# EFFECTIVE USE OF PARTNERSHIPS TO ASSESS A MINING-IMPACTED WATERSHED[1]

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**Abstract:** The Roaring Creek watershed in central West Virginia was known to be impacted by historic coal mining. However, the current degree of the environmental degradation within the watershed was not known. A partnership between the National Mine Land Reclamation Center (NMLRC), the West Virginia Department of Environmental Protection-Division of Water and Waste Management (WVDEP-DWWM), and Trout Unlimited (TU) was formed to assess the impacts of nonpoint-source pollution in the Roaring Creek watershed. Water chemistry, water quantity, and benthic data were gathered four times between 2009 and 2010. The results of this data show that almost all of the mining impacts within the watershed were found in one tributary called Kittle Hollow. Due to these findings, Kittle Hollow was targeted for further sampling. Multiple mine drainage sources were sampled in order to prioritize them for passive treatment. This collected data will be used to develop a watershed-based plan, which will represent the end of the assessment process. Currently, the plan is being written and the remediation projects are in the design phase. Once these projects are completed, they are expected to remove 80% of the metal and acid loads from each mine discharge. The ultimate goal of the watershed assessment process is to improve the quality of the existing trout fishery in Roaring Creek as well as extend the territory in which trout can thrive. It is anticipated that the reclamation of Kittle Hollow will allow the entire Roaring Creek watershed to function as a successful fishery.

**Additional Key Words:** acid mine drainage, watershed-based plan

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## Introduction

Watershed Description

The Roaring Creek watershed is located in central West Virginia in Randolph County (Fig. 1). It is 75 $km^2$ (29 $mi^2$) and drains directly to the Tygart Valley River. This watershed is mostly rural with the two largest settlements being the towns of Coalton and Mabie. Part of the mainstem (from Coalton to the mouth) of Roaring Creek, as well as Kittle Hollow, located west of Coalton, and is on the 1998 EPA 303(d) list of Impaired Streams for acidity, Fe, and Al.

In the lower portion of the watershed, the Lower Kittanning coal seam has been mined extensively. The majority of the mining performed in the Roaring Creek Watershed was underground mining, although some surface mining has occurred in recent years. Water quality from underground mines in this coal seam varies; however, it often has high Fe content and low pH. Figure 2 shows the delineation of the Roaring Creek watershed.

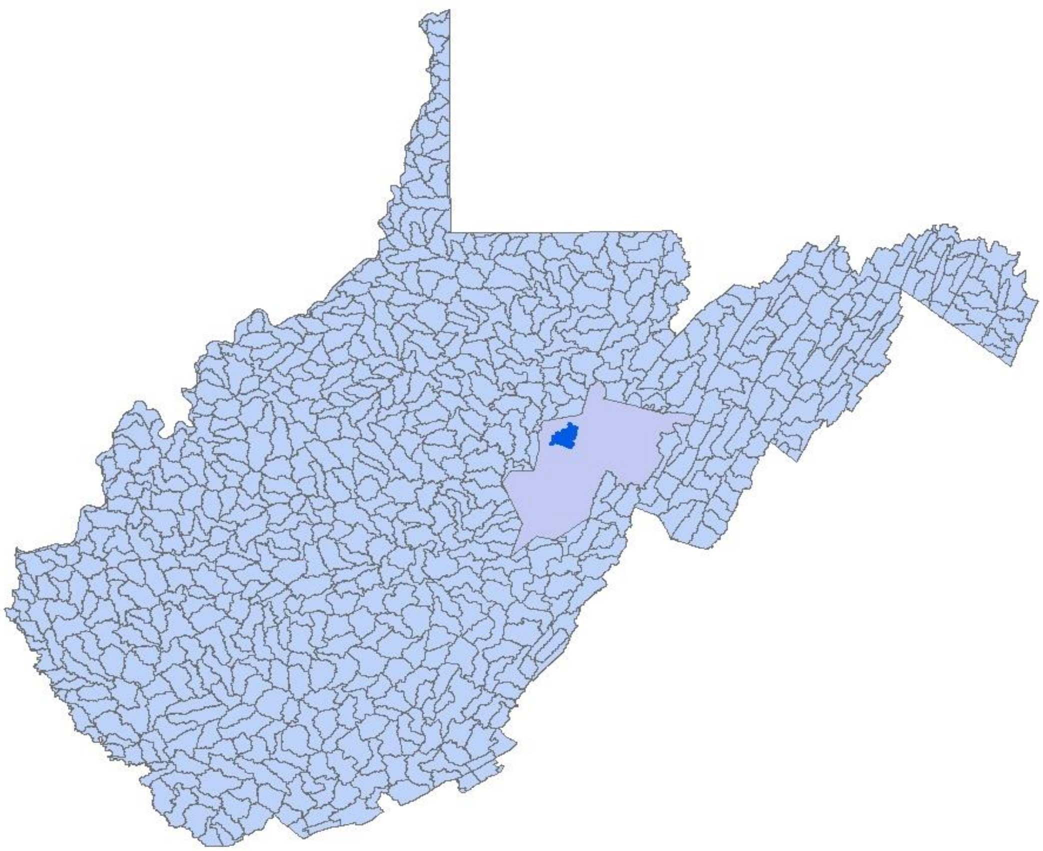

Figure 1. General location of the Roaring Creek watershed. The dark blue area is Roaring Creek and the purple area is Randolph County.

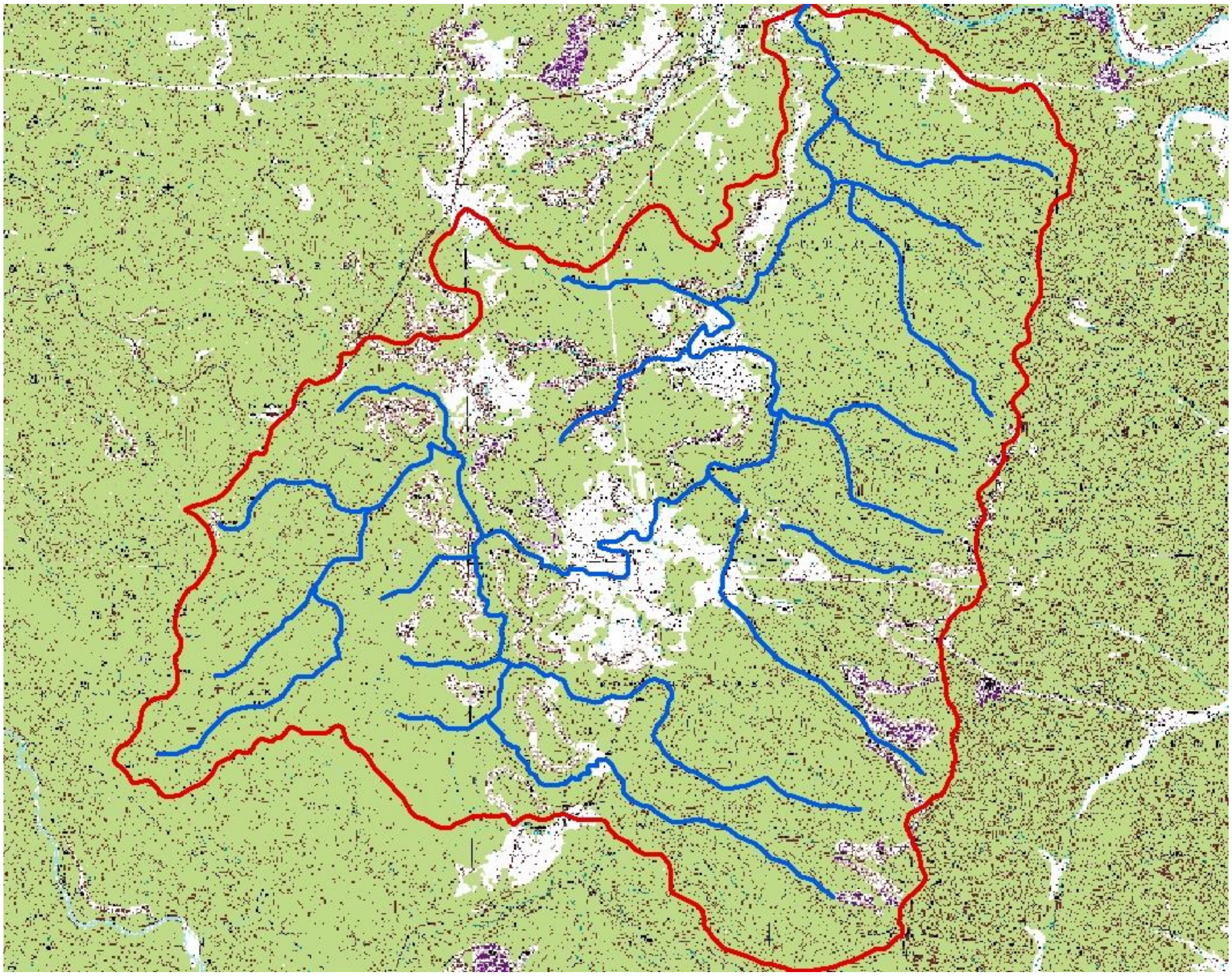

Figure 2. Delineation of the Roaring Creek watershed.

Initial Condition of Roaring Creek

For part of its length, Roaring Creek has been impacted by historical coal mining. At its mouth, Roaring Creek is slightly acidic and has metal concentrations (Fe, Al, and Mn) greater than state water quality standards. However, other parts of the watershed are untouched by mining or other human activities. A trout fishery currently exists within the watershed near the headwaters of the mainstem of the stream (upstream of the town of Mabie) as well as the headwaters of Flatbush Creek (a small tributary that is in the western part of the watershed). Because the mining-affected sections of Roaring Creek are not heavily impacted and some parts of the watershed are unimpacted by mining, this watershed was viewed as a candidate for removal from the 303(d) list of Impaired Streams. One tool that can be used to aid in the removal process is a watershed-based plan (WBP).

Watershed-Based Plan Description

One of the most common methods of funding reclamation work is through Section 319 of the Clean Water Act. Amendments to the Clean Water Act (CWA) implemented in 1987 established the Section 319 Nonpoint Source Management Program. "Under Section 319, states, territories and tribes receive grant money that supports a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source implementation projects (USEPA, 2010)." In order for this funding to be used, a strategic plan (called a watershed-based plan) must be in place for the watershed in which the reclamation work is to occur. Release of Section 319 funds can only occur when a WBP has been created.

Watershed-based plans are comprehensive and strategic documents. The elements found within these plans may include: load reduction estimates, potential reclamation funding sources, implementable measures that could be used to achieve restoration, ways to disseminate the information contained within the plan, and a monitoring component to verify progress. This planning process enables eligible entities to better identify and understand what actions are most needed to improve the health of the affected watershed.

For a WBP to adequately cover all relevant issues within a watershed, many different sources of information must be gathered and analyzed. Partnerships between state and federal agencies, nonprofit groups, academia, and individual citizens enable a complete WBP to be constructed. For example, a partnership between the West Virginia Water Research Institute (WVWRI), the West Virginia Department of Environmental Protection Division of Water and Waste Management (WVDEPDWWM), and the Mountaineer Chapter of Trout Unlimited (MCTU) was formed to create the Roaring Creek WBP. This partnership generated funding from the State of West Virginia to create the WBP (WVDEPDWWM) and for collection of data for the plan (WVWRI and MCTU).

## Methods

The assessment process for the Roaring Creek watershed can be divided into three phases. Phase 1 consisted of the initial formation of the partnership between the three entities and identification of major sources of mining impacts. Phase 2 was the development and implementation of a sampling plan to gather data from major sources of mine drainage found during Phase 1. Phase 3 included the analysis of the sample data collected under Phase 2. After the data has been analyzed, it will be used to determine which mine drainage sites need to be reclaimed first; it will also aid in the design of passive reclamation systems.

Phase 1

Initially, there was not much information regarding Roaring Creek. There was active treatment on a stream next to Roaring Creek and the WVDEP had taken some field measurements for pH where Roaring Creek entered the Tygart River. WVWRI's contact with the WVDEP's Division of Water and Waste Management had seen these field pH results and decided that Roaring Creek was a good candidate for removal from the 303(d) list. He contacted the MCTU and they provided him with anecdotal evidence of trout in Roaring Creek. The WVDEP DWWM then approached WVWRI with the idea of reclaiming this watershed. WVWRI wrote a grant to the WVDEP DWWM for Section 319 funding to create a watershed-based plan. After the grant was approved, this initial partnership created an inventory of problem sites to be used to develop a sampling plan in Phase 2. Using the inventory of problem sites as a guide, potential sampling points were rated based on degree of impairment. To aid in this rating, field parameters including pH, conductivity, dissolved oxygen, and temperature were collected. A threshold value of $pH<5$ was used to determine if a site warranted further sampling because streams un-impacted by mining in this region of West Virginia typically have a pH value between 5 and 8. The location of each site was also determined using a hand held GPS. For Phase 1 of this project, the mouth of Roaring Creek and the mouths of its major tributaries were selected to determine the degree of impairment for each stream segment. Field parameters were also collected on 8 abandoned mine land discharges and one instream point in the Kittle Hollow subwatershed. Figure 3 shows the instream field parameter collection points for Phase 1.

Historic data was also collected as part of Phase 1. From 1965-1969, a USGS gauging station collected water quantity data at the mouth of Roaring Creek (USGS, 2006). The WVDEP Watershed Assessment Protocol (WAP) group also collected some baseline samples within the watershed between 1997 and 2008. Figure 4 shows the locations of both the gauging station and the WAP samples.

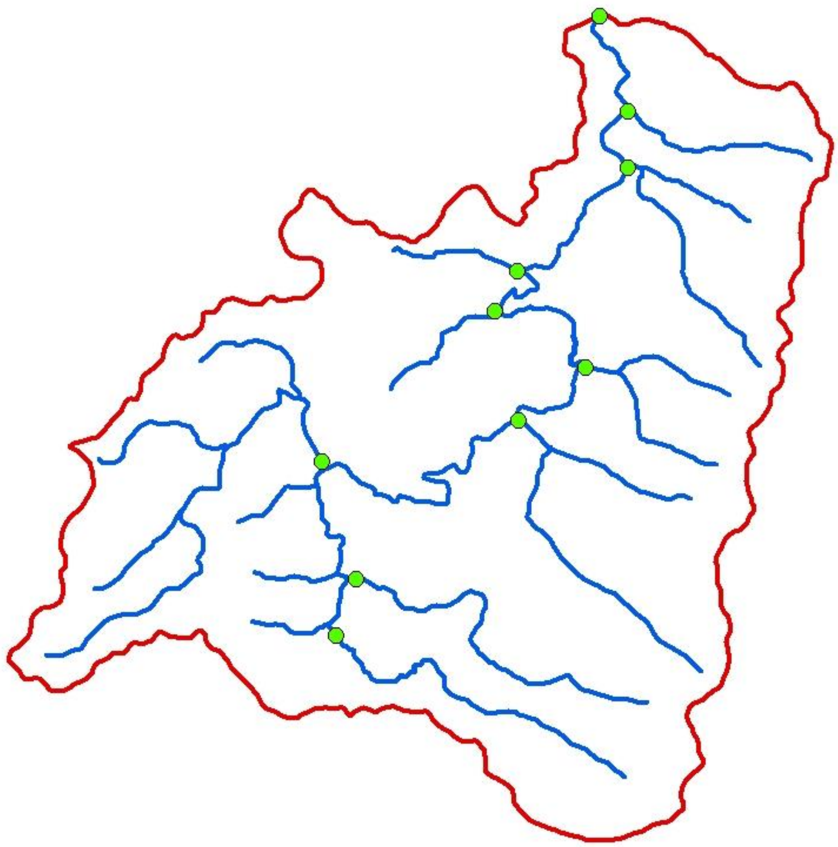

Figure 3. Field parameter collection points (green dots).

Phase 2

Once problem areas were defined, Phase 2 was initiated. Field parameters, water samples, stream flows, and benthic macro-invertebrates were collected from multiple sites within the Roaring Creek watershed. Flows were measured using either a Flo-Scan Doppler flow meter or a Marsh-McBirney Flo-Mate 2000 flow meter with a standard USGS wading rod. Flows were measured at every location on every date that a sample was collected. Sample chemistry for all sites consisted of a filtered acidified sample for Fe, Al, Mn, Mg, and Ca. A non-acidified, non-filtered sample was collected for pH, acidity, alkalinity, conductivity, and $SO_4$. In addition to water samples, the collection of benthic macroinvertebrate organisms was used to determine baseline water quality. Benthic collection was performed by disturbing the rocks and sediment in the stream bed and catching the organisms released from the rocks in a 1 $m^2$ net. These organisms were counted and categorized by species.

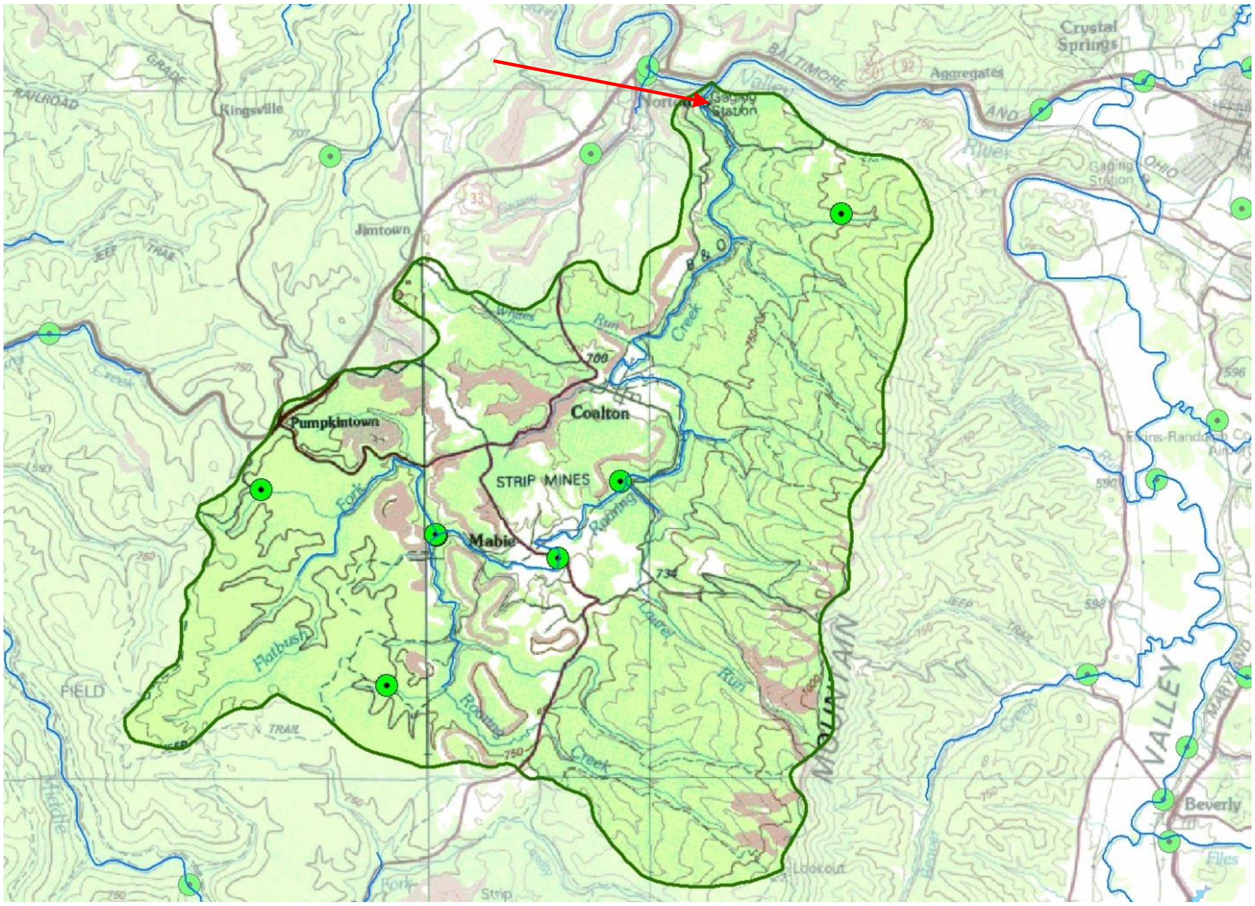


Figure 4. Location of historic sample points within the Roaring Creek watershed. The green circles are WAP sampling points. The red arrow details the location of the USGS gauging station.

Flow readings, field parameters, and chemistry samples were collected four times during 2009-2010. Sample collection was timed to represent spring, summer, and autumn stream conditions. Samples were gathered in April, July, and October 2009, and April 2010. Three teams of volunteers from MCTU, WVWRI, and WVDEP collected a total of 40 instream samples for each of the four sampling periods. These 40 samples included all sample points taken during Phase 1, as well as points that were added to further narrow down the sources of impairment. The seven Phase I sample sites on Kittle Hollow were sampled again during Phase 2. For some sample sites, the collection of all four parameters (flow, field parameters, water chemistry samples, and benthic macro-invertebrates) could not be accomplished because of site specific issues, such as stream flows that were too large. Figures 5, 6, 7, and 8 show Phase 2 flow, field, and chemistry sample point locations and Fig. 9 shows the Kittle Hollow sample points.

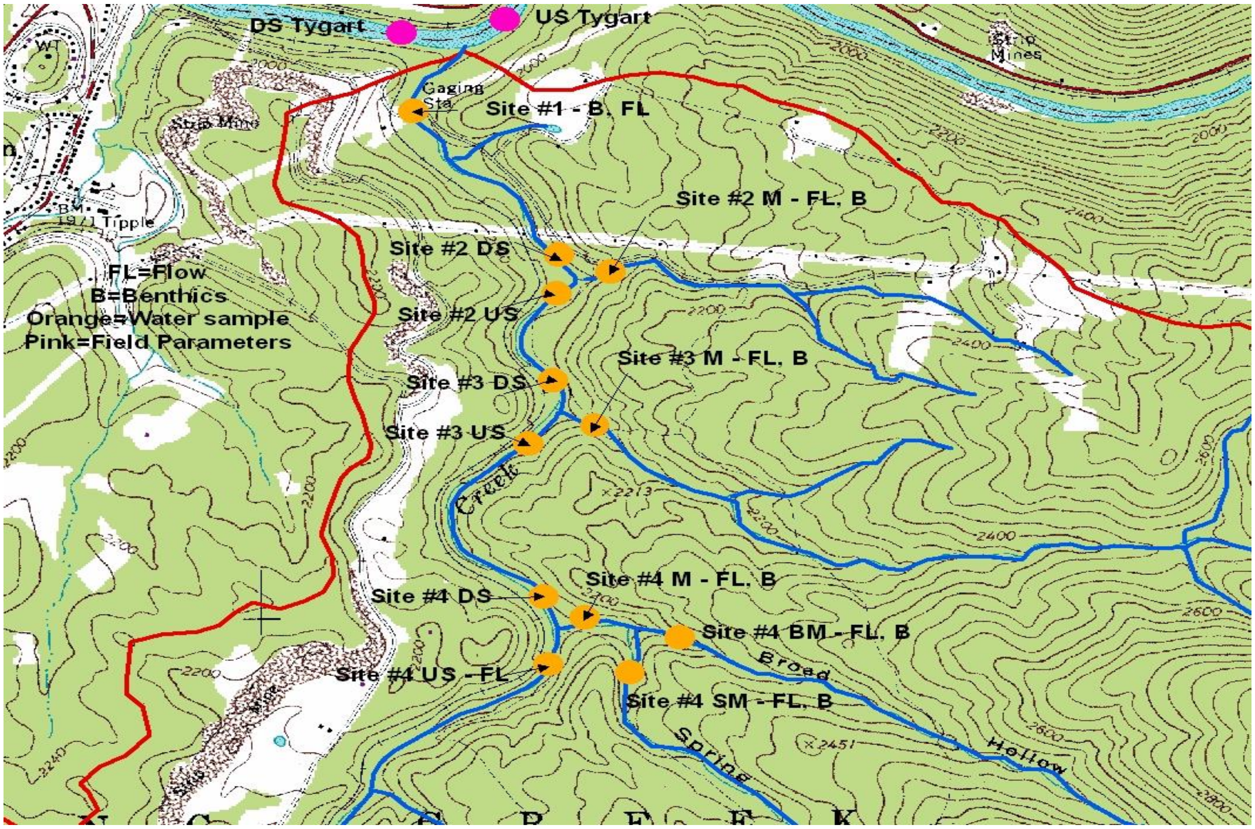


Figure 5. Phase 2 sampling points for lower Roaring Creek. Sites were numbered from upstream to downstream. FL = Flow measured, B = Benthic organisms collected. US = Upstream of confluence, DS = Downstream of confluence, and M = Mouth of stream. Orange dots are sample points at which both field parameters and water samples were taken and pink dots are field parameters only.

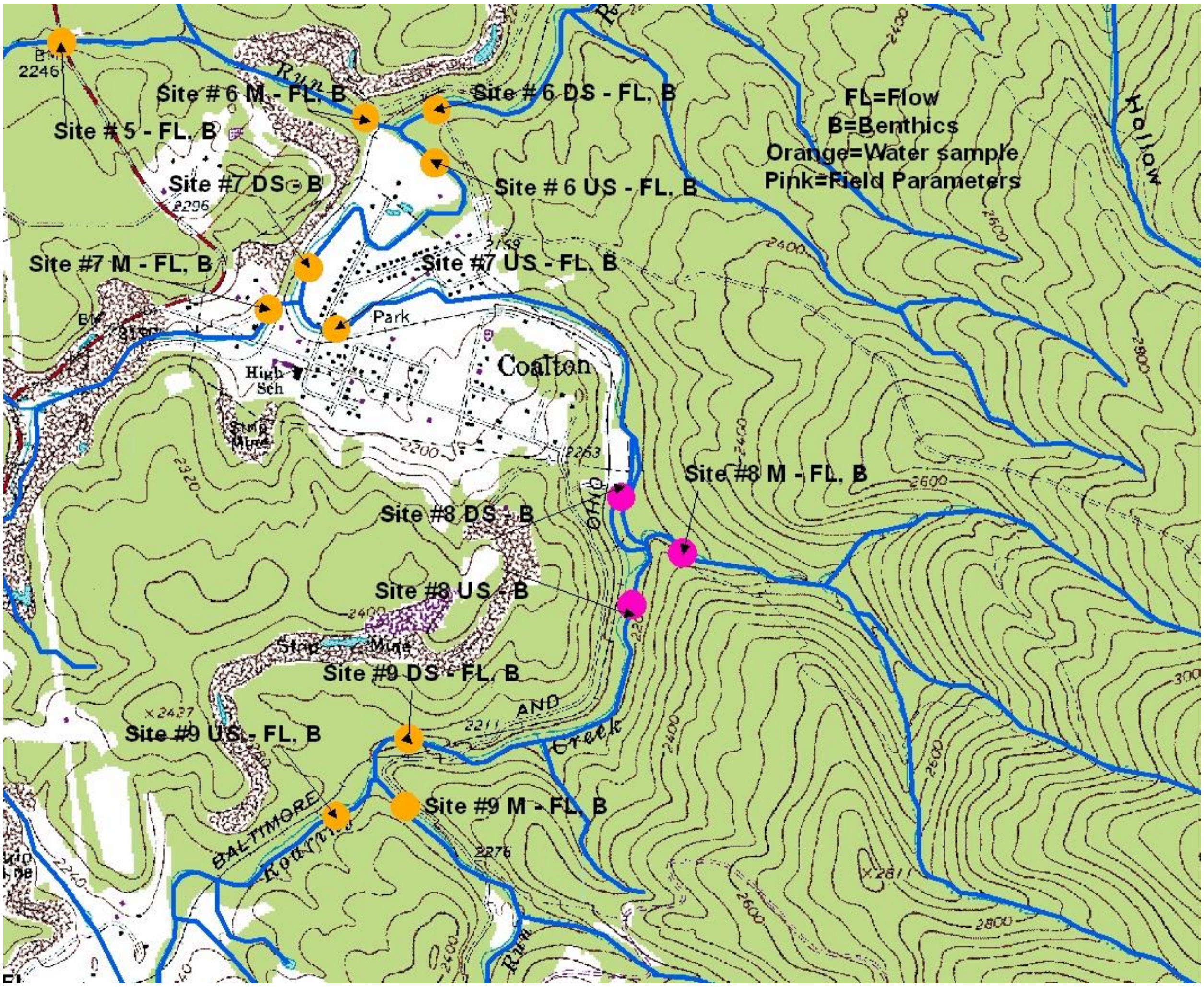


Figure 6. Phase 2 sampling points for the eastern side of middle Roaring Creek. FL = Flow measured, B = Benthic organisms collected. US = Upstream of confluence, DS = Downstream of confluence, and M = Mouth of stream. Orange dots are sample points at which both field parameters and water samples were taken and pink dots are field parameters only.

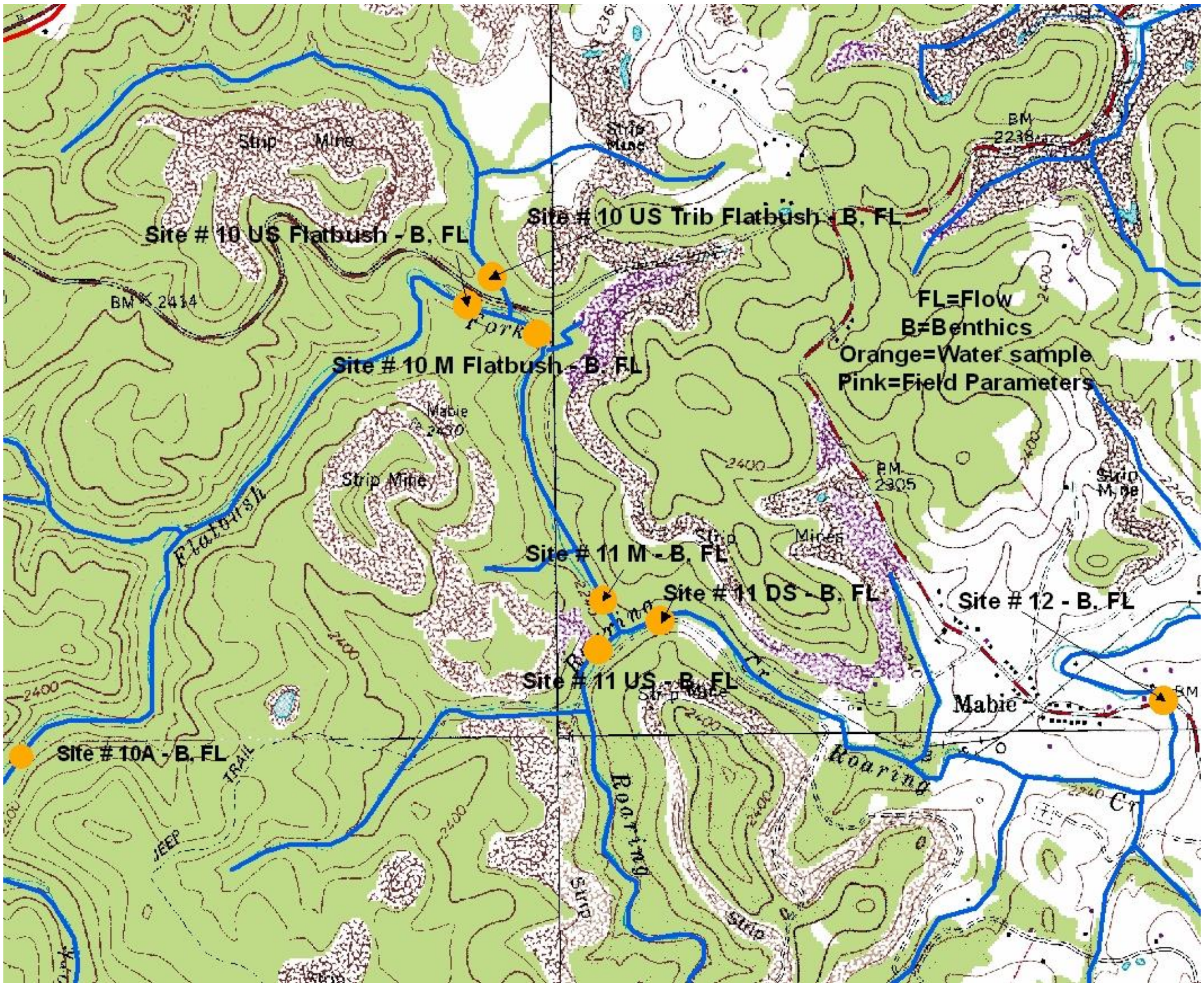


Figure 7. Phase 2 sampling points for the western side of middle Roaring Creek. FL = Flow measured, B = Benthic organisms collected. US = Upstream of confluence, DS = Downstream of confluence, and M = Mouth of stream. Orange dots are sample points at which both field parameters and water samples were taken and pink dots are field parameters only.

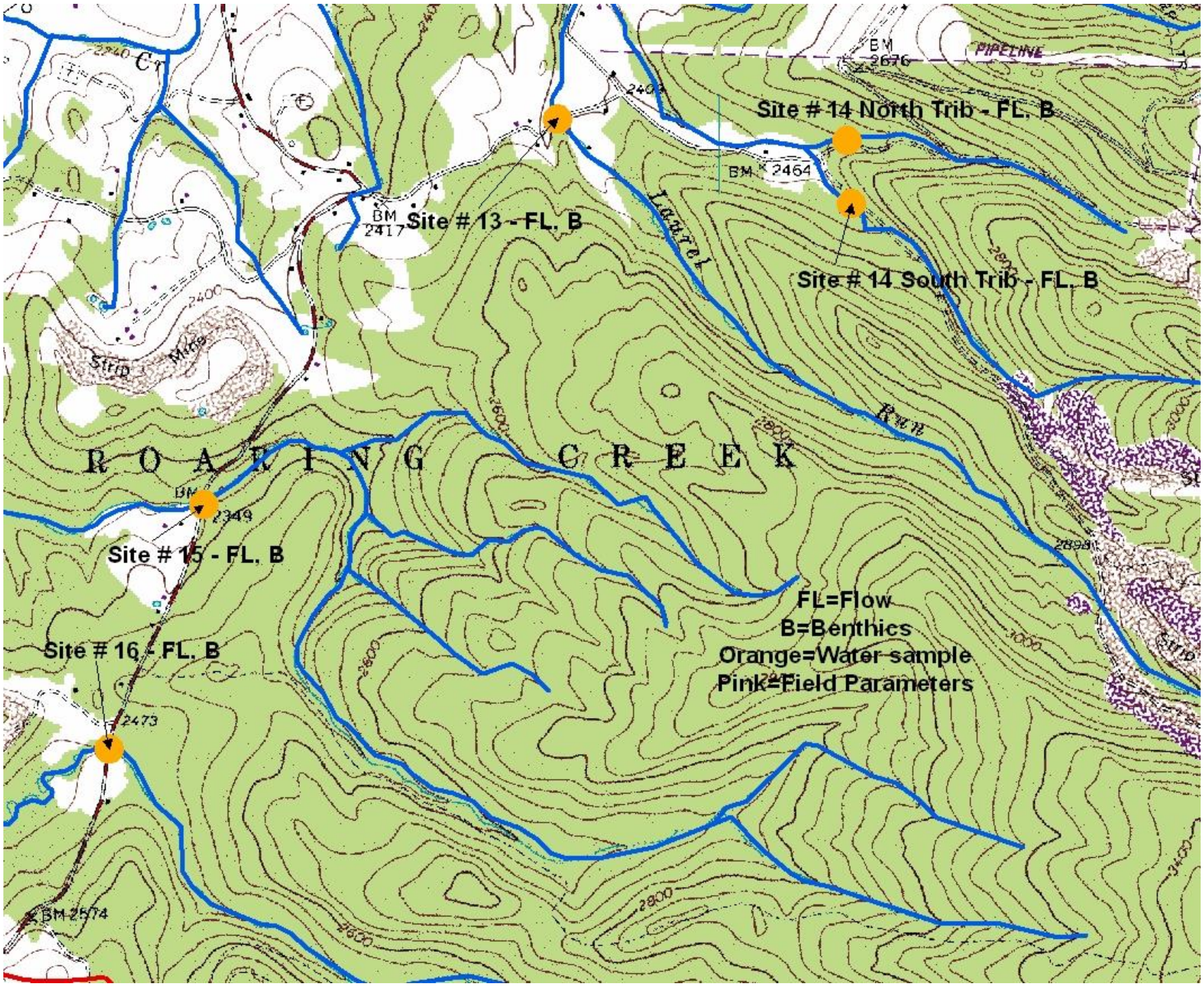


Figure 8. Phase 2 sampling points for upper Roaring Creek. FL = Flow measured, B = Benthic organisms collected. S = Upstream of confluence, DS = Downstream of confluence, and M = Mouth of stream. Orange dots are sample points at which both field parameters and water samples were taken and pink dots are field parameters only.

Benthic samples were collected in October 2009 and April 2010. The research team determined that sampling twice in a year (specifically in spring and autumn) would give an accurate representation of benthic populations. Benthic samples were not collected at every site. For example, no benthics were collected in the Kittle Hollow sub-watershed because water quality results showed low pH values and high metal concentrations; it was decided that benthic life could not flourish in such an environment. Figures 5-8 show benthic collection points.

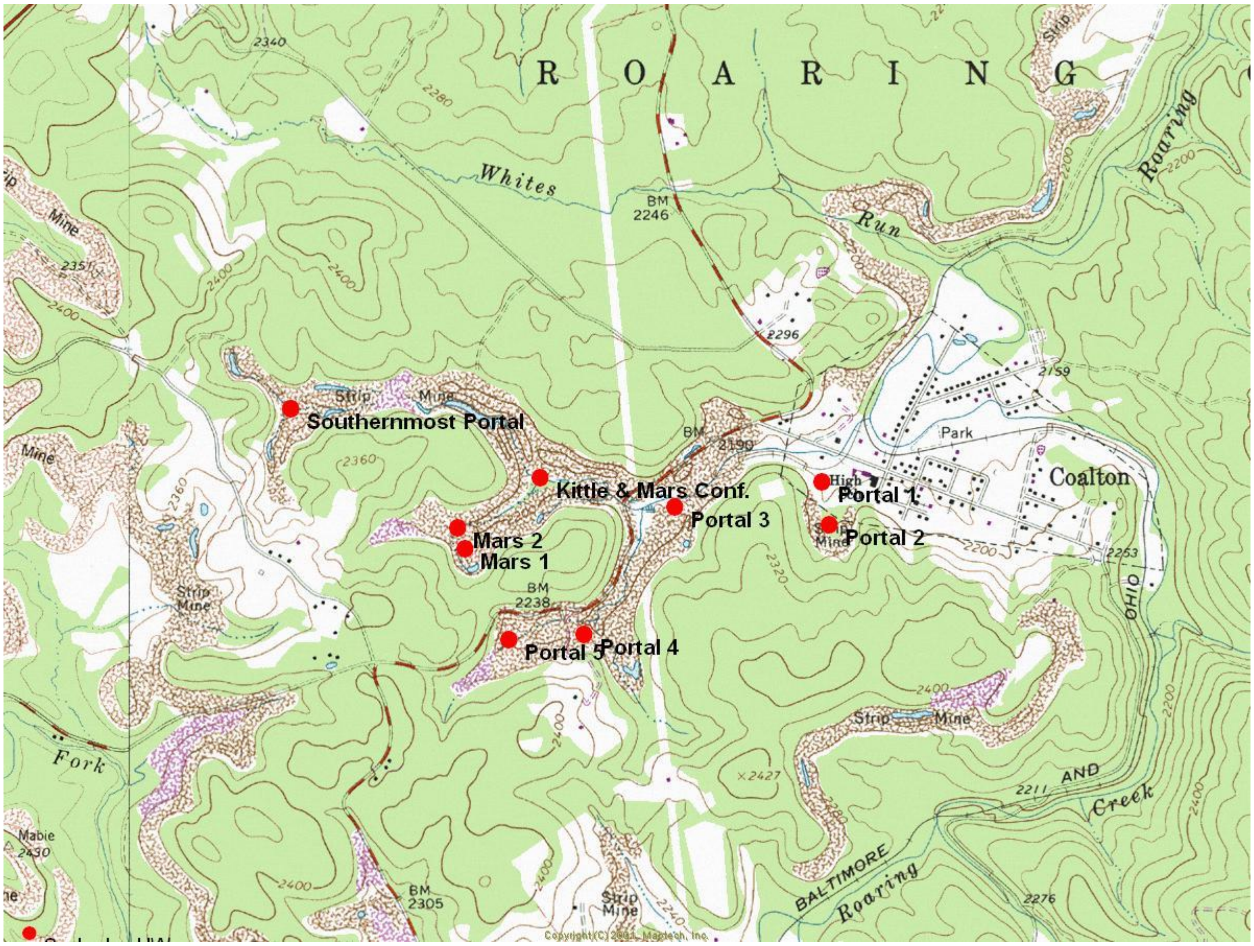


Figure 9. Phase 2 sampling points for Kittle Hollow. Only flow values and water samples were collected in Kittle Hollow.

Phase 3

Once sampling is complete, AMD sites will be selected for the installation of passive treatment systems. Passive treatment will begin upstream and proceed downstream to enable the most efficient use of funding. Passive treatment systems will be designed to remove 80% of the acid and metal loads within the discharge. Previous remediation projects of this type have efficiently removed 80% of metal and acid loads; this percentage has been deemed as the most efficient use of funding sources. The WBP will also be completed to allow for future Section 319 funding.

## Results

Water quality data collected during 2009-2010 was analyzed and used to assess the overall health of the Roaring Creek watershed. Each site was sampled four times during 2009-2010.

Mean values for all Roaring Creek instream water chemistry sample sites are presented in Table 1.

Table 1. Mean values of 40 sample sites taken in the Roaring Creek watershed. NS = Not Sampled. US = Upstream. DS = Downstream.

| Site | Flow L/s | EC us/cm$^3$ | pH su | Net acidity mg/L | Acid load tons/yr | Al mg/L | Fe mg/L | Mn mg/L | $SO_4$ mg/L |
|---|---|---|---|---|---|---|---|---|---|
| US Tygart | NS | 137 | 7.04 | NS | NS | NS | NS | NS | NS |
| DS Tygart | NS | 115 | 6.46 | NS | NS | NS | NS | NS | NS |
| Site 1 | 1115.38 | 152 | 5.35 | 3.51 | 151.39 | 0.5 | 0.16 | 0.4 | 46 |
| Site 2 mouth | 24.27 | 90 | 6.49 | -40.75 | -15.10 | 0.22 | 0.22 | 0.39 | 12 |
| Site 2 US | 349.84 | 133 | 5.37 | 2.83 | 84.47 | 0.48 | 0.12 | 0.45 | 36 |
| Site 2 DS | 379.05 | 133 | 5.07 | 2.13 | 116.49 | 0.57 | 0.17 | 0.41 | 36 |
| Site 3 mouth | 37.36 | 22 | 5.60 | -0.03 | 1.37 | 0.15 | 0.20 | 0.05 | 10 |
| Site 3 US | 2244.09 | 133 | 5.13 | 1.91 | 122.56 | 0.19 | 0.14 | 0.23 | 37 |
| Site 3 DS | 2267.47 | 127 | 5.18 | 14.37 | 523.40 | 1.60 | 1.15 | 1.35 | 35 |
| Site 4 combined mouth | 68.37 | 21 | 5.45 | 1.18 | 6.30 | 0.33 | 0.13 | 0.15 | 10 |
| Site 4 US combined | 160.91 | 172 | 4.87 | 3.12 | 31.42 | 0.35 | 0.22 | 0.33 | 50 |
| Site 4 DS combined | 168.24 | 126 | 4.86 | 3.44 | 30.21 | 0.52 | 0.12 | 0.30 | 41 |
| Site 4 mouth Spring | 53.18 | 20 | 4.66 | 1.67 | 5.76 | 0.16 | 0.28 | 0.11 | 10 |
| Site 4 mouth Broad | 22.56 | 21 | 4.94 | 1.05 | 1.22 | 0.34 | 0.08 | 0.15 | 10 |
| Site 5 | 59.28 | 96 | 6.49 | -22.32 | -26.52 | 0.10 | 0.12 | 0.05 | 13 |
| Site 6 mouth | 38.94 | 503 | 3.87 | 17.02 | 27.60 | 2.11 | 1.11 | 0.78 | 113 |
| Site 6 US | 922.29 | 159 | 4.66 | 8.99 | 372.94 | 1.07 | 0.48 | 0.42 | 64 |
| Site 6 DS | 958.03 | 172 | 4.72 | 10.60 | 509.47 | 1.25 | 0.76 | 0.42 | 67 |
| Site 7 mouth | 66.60 | 567 | 3.86 | 61.81 | 201.59 | 5.74 | 4.79 | 0.82 | 283 |

| Site | Flow L/s | EC us/cm$^3$ | pH su | Net acidity mg/L | Acid load tons/yr | Al mg/L | Fe mg/L | Mn mg/L | $SO_4$ mg/L |
|---|---|---|---|---|---|---|---|---|---|
| Site 7 US | 703.87 | 129 | 5.67 | -2.15 | 52.40 | 0.15 | 0.29 | 0.42 | 32 |
| Site 7 DS | 770.47 | 176 | 4.83 | 8.89 | 141.28 | 1.01 | 0.65 | 0.44 | 55 |
| Site 8 mouth | 84.27 | 20 | 5.32 | -0.25 | 0.40 | 0.13 | 0.20 | 0.08 | 274 |
| Site 8 US | NS | 113 | 5.49 | NS | NS | 0.10 | 0.199 | 0.57 | 31 |
| Site 8 DS | NS | 92 | 5.84 | -2.60 | NS | 0.15 | 0.25 | 0.47 | 27 |
| Site 9 mouth | 191.10 | 91 | 6.73 | -21.68 | -104.68 | 0.20 | 0.29 | 0.05 | 19 |
| Site 9 US | 1063.29 | 125 | 5.94 | 2.23 | 145.48 | 0.46 | 0.61 | 0.68 | 36 |
| Site 9 DS | 1254.38 | 113 | 5.90 | 0.04 | 119.29 | 0.76 | 0.32 | 0.62 | 33 |
| Site 10 mouth | 30.77 | 381 | 4.77 | 18.25 | 9.79 | 1.12 | 0.67 | 4.69 | 160 |
| Site 10 US | 166.52 | 89 | 4.94 | 6.20 | 19.40 | 0.77 | 0.54 | 0.47 | 26 |
| Site 10 DS | 178.56 | 171 | 4.71 | 10.58 | 27.11 | 0.92 | 0.50 | 1.76 | 58 |
| Site 10 A | 232.17 | 31 | 4.73 | 2.01 | 19.97 | 0.39 | 0.20 | 0.15 | 11 |
| Site 11 mouth | 195.61 | 220 | 5.12 | 7.93 | 31.58 | 1.01 | 0.73 | 1.96 | 75 |
| Site 11 US | 283.35 | 96 | 5.64 | -0.06 | -10.54 | 0.26 | 0.19 | 0.37 | 31 |
| Site 11 DS | 518.98 | 118 | 5.20 | 4.23 | 37.24 | 0.49 | 0.36 | 0.82 | 42 |
| Site 12 | 522.86 | 127 | 5.37 | 1.08 | 31.90 | 0.27 | 0.35 | 0.72 | 39 |
| Site 13 | 56.03 | 37 | 7.22 | -6.25 | -11.08 | 0.30 | 0.18 | 0.19 | 13 |
| Site 14 N trib | 41.75 | 109 | 7.08 | -22.54 | -27.89 | 0.15 | 0.15 | 0.16 | 25 |
| Site 14 S trib | 36.93 | 163 | 7.75 | -39.86 | -44.41 | 0.22 | 0.45 | 0.18 | 28 |
| Site 15 | 53.32 | 23 | 5.05 | -0.33 | 0.00 | 0.23 | 0.11 | 0.16 | 10 |
| Site 16 | 118.08 | 53 | 6.16 | -8.78 | -34.52 | 0.48 | 0.16 | 0.16 | 13 |

Kittle Hollow was also sampled four times from 2009-2010. Although the sampling dates for Kittle Hollow differed from the sampling dates for the rest of Roaring Creek, samples were still taken over three different seasons. Mean flow and chemistry values for the Kittle Hollow sites are shown in Table 2.

Table 2. Mean values of nine sample sites taken in the Kittle Hollow subwatershed. NS = Not Sampled.

| Site | Flow | EC | pH | Net Acidity | Acid Load | Al | Fe | Mn | $SO_4$ |
|---|---|---|---|---|---|---|---|---|---|
| | L/s | us/cm$^3$ | su | mg/L | tons/yr | mg/L | mg/L | mg/L | mg/L |
| Southernmost Portal | 8.40 | 1,352 | 2.89 | 178.95 | 50.33 | 10.73 | 16.02 | 1.74 | 683 |
| Mars Portal 1 | 12.45 | 1,288 | 2.89 | 264.59 | 128.63 | 17.13 | 31.63 | 0.91 | 516 |
| Mars Portal 2 | 6.32 | 1,650 | 3.13 | 107.97 | 22.50 | 9.76 | 12.01 | 1.86 | 766 |
| Kittle and Mars Portals confluence | 17.64 | 1,155 | 2.92 | 134.00 | 105.73 | 10.55 | 16.35 | 1.32 | 486 |
| Portal 1 | 3.16 | 580.75 | 3.56 | 71.65 | 7.08 | 11.15 | 1.49 | 1.04 | 330 |
| Portal 2 | 3.37 | 381.25 | 4.30 | 13.28 | 1.32 | 1.77 | 0.26 | 0.47 | 177 |
| Portal 3 | 16.64 | 495.00 | 3.71 | 32.87 | 19.17 | 3.61 | 0.85 | 0.32 | 206 |
| Portal 4 | 0.52 | 1,369.75 | 3.04 | 494.63 | 8.50 | 37.36 | 84.58 | 1.69 | 693 |
| Portal 5 | 0.71 | 1,275.50 | 3.00 | 340.50 | 8.20 | 24.60 | 55.15 | 0.83 | 482 |

Benthic macroinvertebrate samples were also collected. Organisms were identified in the lab down to the order level. The WV Stream Condition Index (WVSCI) score was used to quantify the benthic health of the stream. The WVSCI score is given on a scale of 0-30. The WVSCI groups benthic scores into the following categories:

>25 = Optimal

25 - 19 = Suboptimal

18 - 12 = Marginal

<12 = Poor

Table 3 shows the number of sites that fell under each category. The data in this table consist of the number of sites that fall into each score category and the average WVSCI score for all sites within each category.

Table 3. Number of sample points within each WVSCI score category.

| WVSCI category | # of sites in each category | Average WVSCI score |
|---|---|---|
| Optimal | 0 | N/A |
| Suboptimal | 5 | 20 |
| Marginal | 23 | 16 |
| Poor | 3 | 10 |

## Discussion

Analysis of the data helped the research team to determine the overall health of Roaring Creek. For example, Kittle Hollow was determined to be the main source of mine drainage within the watershed. Samples taken upstream of the confluence of Kittle Hollow and Roaring Creek were of a much better quality than those taken downstream of the confluence. This can be seen in Table 4. The highlighted values show large changes in pH, acidity, and metal concentrations downstream of the confluence of the two streams. The result of this finding was that Kittle Hollow was selected as the subwatershed in which the majority of reclamation would occur.

Table 4. Water chemistry results from the mouth of Kittle Hollow, upstream of the confluence between Kittle Hollow and Roaring Creek, and downstream of the confluence. Highlighted values show increases in pH and decreases in acidity and metal concentrations downstream of the confluence.

| Site | Flow L/s | EC us/cm$^3$ | pH su | Net Acidity mg/L | Acid Load tons/yr | Al mg/L | Fe mg/L | Mn mg/L | $SO_4$ mg/L |
|---|---|---|---|---|---|---|---|---|---|
| Site 7 mouth | 66.69 | 567 | 3.86 | 61.81 | 201.59 | 5.74 | 4.79 | 0.82 | 283 |
| Site 7 US | 704.88 | 129 | 5.67 | -2.15 | 52.40 | 0.15 | 0.29 | 0.42 | 32 |
| Site 7 DS | 771.57 | 176 | **4.83** | **8.89** | 141.28 | **1.01** | **0.65** | 0.44 | 55 |

Analysis of the data also showed that most of the subwatersheds within Roaring Creek were of a fairly good quality (Table 1). Six of the nine tributary mouth sample sites had excess alkalinity as evidenced by negative acidity values. Metal concentrations were also low at these sites. Of the three tributaries that were acidic, none had an acidity concentration greater than 17 mg/L (Table 1). Similar to the alkaline streams, metal concentrations were also low in these streams, with no concentrations of Al, Fe, or Mn > 2.5 mg/L.

The majority of the benthic macroinvertebrate sample points within the watershed fell within the upper section of the marginal range with an average score of 16 (Table 3). Although no sites had a score in the optimal range and only five sites had a score within the suboptimal range, evidence of fish within the watershed were found. Both anecdotal evidence from MCTU volunteers and observations of fish during sampling times showed that the watershed could support a fish population. The majority of optimal WVSCI scores were found in the headwaters of Roaring Creek. Both sites 13 and the south tributary of 14 had a WVSCI score of 20. These are also the two sites where fish were observed during sampling.

Completion of the sampling allows for Phase 3 of the project to begin. The WBP will be completed and submitted to EPA. Once this occurs, further funding from Section 319 and other sources will be applied for. A passive treatment system at the most upstream site (the Southernmost Portal site) will be designed. Pre-construction sampling will occur concurrently with the design process in order to ensure the most efficient use of funding. After design, the project will then be constructed and post-construction monitoring will occur in order to gauge system performance.

## Conclusion

The Roaring Creek watershed in central West Virginia was known to be impacted by historic coal mining. However, the watershed needed to be assessed to determine the degree of degradation. A partnership between the WVWRI, WVDEPDWWM, and MCTU was formed to assess the water quality of Roaring Creek.

Forty sample sites were chosen to assess the water quality and quantity of Roaring Creek. Water chemistry, water quantity, and benthic data were gathered four times within a one year period. Samples were taken in spring, summer, and autumn. Analysis of the water quality data showed that the overwhelming majority of mine drainage within the watershed was found in the Kittle Hollow subwatershed.

Due to these findings, eight mine drainage sample sites within Kittle Hollow were added to the sampling plan. The site known as Southernmost Portal was chosen as the first site to be reclaimed.

The water quality data will be used to create a watershed-based plan. The finished watershed-based plan will represent the end of the assessment process. Passive treatment projects will be used to remediate the mine drainage sources. These projects are expected to remove a substantial amount of the metal and acid loads from each mine discharge, with previous projects of this type removing ~80% of the acid and metal loads. The reclamation of Kittle Hollow through the use of passive treatment will encourage greater biological diversity and improve the overall quality of the Roaring Creek watershed.

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