baseline study characterizing the current state of the stream habitats and the execution of a long-term, volunteer-led, stream monitoring program. To this end, the purpose of this study was to characterize the hydromorphology of Piney Creek Watershed streams using reproducible, cost-effective methods for sustainable monthly monitoring. This current study utilized the WVSOS protocols for characterization of important sites within the Piney Creek Watershed.

Materials and Methods

Piney Creek Water Monitoring Program Partners

In Raleigh County, West Virginia, three organizations have formed a strategic partnership to improve water management in the area. One organization is the Piney Creek Watershed Association (PCWA), which is a 501(c)(3) nonprofit organization formed in 2004. PCWA maintains an active role in restoring and protecting each of the watersheds in the area drained by Piney Creek. The second organization is the Beckley Sanitary Board (BSB), which is charged with the task of maintaining the storm and sanitary systems of Beckley, West Virginia the main urban center in the Piney Creek watershed. West Virginia University Institute of Technology (WVU Tech) Department of Biology, is charged with advancing scientific research support of the program and in community advisement, laboratory space utilization, continuous organization and training of a volunteer force.

Establishment of the Study Area

The Clean Water Act's National Pollution Discharge Elimination System (NPDES) instituted the requirement for small urban areas to implement storm water management programs in the early 2000s. The municipal separate stormwater sewer system (MS4) boundary is the area of operation that the BSB is responsible for implementing a stormwater management program as prescribed by the NPDES. For initiation of this study, the MS4 boundary falls within the sub-watersheds draining Beckley and its urban extensions and thus, served as the limit of the sampling area for the Piney Creek Water Monitoring Program study area.

Site Selection

All characterization sites were first tentatively identified based on a variety of factors using ESRI geographic-interface software (GIS) with the intention of conducting future biological and chemical analyses. Examples of the factors considered include (but are not limited to) proximity to the MS4 border or suspected impact from nonpoint-source pollution. The reasoning behind individual site selection is given in greater detail in succeeding paragraphs describing specific sites. Following ESRI identification, each site was ground-truthed to locate areas such that an entire reach – including a run with relatively even flow for discharge calculations – could be safely accessed and observed. When such a site was identified, a Garmin Foretrex 401 was used to geolocate the site. In total, 21 characterization sites were selected. Table 1 displays the abbreviated site ID, stream site location, and World Geodetic System 1984 (WGS84) coordinates in degrees latitude and longitude.

Habitat and Hydromorphology Surveys

The monitoring site characterization methods utilized for this study were based largely on practices and procedures prescribed by the WVSOS (WV DEP, 2012), including: channel width and depth, velocity, flow, sediment deposition, embeddedness, bank stability, riparian buffer, and stream bed composition. Benthic macroinvertebrate sampling was not included in this study. Rather, this study focused on establishing habitat and the stream hydromorphological characteristics of the sample sites.

Stream Profile Measurement

Upon arrival at each stream, observers first identified a run with minimal obstacles, even streambanks, and relatively even flow. Once this location was identified, a length of stream within this run was identified for flow calculations, using the longest interval feasible in comparison to the size of the stream but not to exceed 6.10 m (20 ft). At the upstream limit of this interval, the wet-width of the channel was measured with a survey tape measure. Depth was measured along the wet-width of this single transect at as many positions across the stream as feasible given the width of the stream (stream width range was 0.137 m to17.16 m), but no less than four positions across the stream were recorded along a single transect.

Stream Velocity Measurement

Float gauging is the term and method outlined for calculating water velocity by WVSOS protocol (Herschy, 2009). Although this method is not vertically integrated and offers less point control to the observer during measurements, the method is easy to reproduce among volunteers and circumvents the need for costly flowmeters or other sensors.

Water velocity is calculated by recording the time required for a floating object to travel a predetermined distance downstream.

For this study, the floating objects for each of the sites were *Citrus reticulata hesperidia* (oranges). According to the United States Environmental Protection Agency (USEPA, 2012), the buoyancy of oranges allow them to float just beneath the surface of the water and can provide a good estimate of channel water velocity. However, many of the streams could not support the entire fruit, so observers used an approximately 2.54 cm diameter section of the fruit peel or an individual slice of orange as necessary. When able, the slice method was preferred over the peel, because the slices had a similar buoyancy to the whole fruit that allowed most of the mass of the orange to float beneath the water's surface. In contrast to the WVSOS guidelines, which only require a single channel within the stream to be floated, observers divided the stream width into halves, thirds, or quarters for velocity measurements.

Stream Discharge Calculation

After building the stream profile and calculating the velocities, an adjusted discharge calculation method differing from the WVSOS guidelines was employed. Cross sectional shape varies with position in the stream, and discharge. Flow was calculated by float method in transect segments multiplied by stream cross-sectional area and float segments then summed to estimate stream discharge. The WVSOS method of calculating discharge provides a simple estimate, using only the average depth and wet-width measurements multiplied by the averaged velocity of a single floated run to get a volumetric rate (WV DEP, n.d.).

Streambed Composition

Streambed sediment composition was estimated along the same reach utilized in the velocity calculations (WV DEP, n.d.). Size categories are determined by the axis measured in millimeters. The criteria for each are as follows: "silt/clay" very small < 0.06 mm and having a smooth slick feel, "sand" very small 0.06-2.0 mm and having a grainy feel, "gravel" very small 2-24 mm fine and 25-64 mm course pea to tennis ball size, "cobble" 65-255 mm tennis ball to basketball size, "boulder" 256-1096 mm basketball to car size, and "woody debris" that includes sticks and leaves.

Stream Embeddedness

WVSOS recommends gathering embeddedness in riffles, so this character was observed only in riffles within the reach. Observations of embeddedness were based on the amount of silt and sand sediments overlying and surrounding the larger gravel- and cobble-size particles. Estimates of embeddedness were scored out of 20 possible points. The "optimal" range of embeddedness scores (range 16-20) comprises fine sediment surrounds less than ten-percent of the spaces between the gravel, cobble, and boulders. The "suboptimal" embeddedness (range 11-15) corresponds to between ten- and thirty-percent, "marginal" embeddedness (range 6-10) comprises between thirty- and sixty-percent, and "poor" embeddedness scores (range 1-5) was greater than sixty-percent of spaces between gravel, cobble, and boulders were surrounded by fine sediment (WV DEP, n.d.).

Stream Sediment Deposition

Sediment deposition is an estimate of accumulated sediment and depositional features (including islands, point bars, and shoals) that have occurred due to large-scale movement of sediment throughout the reach. The displayed scores for sediment deposition are out of 20 possible points and were observed throughout the entire reach. The "optimal" range of sediment deposition scores (range 16-20) was less than twenty-percent of the reach affected by sediment deposition and little or no formation of depositional features. The "suboptimal" sediment deposition (range 11-15) corresponds to between twenty- and forty-percent of the reach affected and some increases in depositional features, "marginal" sediment deposition (range 6-10) comprises between forty- and sixty-percent sediment deposition with moderate amounts of depositional features, and "poor" embeddedness scores (range 1-5) was greater than sixty-percent of the reach affected and heavy amounts of sediment deposition (WV DEP, n.d.).

Stream Bank Stability

Stream bank stability evaluates whether each stream bank is eroded or has potential for erosion. Bank stability were scored out of 10 for both the left and right bank by looking downstream in each reach observed (WV DEP, n.d.). For "optimal" bank stability scores (range 7.5-10) less than ten-percent of the reach was affected with no evidence of erosion or bank failure and little or no potential for future problems. A "suboptimal" bank stability score (range 5-7.5) indicates ten- to thirty-percent of the reach affected with infrequent areas of erosion as indicated by banks healed over or a few bare spots. The "marginal" bank stability score (range 2.5-5) was an indication that a bank was moderately unstable with thirty- to fifty-percent of the reach having areas of erosion or high potential for erosion during flooding events. Lastly, "poor" bank stability score (range 1-2.5) indicated bank was unstable with greater than fifty-percent of the reach having eroded areas along straight sections or bends or obvious bank collapse and failure.

Stream Riparian Buffer

Riparian buffer width is an estimation of width of natural vegetation from each edge of the stream bank outwards. Examples of human disruption of riparian buffer include: parking lots, road beds, clear-cuts, mowed areas, crops, and lawns. For riparian buffer evaluation, the scores were estimated are out of 10 possible points for both the left and right bank of each reach observed. In brief, for "optimal" riparian buffer scores (range 7.5-10) there are no evidence of human impacts and mainly undisturbed areas for greater than 18.29 m (60 ft) width from the stream. The "suboptimal" riparian buffer score (range 5-7.5) indicates a zone of undisturbed vegetation between 12.19-18.29 m (40-60 ft) width and some areas of human disturbance. The "marginal" bank stability score (range 2.5-5) indicates a zone of undisturbed vegetation between 6.10-12.19 m (20-40 ft) width and human-disturbed areas common throughout. Lastly, "poor" riparian buffer score (range 1-2.5) signified a zone of undisturbed vegetation less than 6.10 m (20 ft) wide and disturbed areas common throughout the reach.

Observation Site Habitat Assessment

Observation site habitat assessments were calculated based on the scores from the observations of embeddedness, sediment deposition, bank stability and riparian buffer (WV DEP, n.d.). In brief, a summation of the individual habitat assessments was performed for each site and percent habitat score calculated by taking the sum and dividing by eighty (the maximum possible score), which was then multiplied by 100-percent. Based on the Save Our Streams criteria, a "optimal" habitat percent condition corresponds to greater than 87.5%, "suboptimal" habitat between 68%-87.5%, "marginal" habitat between 50%-67.5%, and "poor" habitat less than 50% habitat score.

Results

Within the MS4 boundary of the Piney Creek Watershed, 14 sites from five named streams (Beaver Creek, Cranberry Creek, Little Whitestick Creek, Whitestick Creek, and Piney Creek) and seven unnamed non-total maximum daily load streams (Non-TMDL) were selected. Site IDs and locations are shown in Table 1.

Table 1. List of piney creek watershed characterization sites.

Site ID	Site Location	Latitude and Longitude
B-1	Beaver Creek	37.75585037° -81.15317546°
C-1	Cranberry Creek	37.81849372° -81.18581012°
C-2	Cranberry Creek	37.79503444° -81.17205473°
LW-1	Little Whitestick Creek	37.80718433° -81.22343167°
LW-2	Little Whitestick Creek	37.80012651° -81.20872523°
LW-3	Little Whitestick Creek	37.79120391° -81.1917872°
LW-4	Little Whitestick Creek	37.78894962° -81.18381488°
LW-5	Little Whitestick Creek	37.78967103° -81.17350706°
NON-1	UT Cranberry Creek	37.82542674° -81.21444918°
NON-2	UT Cranberry Creek	37.77992947° -81.16566018°
NON-4	UT Piney Creek	37.76478992° -81.16850616°
NON-5	UT Little Whitestick Creek	37.78499101° -81.19664659°
NON-7	UT Whitestick	37.76567627° -81.18156274°
NON-8	UT Whitestick	37.76652471° -81.18772827°
NON-9	UT Cranberry Creek	37.81188776° -81.18693005°
P-1	Piney Creek	37.75659686° -81.1683548°
P-2	Piney Creek	37.75705327° -81.1569491°
P-3	Piney Creek	37.76216708° -81.15225715°
W-1	Whitestick Creek	37.78043614° -81.22106882°
W-2	Whitestick Creek	37.76420514° -81.20095426°
W-3	Whitestick Creek	37.75688723° -81.16968618°

Abbreviations: B, Beaver Creek; C, Cranberry Creek; LW, Little Whitestick Creek; NON, Non-Total Maximum Daily Load; UT, upper tributary; P, Piney Creek; W, Whitestick Creek

Whitestick Monitoring Baselines

Whitestick Creek was characterized at three sites (Fig. 1). Observation site W-1 was placed near the western border of the MS4 beneath an Interstate-77 overpass and upstream of a small livestock farm suspected to be a significant nonpoint pollution source due to the lack of riparian buffer and fencing to reduce access of livestock to the stream. The location of W-2 was selected at a site downstream of the livestock farm and a salvage yard. W-3 was placed at the lower portion of the stream prior to its confluence with Piney Creek just upstream of site P-1 (Fig. 1). Non-TMDL observation sites NON-8 and NON-7 both lie elevated north of Whitestick Creek on separate unnamed streams feeding into Whitestick Creek's watershed (Fig. 1).

At observation site W-1, the stream is in a clear-cut area underneath Interstate-77. Because of the regular maintenance underneath the overpass, there was almost no natural shade for this segment of stream. Additionally, only a single dead crayfish was observed in the water, and there was moderately distributed brown, filamentous algae. Maximum stream width and depth was 3.14 m and 0.18 m respectively (Fig. 2A). The stream bottom composition throughout the reach was estimated as follows: 5% silt/clay, 5% gravel, 80% cobble, and 10% boulder (Fig. 2B). At the time of observation, the estimated discharge was 0.073 cubic meters per second (cms) at W-1.

During W-2 site observation a small PVC pipe was noticed, likely transporting stormwater, entering the stream approximately 18 meters upstream. Two living crayfish were observed in the stream, but no other wildlife was noted. Moderately distributed, brown, filamentous algae were also found at this site. Maximum stream width and depth was 2.74 m and 0.27 m, respectively (Fig. 2A). The stream bottom composition throughout the reach was estimated as follows: 10% silt/clay, 30% gravel, 40% cobble, and 20% boulder (Fig. 2B). At the time of observation, the estimated discharge was 0.028 cms.

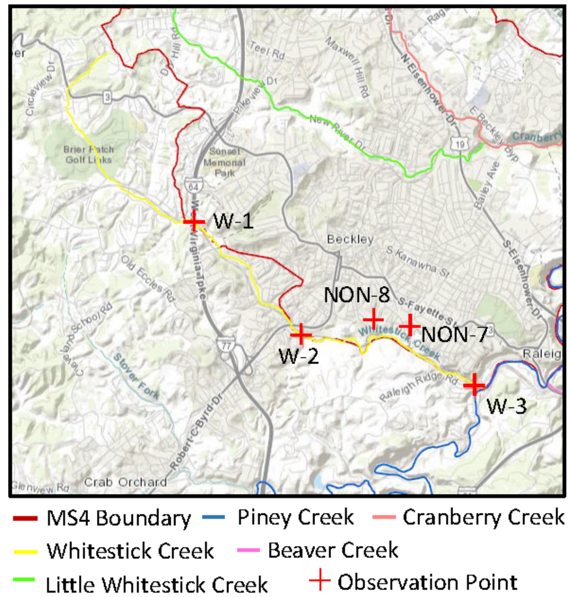

Figure 1. Map of Whitestick Creek observation points. ESRI map showing the three observation site locations on Whitestick Creek (yellow solid line) indicated by red waypoints. Other solid lines indicate watershed points of interest (red solid line- MS4 boundary, blue solid line – Piney Creek, pink solid line – Cranberry Creek, green solid line - Little Whitestick Creek, purple solid line – Beaver Creek.

Observation site NON-8 (Whitestick Creek watershed) lies on a small unnamed stream, which travels primarily through older neighborhoods dotted by patches of woodland. Upstream of the observation site NON-8, significant erosion is visible surrounding the outflow of the 61-cm (24-in) culvert conveying the water underneath Granville Avenue. Maximum stream width and depth at NON-8 was 0.91 m and 0.061 m, respectively (Fig. 2A). At time of observation, stream discharge was estimated at 0.0340 cms. Orange-brown sediment covers the stream bed, and an opaque film has formed on the surface of the water approximately five meters upstream, where flow is minimal. Streambed composition was 80% silt/clay, 15% cobble, 3% bedrock, and 2% woody debris (Fig. 2B).

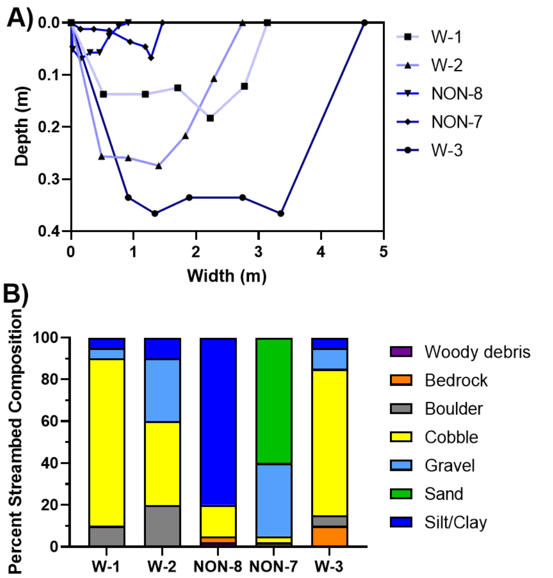

Figure 2. Whitestick Creek watershed streambed measurements. Streambed cross-sectional area measurements (A). Percent streambed composition for Whitestick Creek watershed sites W-1, W-2, NON-8, NON-7, W-3 (B).

Site NON-7 (Whitestick Creek watershed) lies in a forested area separating residential neighborhoods. Maximum stream width was 1.46 m, maximum stream depth was 0.067 m (Fig. 2A) and the estimated discharge for the site was 0.00595 cms. The bed composition was 2% boulder, 3% cobble, 35% gravel, and 60% sand (Fig. 2B).

At observation site W-3 the right side of the stream at this point had been converted to a concrete wall with numerous drainage pipes leading into the stream. Located in a mostly residential area, this site also lacked riparian buffer. Furthermore, a municipal waterline crossing the stream was suspended approximately 1.5 m above the stream bottom. Numerous crayfish and small fish were observed at this site, as well as scattered sections of brown, filamentous algae. Maximum stream width and depth at W-3 was 4.69 m and 0.366 m, respectively (Fig. 2A). For site W-3 At the time of observation, the estimated discharge was 0.174 cms. The stream bottom composition throughout the reach was estimated as follows: 5% silt/clay, 10% gravel, 70% cobble, 5% boulder, and 10% bedrock (Fig. 2B).

Piney Creek Monitoring Baseline

Three characterization sites were identified directly on Piney Creek (Fig. 3). The first, P-1, was placed proximal to the Whitestick Creek convergence, where Piney Creek emerges into the MS4. The second site, P-2, was placed immediately upstream of the confluence with Beaver Creek. Lastly, the third site, P-3, was placed upstream of BSB's Piney Creek Sanitary Sewer Treatment Plant (Fig. 3). An additional site was to be placed downstream, however, terrain and limited access made the site unfeasible for follow-on monitoring. NON-4 stream site eventually connects down into Piney Creek between sites P-1 and P-2 (Fig. 3).

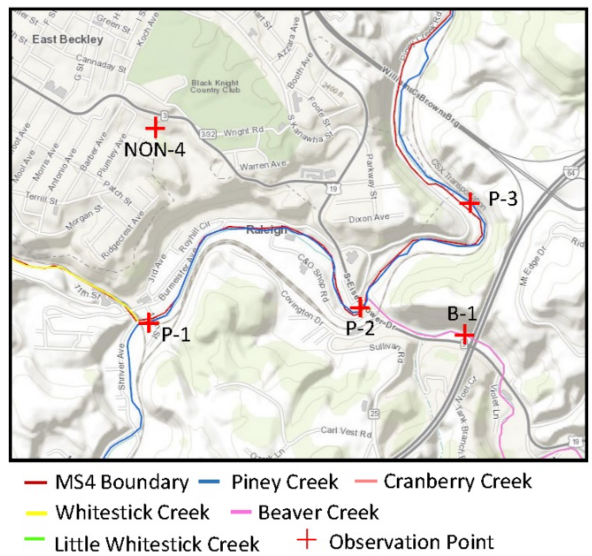

Figure 3. Map of Piney Creek observation points. ESRI map showing the three observation site locations on Piney Creek (blue solid line) indicated by red waypoints. Other solid lines indicate watershed points of interest (red solid line- MS4 boundary, pink solid line – Cranberry Creek, green solid line - Little Whitestick Creek, yellow solid line – Whitestick Creek, purple solid line – Beaver Creek.

Only one site on Beaver Creek (B-1) was characterized for this study. Much of Beaver Creek meanders outside the bounds of the Sanitary Board's MS4. Despite this, B-1 was selected on Beaver Creek to compare the quality of the second largest stream in the watershed prior to its confluence with Piney Creek downstream of P-2 but upstream of P-3 (Fig. 3). The specific site selection was driven largely by accessibility, as the stream closely parallels the roadway on one side and steep mountainside on the other. As a result, B-1 was placed at one of the few sites with available parking and safe access to a stream reach meeting the selection criteria (Fig. 3).

At observation site P-1 pilings from an old bridge remain at the site, and much of the area adjacent to the stream had been mowed by nearby homes. An apparently healthy *Oncorhynchus mykiss* and numerous small fish were observed at the location during initial characterization. The maximum stream width was 17.16 m and maximum depth was 0.503 m at P-1 (Fig. 4A). At the time of observation, the estimated discharge was 2.245 m. The stream bottom composition throughout the reach was estimated as follows: 5% silt/clay, 15% gravel, 70% cobble, and 10% boulder (including manmade pilings) (Fig. 4B).

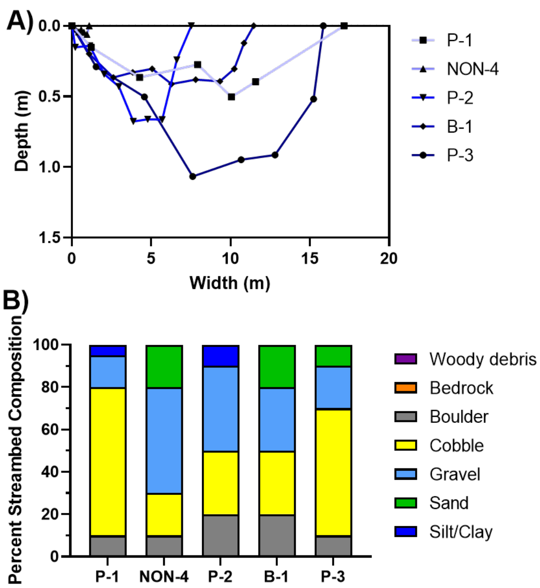

Figure 4. Piney Creek watershed streambed measurements. Streambed cross-sectional area measurements (A). Percent streambed composition for Piney Creek subwatershed sites P-1, NON-4, P-2, B-1, and P-3 (B).

Observation site NON-4 within the Piney Creek's subwatershed was observed to have a width of 1.10 m and a maximum depth of 0.061 m (Fig. 4A). The estimated discharge at the time was 0.00085 cms. The streambed composition was 10% boulder, 20% cobble, 50% gravel, and 20% sand (Fig. 4B).

At site P-2 the maximum stream width was 7.53 m and maximum depth measured was 0.677 m (Fig. 4A). At the time of observation, the estimated discharge was 2.134 cms. The stream bottom composition at P-2 was estimated as follows: 10% silt/clay, 40% gravel, 30% cobble, and 20% boulder (Fig. 4B). Initial stream measurements of Beaver Creek at site B-1 indicated a width of 11.46 m and maximum depth of 0.411 m (Fig. 4A). Discharge was calculated to be 0.9039 cms, and the streambed composition was 20% sand, boulder, 30% gravel, 30% cobble, and 20% boulder (Fig. 4B).

The area surrounding the P-3 observation site was mostly wooded, with stands of mature Eastern Hemlock and Rhododendron lining the banks. At the time of observation, the estimated discharge at P-3 was 5.952 cms with a stream width of 15.8 m and maximum measured depth of 1.07 m (Fig. 4A). The stream bottom composition throughout the reach was estimated as follows: 10% sand, 20% gravel, 60% cobble, and 10% boulder (Fig. 4B).

Little Whitestick Monitoring Baselines

Little Whitestick Creek contained the greatest number of assessment points, with five spanning the length of this stream (Fig. 5). Monitoring site LW-1 was placed near the border of the MS4 at the uppermost extent of the stream and prior to conveyance under the heavily trafficked Interstate-77. LW-2 was selected for its location downstream of I-77, where sedimentation, restricted flow, and frequent flash-flooding had been observed. LW-3 was placed along a naturalized area along the creek upstream of numerous tributaries including a retention pond that captures a watershed and LW-4 was placed downstream of the pond's outflow to better elucidate the relationship of the pond and its receiving stream (Fig. 5). Little Whitestick Creek converges into Cranberry Creek downstream of monitoring site C-2 and upstream of confluence of Cranberry Creek with Piney Creek. Site NON-5 represents a stream that convergences into Little Whitestick Creek downstream of LW-3 but upstream of site LW-4 (Fig. 5).

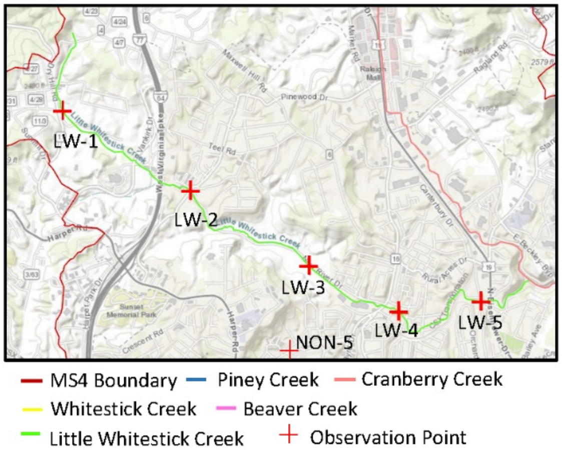

Figure 5. Map of Little Whitestick Creek observation points. ESRI map showing five observation site locations on Little Whitestick Creek (green solid line) indicated by red waypoints. Other solid lines indicate watershed points of interest (red solid line- MS4 boundary, pink solid line – Cranberry Creek.

Observation site LW-1 was in a naturalized wooded area adjacent to Dry Hill Road. No pipes were found in the stream. There was moderate distribution of a tan/orange algae or iron-oxidizing bacteria throughout the reach, and two small, healthy fish were observed. The LW-1 stream measured 1.13 m wide and maximum depth was 0.055 m (Fig. 6A), discharge was estimated to be 0.0150 cms. The stream bottom composition was estimated to be 70% silt/clay, 20% sand, and 10% gravel (Fig. 6B).

During initial observation of site LW-2, high mortality of trees was observed, in particular, pines and hemlocks upstream of site LW-2. Two stormwater pipes were observed entering at the same point as the twin culverts that carry the stream, as well as, significant erosion underneath the stormwater pipe entering stream-right (as the viewer looked downstream). Japanese Knotweed dominated the stream banks, and there was little mature vegetation otherwise until much further down the stream. Additionally, light-to-moderate distribution of a matted brown algae was found throughout the reach. At the time of observation, the stream width was measured to be 1.83 m and maximum depth 0.094 m (Fig. 6A). Estimated discharge was 0.0198 cms. The streambed composition was estimated to be: 5% silt/clay, 15% sand, 65% gravel, 5% cobble, 5% boulder, and 5% bedrock (Fig. 6B).

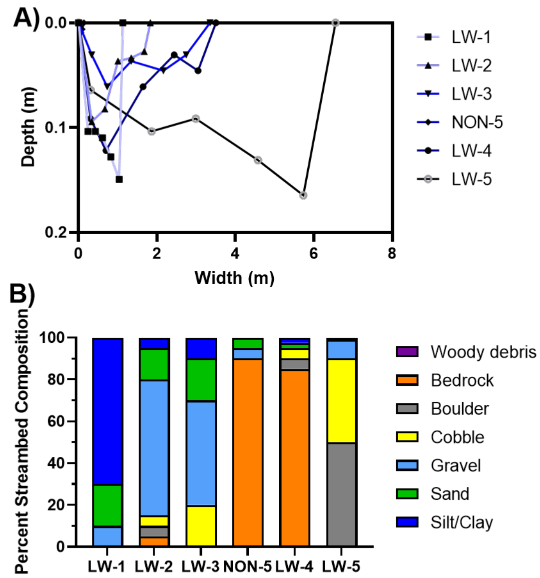

Figure 6. Little Whitestick Creek watershed streambed measurements. Streambed cross-sectional area measurements (A). Percent streambed composition for Little Whitestick Creek watershed sites LW-1, LW-2, LW-3, NON-5, LW-4, and LW-5 (B).

At LW-3, diverse naturalized area lined both sides of the stream, but several ATV crossings were observed near the observation site. Multiple small fish and Common Snapping Turtle were observed, as well as a moderately distributed green and brown algae throughout the reach. At the time of observation, stream width was 3.35 m and maximum depth 0.0610 m (Fig. 6A), the estimated discharge was 0.0306 cms. The stream bottom composition throughout the reach was estimated to be: 10% silt/clay, 20% sand, 50% gravel, and 20% cobble (Fig. 6B).

Observation site NON-5 (Little Whitestick Creek subwatershed) sediment deposition and embeddedness were moderately visible at the observation point, and both banks lacked riparian buffer. However, bank stability was optimal, because the channel is constructed of concrete to direct flow into a culvert. During time of observation the measured width was 0.137 m and maximum depth was 0.0091 m (Fig. 6A). The flow was nominal with a calculated discharge of 0.000283 cms and the streambed composition was 90% bedrock, 5% gravel, and 5% sand (Fig. 6B).

At LW-4 observation site, much of the

surrounding area was found to be closely mowed with minimal riparian buffer intact. Many small fish and crayfish were observed, as well as a widespread, filamentous brown algae. A single, small stormwater pipe extending from a nearby home was observed at the observation point. The streambed had been reinforced with concrete and rock. At the time of observation, the stream width was 3.51 m and maximum depth 0.122 m (Fig. 6A), the estimated discharge was 0.0490 cms. The streambed composition throughout the reach was estimated as follows: 2.5% silt/clay, 2.5% sand, 5% cobble, 5% boulder, and 85% bedrock (Fig. 6B).

The LW-5 site contained numerous crayfish and small fish, as well as a three wild ducks. Additionally, moderately distributed, filamentous green algae could be found throughout the entire reach. The stream appeared to receive little-to-no shade, and much of the proximal area had been mowed by nearby residents. Furthermore, the banks are largely reinforced by concrete and stone. No significant piping noted inside of the reach, but a BSB sanitary sewer manhole was identified at the top of the right streambank. Stream width was 6.55 m and maximum depth measured was 0.165 m (Fig. 6A). The stream bottom composition throughout the reach was estimated as follows: 1% silt/clay, 9% gravel, 40% cobble, and 50% bedrock (Fig. 6B). The estimated discharge was 4.49 cfs.

Cranberry Monitoring Baselines

Characterization of Cranberry Creek took place at four sites. To elucidate the impacts of urbanization on stream quality, sites were established upstream and downstream of Beckley's main commercial hub. C-1 was placed upstream of the extensive stretch of shopping centers and restaurants, and C-2 was placed downstream of the activity center but above the North Beckley Public Service District Sanitary Sewer Treatment Plant (Fig. 7). The Cranberry Creek converges with Piney Creek near the Northern MS4 boundary. NON-1 and NON-9 are situated near residential communities and along major roadways.

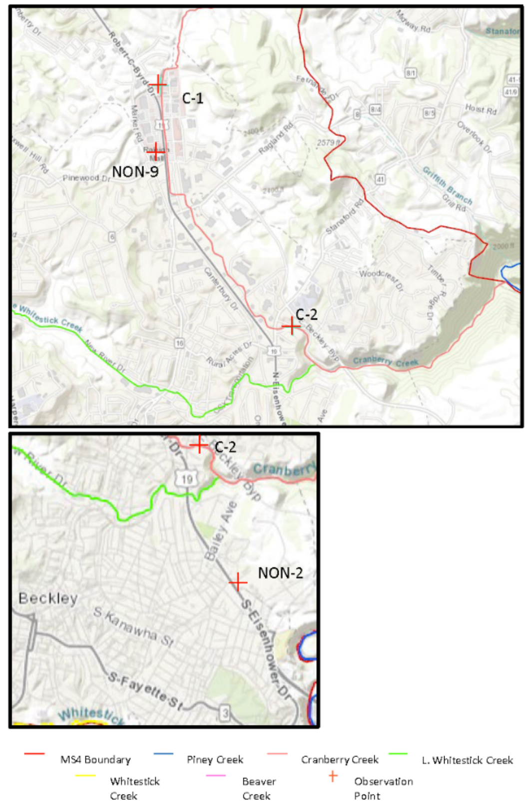

Figure 7. Map of Cranberry Creek observation points. ESRI map showing five observation site locations on Cranberry Creek (pink solid line) indicated by blue waypoints. Other solid lines indicate watershed points of interest (red solid line- MS4 boundary, green solid line – Little Whitestick Creek.

NON-1 within the Cranberry Creek subwatershed, site width was 1.37 m and maximum depth was 0.64 m. The discharge at the time of observation was 0.00963 cms, and the stream bed composition was estimated at 30% silt/clay, 30% sand, 30% cobble, and 10% bedrock (Fig. 8B). Located within NON-1 is a 0.305 m (12 in) drain culvert along the roadway that the stream feeds into.

Much of the stream at observation site C-1 was reinforced by large cobble, and the estimated stream bottom composition throughout the reach was: 60% silt/clay, 10% sand, and 30% cobble (Fig. 8B). Even in wet weather, the flow was found to be nearly zero, and the observers were forced to use a small chute formed by a larger rock and the stream bank to obtain a flow value. Stream width measured 0.204 m and maximum depth 0.0762 m (Fig. 8A). At the time of observation, discharge was found to be 0.00113 cms. Observation site NON-9 (Cranberry Creek watershed) was in a major commercial district along a major roadway. There are two 0.305 m (12 in) drain culverts that drain from the stream and under the roadway. Site stream width was 3.63 m and maximum depth was 0.671 m. Estimated discharge at time of observation was 0.0515 cms. Stream bottom composition throughout the reach was: 20% silt/clay, 20% sand, 10% gravel, 20% cobble, and 30% boulder (Fig.8B).

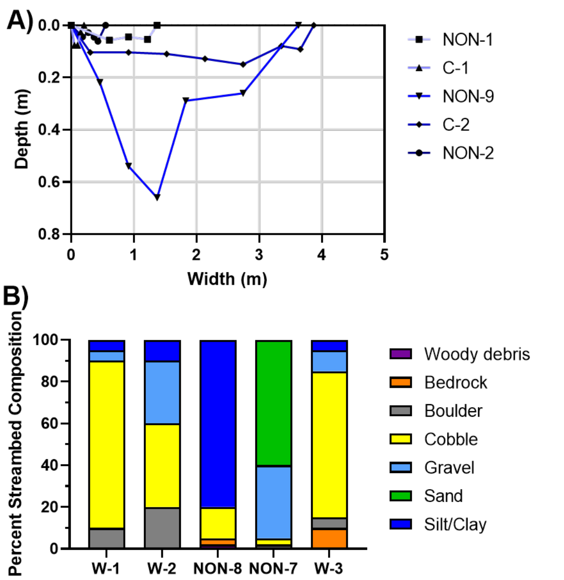

Figure 8. Cranberry Creek watershed streambed measurements. Streambed cross-sectional area measurements (A). Percent streambed composition for Cranberry Creek watershed sites NON-1, C-1, NON-9, C-2, NON-2 (B).

At the C-2 monitoring site, the stream was completely reinforced with concrete and rock. Due to the extensive reinforcement layer, riparian buffer was minimal, with only occasional patches of vegetation breaking through seams in the concrete. Stream width of C-2 was 3.87 m and maximum depth was 0.149 m (Fig. 8A). The estimated discharge at this location was 0.0663 cms. The streambed composition was estimated as: 5% sand, 5% gravel, 10% cobble, and 80% bedrock (Fig. 8B).

Observation site NON-2, within the Cranberry Creek watershed, discharge at the time of observation was 0.00170 cms, and the width was 0.549 m and maximum depth was 0.0518 m (Fig. 8A). NON-2 streambed composition was estimated at 90% gravel, 5% sand, and 5% silt/clay (Fig. 8B). For the habitat assessment, the greatest score reduction resulted from the lack of riparian buffer on both sides of the stream. Infrequent signs of erosion and bank instability were observed on both sides of the stream, and there did not appear to be a substantial amount of sedimentation.

Watershed Habitat Assessment

Overall, five named and seven unnamed streams with a combined total of 21 sample sites were observed during this survey. Whitestick Creek watershed sites include W-1, W-2, NON-8, NON-7, and W-3 (Fig. 1). Table 2 habitat assessments of W-1 were as follows: 18 embeddedness (optimal); 8 sediment deposition (marginal); 5 left bank stability (marginal); 6 right bank stability (suboptimal); 4 left riparian buffer (suboptimal); and 4 right riparian buffer (suboptimal) (Fig. 9). Overall, the W-1 site received an overall percent habitat score of 56.2% and was defined as "marginal" (Fig. 10A). Habitat assessments of W-2 were as follows: 16 embeddedness (optimal); 17 sediment deposition (optimal); 1 left bank stability (poor); 8 right bank stability (optimal); 1 left riparian buffer (poor); and 5 right riparian buffer (marginal) (Table 2). Overall, W-2 received percent habitat score of 60.0% and was defined as "marginal" (Fig. 10A).

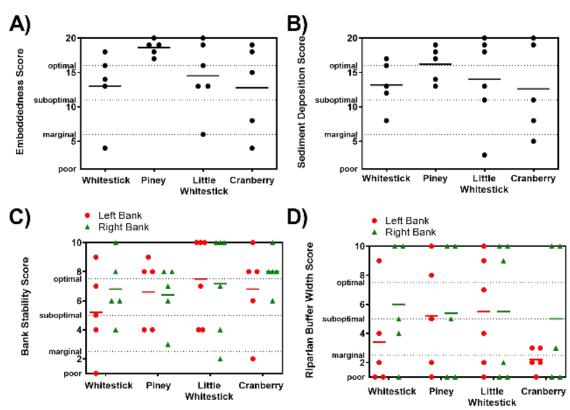

Figure 9. Streambed scores for embeddedness, sediment deposition, bank stability, and riparian buffer.

Habitat assessments of NON-8 were as follows: 4 embeddedness (poor); 12 sediment deposition (suboptimal); 9 left bank stability (optimal); 6 right bank stability (suboptimal); 2 left riparian buffer (poor); and 10 right riparian buffer (optimal) (Fig. 9 and Table 2). Areas of heeling and bare soil were observed, and the left side of the stream lacks sufficient riparian buffer. Sediment deposition, riparian buffer, and bank stability were all found to be areas of concern, contributing to a percent habitat score of 53.8% and overall ranking as "marginal" (Fig. 10B).

Table 2. Monitoring site streambed scores for embeddedness, sediment deposition, bank stability, and riparian buffer.

Site ID	Embeddedness Score	Sediment Deposition Score	Bank Stability Score (L,R)	Riparian Buffer Width Score (L,R)
Whitestick Creek Sites				
W-1	18	8	5,6	4,4
W-2	16	17	1,8	1,5
NON-8	4	12	9,6	2,10
NON-7	13	13	4,4	9,10
W-3	14	16	7,10	1,1
Piney Creek Sites				
P-1	20	17	9,8	2,1
NON-4	19	13	4,3	10,10
P-2	17	18	4,8	5,5
B-1	19	14	8,6	1,10
P-3	18	19	8,7	8,1
Little Whitestick Creek Sites				
LW-1	6	3	4,4	10,10
LW-2	13	18	7,7	9,9
LW-3	16	13	4,2	7,10
NON-5	13	11	10,10	4,1
LW-4	19	19	10,10	2,2
LW-5	20	20	10,10	1,1
Cranberry Creek Sites				
NON-1	4	11	8,8	3,10
C-1	8	8	8,8	3,10
NON-9	15	5	2,6	2,3
C-2	19	20	10,10	2,1
NON-2	18	19	6,7	1,1

Abbreviations: B, Beaver Creek; C, Cranberry Creek; L, stream bank left; LW, Little Whitestick Creek; NON, Non-Total Maximum Daily Load; P, Piney Creek; R, stream bank right; W, Whitestick Creek

NON-7 site received optimal scores for 9 left and 10 right riparian buffer (Fig. 9). Moderate frequency of scarring and collapses reduced the bank stability scores as marginal for a score of 4 left and to 4 right, as well as, apparent embeddedness score of 13 and sediment deposition scores of 13 as suboptimal (Fig. 9 and Table 2). Overall, the site received a percent habitat score of 66.3% and classified as "marginal." (Fig. 10B) Habitat assessments of W-3 were as follows: 14 embeddedness (suboptimal); 16 sediment deposition (optimal); 7 left bank stability (suboptimal); 10 right bank stability (optimal); 1 left riparian buffer (poor); and 1 right riparian buffer (poor) (Fig. 9 and Table 2). The overall percent habitat score was 60.0% and was "marginal" (Fig. 10A).

Piney Creek subwatershed sites include P-1, NON-4, P-2, B-1, and P-3 (Fig. 3). Observation site habitat assessments for P-1 were as follows: 20 embeddedness (optimal); 17 sediment deposition (optimal); 9 left bank stability (optimal); 8 right bank stability (optimal); 2 left riparian buffer (poor); and 1 right riparian buffer (poor) (Fig. 9 and Table 2). In the face of the highly reduced riparian buffer, the site received an overall habitat score of 71.0% classified as "suboptimal" (Fig. 10A).

Habitat assessment of site NON-4 were as follows: 19 embeddedness (optimal); 13 sediment deposition (suboptimal); 4 left bank stability (marginal); 3 right bank stability (suboptimal); 10 left riparian buffer (optimal); and 10 right riparian buffer (optimal) (Fig. 9 and Table 2). The major habitat impairments observed were bank instability, with both stream banks exhibit frequent signs of erosion and collapse, and some sediment deposition. With extensive riparian buffer on both sides of the stream and little sign of sedimentation, the site percent habitat score was 73.8% with an overall ranking of "suboptimal" (Fig. 10B).

Observation site habitat assessments for P-2 were as follows: 17 embeddedness (optimal); 18 sediment deposition (optimal); 4 left bank stability (marginal); 8 right bank stability (optimal); 5 left riparian buffer (marginal); and 5 right riparian buffer (marginal) (Fig. 9 and Table 2). Riparian buffer and bank stability both impacted the score of this site, with a percent habitat score of 71.2% but the site was still rated "suboptimal" overall (Fig. 10A).

Baseline assessment of B-1 indicated the stream did exhibit some signs of sedimentation (14, suboptimal) and embeddedness (19, optimal) (Fig. 9 and Table 2). The stream banks are largely reinforced by large cobble and boulders at this site; however, in the isolated areas lacking the stone, signs of bank instability and erosion were evident. Overall bank stability scores at B-1 were 8 for bank left (optimal) and 6 for bank right (suboptimal) (Fig. 9). With only a few feet of vegetation along the right bank closest to the roadway the score was 10 (optimal) for the right side but the site lacked sufficient riparian buffer on the left side with a score of 1 (poor) (Fig. 9). Overall, B-1 habitat score was 72.5% and was given an "suboptimal" rating (Fig. 10B).

Observation site habitat assessments for P-3 were as follows: 18 embeddedness (optimal); 19 sediment deposition (optimal); 8 left bank stability (optimal); 7 right bank stability (suboptimal); 8 left riparian buffer (optimal); and 1 right riparian buffer (poor) (Fig. 9 and Table 2). The riparian buffer layer was found to be narrow on the right side (1, poor), contributing to a diminished overall percent habitat score of 76.2% and overall habitat assessment rated "suboptimal" (Fig. 10A).

Little Whitestick Creek watershed sites included LW-1, LW-2, LW-3, NON-5, LW-4, and LW-5 (Fig. 5). Observation site habitat assessments for LW-1 were as follows: 6 embeddedness (suboptimal); 3 sediment deposition (marginal); 4 left bank stability (marginal); 4 right bank stability (marginal); 10 left riparian buffer (optimal); and 10 right riparian buffer (optimal) (Fig. 9 and Table 2). Due to sedimentation, embeddedness and bank instability, the stream received an overall percent habitat score of 46.3% and ranked as "poor" (Fig. 10A).

Observation site LW-2 habitat assessments were as follows: 13 embeddedness (suboptimal); 18 sediment deposition (optimal); 7 left bank stability (suboptimal); 7 right bank stability (suboptimal); 9 left riparian buffer (optimal); and 9 right riparian buffer (optimal) (Fig. 9 and Table 2). Although embeddedness and streambank instability were visible, the percent habit score was 78.8% and score "suboptimal" at LW-2 (Fig. 10A).

Observation site LW-3 habitat assessments were as follows: 16 embeddedness (optimal); 13 sediment deposition (suboptimal); 4 left bank stability (marginal); 2 right bank stability (poor); 7 left riparian buffer (suboptimal); and 10 right riparian buffer (optimal) (Fig. 9 and Table 2). Stream banks were found to be high unstable, with frequent signs of erosion and collapses visible throughout much of the reach. Overall, LW-3 received a percent habitat score of 65.0% and "marginal" at this site (Fig. 10A).

Habitat assessment at NON-5 were as follows: 13 embeddedness (suboptimal); 11 sediment deposition (suboptimal); 10 left bank stability (optimal); 10 right bank stability (optimal); 4 left riparian buffer (marginal); 1 right riparian buffer (poor) (Fig. 9 and Table 2). Therefore, percent habitat score was 61.2% and defined as "marginal" (Fig. 10A).

Habitat assessments at LW-4 were as follows: 19 embeddedness (optimal); 19 sediment deposition (optimal); 10 left bank stability (optimal); 10 right bank stability (optimal); 2 left riparian buffer (poor); and 2 right riparian buffer (poor) (Fig. 9 and Table 2). For the overall habitat assessment, LW-4 percent habitat score was 77.5% and site received a score of "suboptimal" (Fig. 10A). Habitat assessments at LW-5 were as follows: 20 embeddedness (optimal); 20 sediment deposition (optimal); 10 left bank stability (optimal); 10 right bank stability (optimal); 1 left riparian buffer (poor); and 1 right riparian buffer (poor) (Fig. 9). Overall, the 77.5% habitat score for site LW-5 was rated as "suboptimal" (Fig. 10).

Cranberry creek watershed sites include: NON-1, C-1, NON-9, C-2, and NON-2 (Fig. 7). NON-1 habitat assessment was as follows: 4 embeddedness (poor); 11 sediment deposition (suboptimal); 8 left bank stability (optimal); 8 right bank stability (optimal); 3 left riparian buffer (marginal); 10 right riparian buffer (optimal) (Fig. 9 and Table 2). NON-1 embeddedness and riparian buffer displaying the greatest impairments. Although both banks displayed signs of significant instability, only the left banks truly lacked riparian buffer. Overall habitat score of 55.0% and overall ranking as "marginal" (Fig. 10B).

C-1 habitat assessments were as follows: 8 embeddedness (marginal); 8 sediment deposition (marginal); 8 left bank stability (optimal); 8 right bank stability (optimal); 3 left riparian buffer (marginal); 10 right riparian buffer (optimal) (Fig. 9 and Table 2). With issues of embeddedness, sedimentation, bank instability and riparian buffer, the stream received a percent habitat score of 56.2% and was "marginal" (Fig. 10B). Habitat assessments of NON-9 were as follows: 15 embeddedness (suboptimal); 5 sediment deposition (poor); 2 left bank stability (poor); 6 right bank stability (suboptimal); 2 left riparian buffer (poor); and 3 right riparian buffer (marginal) (Fig. 9 and Table 2). Overall habitat score of 41.3% and overall ranking as "poor" (Fig. 10B).

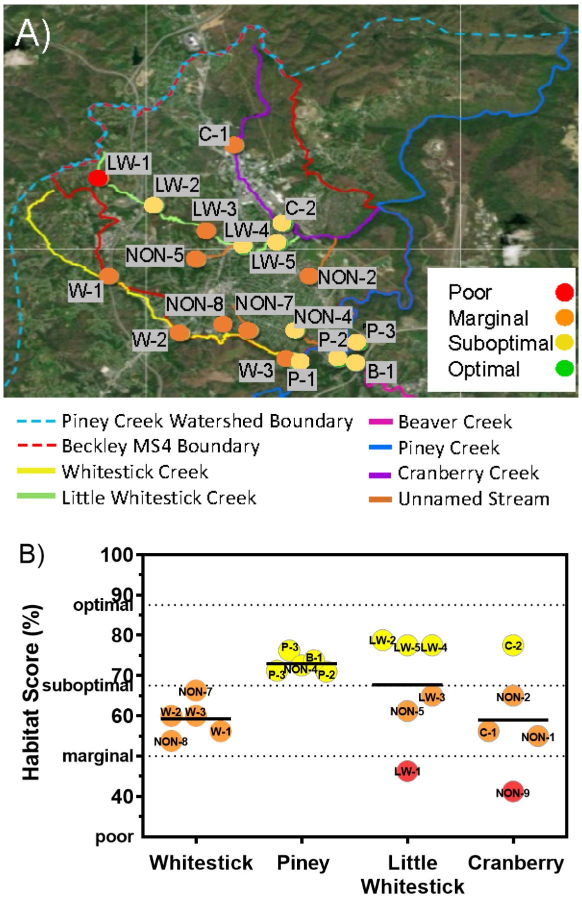

Figure 10. Percent habitat scores for Piney Creek Watershed.

Habitat assessments at C-2 were: 19 embeddedness (optimal); 20 sediment deposition (optimal); 10 left bank stability (optimal); 10 right bank stability (optimal); 2 left riparian buffer (poor); 1 right riparian buffer (poor) (Fig. 9 and Table 2) and the site received a percent habitat score of 77.5% and was "suboptimal" (Fig. 10B). Habitat assessments of NON-2 were as follows: 18 embeddedness (optimal); 19 sediment deposition (optimal); 6 left bank stability (suboptimal); 7 right bank stability (suboptimal); 1 left riparian buffer (poor); and 1 right riparian buffer (poor) (Fig. 9 and Table 2). Overall, the site percent habitat score was 65.0% and rated "marginal" (Fig 10B).

Discussion

The Piney Creek watershed lies within the Lower New watershed of the Kanawha river basin. During the initiation of the study, fecal coliform total maximum daily loads (TMDLs) were being enforced on four streams in the MS4: Whitestick Creek, Little Whitestick Creek, Cranberry Creek, and Piney Creek (West Virginia Department of Environmental Protection, 2008). As both the largest and those with previously identified areas of concern, these four streams were also identified as the highest priority sites of this study. In addition to these, Beaver Creek and seven nearly ephemeral streams, referred to as "non-TMDL" for their lack of maximum load enforcement, were also characterized.

Calculated discharge averages among stream observation sites within each of the four watersheds are as follows: Whitestick 0.0765 cms (0.0651 SD); Piney 2.248 cms (2.268 SD); Little Whitestick 0.0396 cms (0.0453 SD); and 0.0255 cms (0.0311 SD) Cranberry watershed streams. Predominant streambed composition among most of the Piney Creek and Whitestick Creek sites were cobble and gravel (Fig. 2 and Fig. 4). However, streambed composition predominance for Little Whitestick and Cranberry sites were variable according to specific site locations (Fig. 6 and Fig. 8). Notably, specific sites with silt/clay predominance in the streambed include NON-8 (Fig. 2), LW-1 (Fig. 6), NON-1, and C-1 (Fig. 8).

According to the WVDEP, increased sedimentation and the resulting increased embeddedness are one of the most important problems facing West Virginia streams (West Virginia Department of Environmental Protection, 2016). Specifically, within the Central Appalachian region 22.8% of stream miles have poor or very poor ratings for stream embeddedness (West Virginia Department of Environmental Protection, 2016). In the Piney Creek watershed only four of the 21 sites scored marginal or poor for embeddedness that includes sites NON-8, LW-1, NON-1, and C-1 (Fig. 9A). Also, four of the 21 sites scored marginal or poor for sediment deposition (Fig. 9B) that includes sites W-1, LW-1, NON-9, and C-1 sites. These sites are likely to have increased embeddedness and sedimentation because they have slower, low-gradient streams, more erodible soils, and more land-disturbing activities than in other areas of the Piney Creek watershed.

Lack of riparian buffer appears to be the most common habitat issue among all observation sites, with 18 out of 42 (42.9%) possible banks (two banks per site) receiving a poor riparian buffer score and 6 banks out of 42 (14.3%) possible banks scored marginal in this category (Fig. 9D). In comparison, the Central Appalachian region 23.6% of stream miles have poor or very poor riparian zone vegetation scores for West Virginia (West Virginia Department of Environmental Protection, 2016). According to Dillaha *et al.* (1989), riparian buffers can reduce solids and sediment loads by an average of 70-84% for buffer widths of 4.6 meters and 9.1 meters, respectively. Vegetative filter strips are man-made areas of vegetation designed to remove sediment and other pollutants from water runoff and have been used in agricultural applications to reduce water pollutant load (Dillaha *et al.*, 1989). Furthermore, Young *et al*. (1980) revealed that vegetative buffers could be effective in reducing up to 70% of bacterial loads. Therefore, future implementation of widespread riparian revegetation or implementation of vegetative filter strips across the Piney Creek watershed may offer a significant reduction of bacterial and nutrient loads that are currently impairing the Piney Creek watershed.

Bank instability was the next most prevalent form of habitat degradation, with of the possible 42 scores, three banks scored poor (7.1%) and eight banks scored marginal (19.0%) (Figure 9C). The reduction in riparian buffer and bank instability may very well be interrelated, as Zhang *et al*.(2008) discuss the effects of urban sprawl and reduction of natural vegetative cover in increasing rainfall return rates. This increase in return rate and water discharge volume in local streams can increase erosion, decrease the stability of the banks, and increase sediment loading in the streams. An increase in suspended sediment may be partly to blame for the increased sediment deposition and build up that are restricting flow at sites like LW-1 and C-1. As previously discussed, urbanization exhibits a positive correlation with increased pollution loading. According to Wang *et al.* (2017), bioretention basins were responsible for 25%, 46%, and 53% reductions in nitrogen, phosphorous, and total suspended solids, respectively. Addressing these issues will certainly require holistic approaches over time to simultaneously reduce nutrient, sediment, and bacterial load while improving stream water conveyance.

Of the overall habitat score surveys of the 21 sites, nine sites were found to be in suboptimal condition, ten rated as marginal, and two as poor (Fig. 10A). Average habitat scores and standard deviation (SD) for each of the four subwatersheds are as follows: Whitestick subwatershed 59.3% (4.7 SD), marginal; Piney Creek 72.9% (2.1 SD), suboptimal; Little Whitestick subwatershed 67.7% (12.8 SD), suboptimal; and 59.0% (13.4 SD), marginal Cranberry subwatershed (Fig. 10B). Although categorical thresholds are somewhat subjective, they do provide a good comparison of habitat conditions between geographic areas. For instance, habitat parameters from EPA's Rapid Bioassessment Protocol indicate based on probability data that just 9.9% of stream miles state-wide have good habitat score, 73.5% of stream miles have moderate habitat quality, and 16.6% of stream miles have poor habitat quality (West Virginia Department of Environmental Protection, 2016). As such, most of the state's stream miles (approximately 90%) have at least some degree of habitat degradation. Therefore, examining specific habitat characteristics associated with habitat degradation are likely to have importance towards gaining insights for remediation of other West Virginia waterways as well.

Overall our findings help to characterize this important watershed by establishing locations for ongoing monitoring of numerous water quality parameters to help further define this tributary of the New River. This report shows successful implementation of the WVSOS protocols and gives a baseline for future improvement and research efforts.

Acknowledgements

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