A Preliminary Stream Assessment for Watershed Restoration[1]

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Abstract. An assessment of Laurel Run, Indiana County, was conducted in the summer of 2001 through a partnership effort between the Pennsylvania Department of Environmental Protection and Stream Restoration Inc. The purpose of the assessment was to evaluate the potential recoverability of a stream affected by abandoned mine drainage (AMD) before construction of a passive treatment system in the headwaters of Laurel Run. Several major discharges have severely degraded the stream to the confluence with Blacklick Creek (Ohio River Basin). At the mouth of Laurel Run, the stream has a flow rate exceeding 4,200 L/min (1,100 gpm) with pH 5.5, 42 mg/L acidity, 2.5 mg/L iron, and 2.9 mg/L manganese. In addition, baseline data were collected to examine the overall health of the watershed for future planning and preliminary Total Maximum Daily Load (TMDL) studies. Twenty-one sites were assessed using standard EPA Rapid Bioassessment Protocol sampling methods, examining physical, chemical, and biological characteristics. The number and variety of benthic macroinvertebrate taxa were much lower when compared to a physically similar, healthy stream. The primary contributors of flow to the headwaters are an acidic, abandoned, underground mine discharge with an average flow rate of 379 L/min (100 gpm) and several spring fed tributaries. Two unnamed tributaries located above the AMD were found to contain low tolerant macroinvertebrate taxa, indicative of excellent water quality and a reference for the future potential of Laurel Run. In September 2001, a passive system was placed online to treat the AMD. This system consists of two vertical flow ponds built in parallel, a flush pond, and a ½-acre wetland. Water quality analysis shows that Laurel Run has improved to the confluence with the next major discharge, located approximately one mile downstream. Even though the passive treatment system has dramatically improved the quality of the water, several other discharges are inhibiting the full recovery of the stream.

Additional Key Words: abandoned mine drainage (AMD), benthic macroinvertebrates, passive treatment, Rapid Bioassessment Protocol (RBP), restoration, stream assessment, Total Maximum Daily Load (TMDL)

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Introduction

The initiative for assessing and reclaiming the water resources of the United States has been growing within the last 20 years. The Pennsylvania Department of Environmental Protection, for example, has encouraged the development of public-private partnership efforts in order to tackle the almost 101,172 hectares (250,000 acres) of abandoned mine lands and 3,862 km (2,400 miles) of streams impacted by abandoned mine drainage. On Dec. 15, 1999, Gov. Ridge signed "Growing Greener" into law, marking the largest environmental investment ever by a Pennsylvania governor -- $650 million over five years. Within the first two years of the Growing Greener initiative, over 809 hectares (2,000 acres) of abandoned mine lands have been reclaimed, over 1,700 hectares (4,200 acres) of wetlands have been restored or created, and over 595 km (370 miles) of streams have been significantly improved. The overwhelming support for these projects by the community has been demonstrated through doubling the state funding through in-kind and matching contributions (PA DEP, 2001).

Checking the overall health of waterways is important, especially in a region as deeply affected by mine drainage as in the Appalachian Coal Region. Mine drainage has a negative impact on three major components of a watershed. Past mining practices have adversely changed the physical geology within a watershed, which has altered water chemistry and affected the environment for aquatic plants and organisms (Earle and Callaghan, 1998). Watershed monitoring is necessary to determine not only one parameter or source of pollution, but also the overall health of a watershed's individual streams and their surrounding areas. In addition, the monitoring of pristine waterways is equally important since non-impacted streams serve as a reference to measure the recovery of similar impacted streams (Barbour et al., 1999). This paper will address the benefits of utilizing watershed monitoring as a method for 1) obtaining a foundation of preliminary, baseline data for historical and pre-restoration construction, and 2) future comprehensive planning for individual projects in a consecutive order from the headwaters to the mouth. This case study of the Laurel Run Watershed is presented as an illustration.

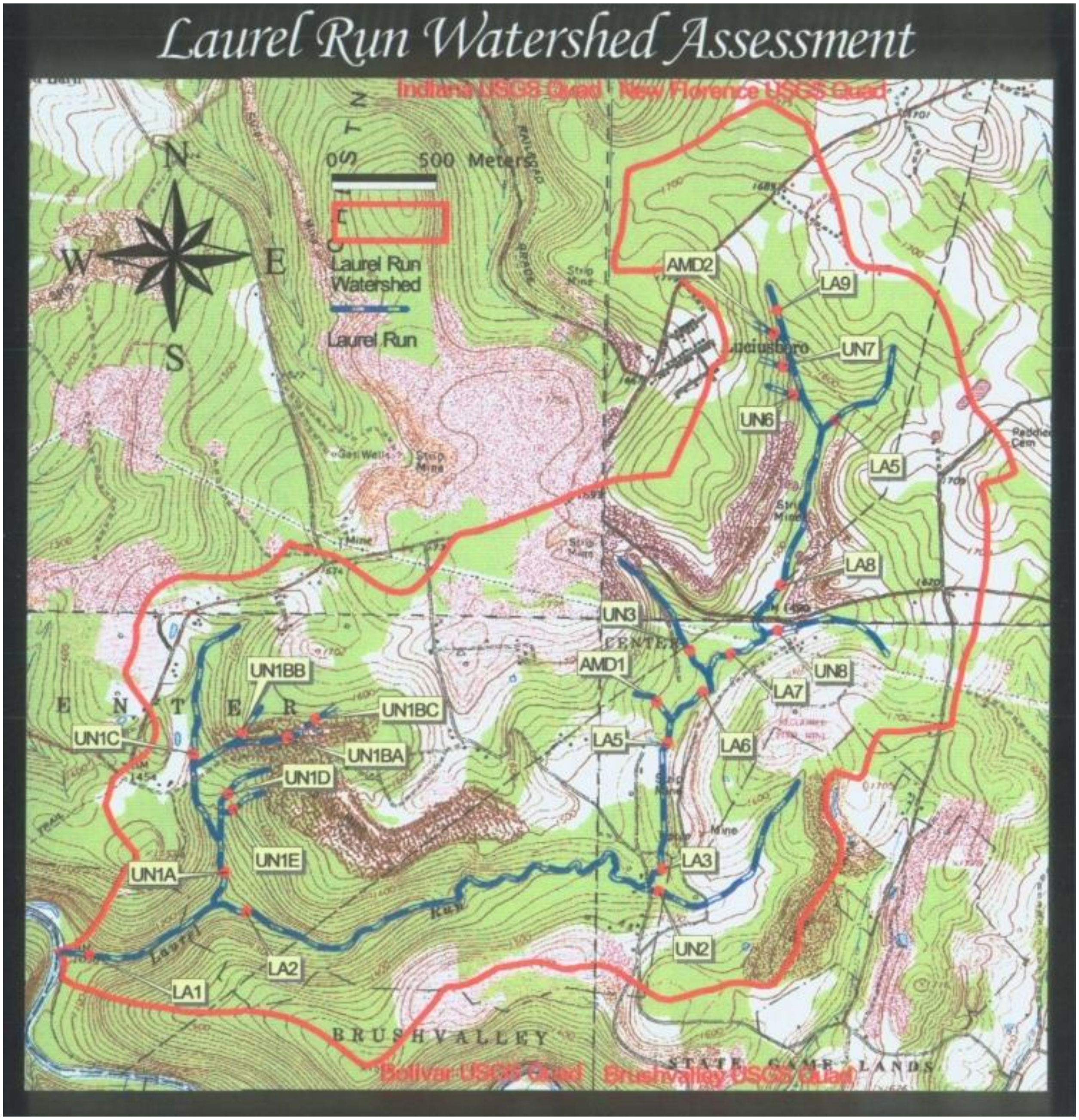

Figure 1. Watershed map of Laurel Run, Center and Brushvalley Townships, Indiana Co., PA.

<u>Laurel Run</u>

Laurel Run is a tributary to Blacklick Creek in the Ohio River Basin (Figure 1). The watershed lies in Center and Brushvalley Townships, Indiana County, PA. The drainage encompasses approximately 10.6 sq. km (4.1 sq. mi.) and flows in a southwesterly direction. The headwaters of Laurel Run are a series of springs and a deep mine discharge traveling approximately 9.8 km (6.1 mi.) into Blacklick Creek. With elevations ranging from 488 to 372 meters (1602 to 1220 feet) traveling downstream, the topography of the watershed is characterized by flat rural and forested lands with gently rolling hills of low relief in the headwaters, as well as high gradient, stream bed relief toward the mouth of Laurel Run.

During July 11-13, 2001, a qualitative watershed assessment was conducted on Laurel Run through a public-private partnership effort. Personnel from Stream Restoration Inc. and the PA Department of Environmental Protection, Bureau of Mining and Reclamation planned and implemented collection of data at twenty-three sites. The sampling stations include the main stem, polluted and non-polluted tributaries, and various mine drainage discharges (Figure 1).

In September 2001, a passive treatment system was placed online through a public-private partnership effort involving Stream Restoration Inc., Amerikohl Mining, Inc., PA Game Commission, private landowners, and the Pennsylvania Department of Environmental Protection. This system consists of two Vertical Flow Ponds built in parallel, a flush pond, and a ½-acre wetland. The vertical flow ponds were built entirely of environmentally-friendly materials (limestone and mushroom compost) and utilized an innovative piping system to flush metal particulates from the ponds (Figure 2, 4, 5).

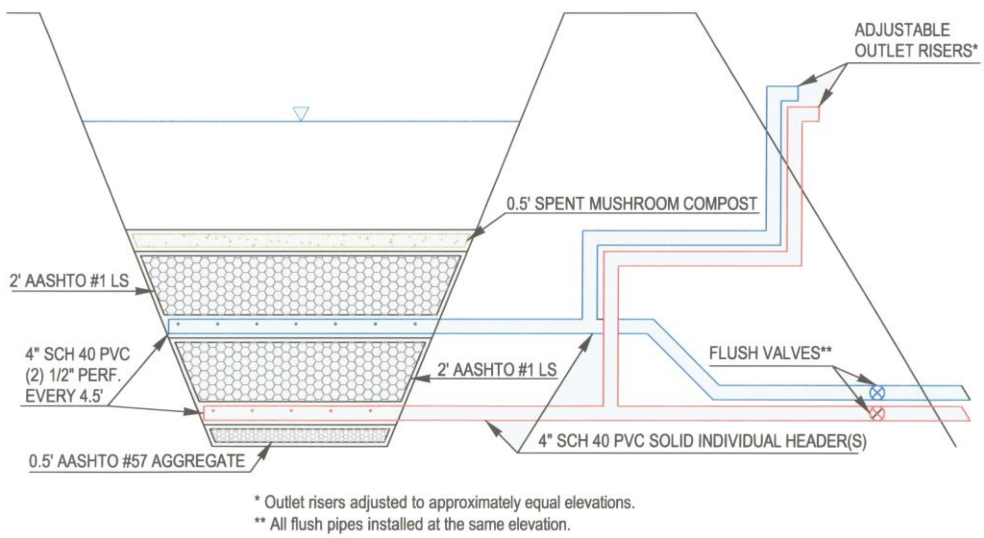

Figure 2: Cross-section of Vertical Flow Pond depicting the type and placement of materials used in construction.

Methods and Materials

A watershed is the region from which surface runoff drains the surrounding land into a stream, river, lake, reservoir, or other body of water. Ideal watershed monitoring should test specific parameters from three general categories: physical, chemical, and biological.

Physical Characteristics

Physical parameters analyzed included a background description of the waterway, various field conditions, benthic habitat and gradient, and a description of the stream banks. The stream was evaluated for depth, width, flow, hydrogeologic origin, water level, and in-stream coloration. Field conditions tested included weather, odors, air temperature, evidence of wildlife presence, and any comments concerning the monitoring station. Adjacent banks were examined for water-saturated soils, upstream land use and potential impacts, bank vegetation disruption, and bank erosion. In-stream habitat conditions were evaluated at each station. The type of benthic environment and bed coating were documented. The habitat evaluation consists of rating twelve habitat parameters to derive a station habitat score (Barbour et al., 1999).

Chemical Characteristics

Chemical parameters evaluated in the field were temperature, pH, dissolved oxygen, and conductivity. Acidity, alkalinity, manganese, iron, aluminum, sulfates, suspended solids, and turbidity were measured in the lab. At each sampling station, water samples were collected by the grab method using a 500 ml bottle and one 125 ml bottle fixed with nitric acid (APHA, 1998). Sampling was conducted from the mouth to the headwaters of Laurel Run in order to collect undisturbed samples. These samples were analyzed using an ICP/Atomic Emission Spectrometry (EPA 200.7) by the Department's laboratory.

Biological Characteristics

The indigenous aquatic community is an excellent indicator of long-term conditions and is used as a measurement of both water quality and ecological significance (Barbour et al., 1999). Benthic macroinvertebrate collections were completed using the EPA Rapid Bioassessment Protocol benthic sampling methodology at the time of water sampling (Barbour et al., 1999). The collected and processed benthic samples serve as a basis for analysis and comparison of tolerance values to generally accepted water quality predictive scoring ranges. Ranging from 1 to 10, low scores are indicative of extremely sensitive organisms and good water quality, while higher scores represent tolerant organisms and poor water quality (Barbour et al., 1999). Due to stream degradation and lack of consistent numbers, the results were limited to a qualitative analysis (family and tolerance index). A fish survey was not conducted as the stream was heavily impacted by AMD.

Results and Discussion

Physical Characteristics

In-stream habitat conditions were evaluated and summarized at each station (Table 1). The range of cumulative habitat score totals for Laurel Run stations were 142 to 213, generally considered to reflect sub-optimal to optimal habitat conditions. Laurel Run received the lowest score under the vegetative protection and grazing/disruptive pressures habitat parameter. Many types of land disturbance will affect a watershed (Earle and Callaghan, 1998). At the time of the assessment, there were several activities that could potentially impact the watershed, including road maintenance, farming, mining, logging, and landfill operations. In addition, multiple sources of AMD have cemented the streambed with metal precipitates giving Laurel Run a score of 68% for sediment deposition. Even with these lower scores, the stream channel has been generally unaltered with above average riffle and pool habitat and channel sinuosity. With properly installed erosion and sediment control measures and continued reclamation of mine drainage sites, the stream has high potential for recovery.

Chemical Characteristics

From the very headwaters of Laurel Run, the stream has been affected by mine drainage (Table 2). AMD2, the first significant mine discharge, greatly degrades water quality and supplies the majority of flow to the headwaters of Laurel Run. The flow of this discharge ranges from 132 to 1,987 L/min (35 to 525 gpm) and contributes over 30,380 kg (81,400 lbs) of acidity and 4,740 kg (12,700 lbs) of metals to Laurel Run every year. Comparison between LA9 and LA8 verifies AMD2's impact to Laurel Run. The headwaters also have several small streams with excellent water quality, LA9, UN7, UN6, and UN5. In general, pH, alkalinity, acidity,

Table 1. Habitat assessment summary.

HABITAT PARAMETER	Scoring Range	STATIONS														STATISTICS	
		LA1	UN1A	UN1D	LA2	UN2A	LA3	LA5	LA6	UN8	LA8	UN5	UN6	UN7	UN8	Avg.	%
1. epifaunal substrate 2. upstream cover	0 - 40	38	36	36	36	26	26	26	36	26	36	28	36	36	26	32.0	80%
3. embeddedness (HG)/ pool substrate characterization (LG)	0 - 20	18	14	19	17	9	9	18	17	13	13	13	14	19	13	14.7	74%
4. velocity/depth (HG)/ pool variablility (LG)	0 - 20	18	18	17	18	5	18	17	18	8	17	8	17	10	8	14.1	70%
5. sediment deposition	0 - 20	15	14	18	13	13	13	4	13	14	14	14	13	19	14	13.6	68%
6. channel flow status	0 - 20	17	18	18	18	15	8	13	13	13	14	13	14	20	13	14.8	74%
7. channel alteration	0 - 20	20	20	20	20	20	19	19	19	19	19	19	19	20	19	19.4	97%
8. frequency of riffles (HG)/ channel sinousity (LG)	0 - 20	19	18	19	18	12	13	13	13	18	18	13	18	19	18	16.4	82%
9. bank stability	0 - 20	17	18	19	18	14	7	14	14	10	16	14	16	18	10	14.6	73%
10. vegetative protection & 11. grazing/disruptive pressures	0 - 40	32	27	27	21	21	30	21	21	21	21	27	21	27	21	24.1	60%
12. riparian vegetative zone width	0 - 20	10	18	20	18	16	9	12	16	18	14	18	12	18	18	15.5	78%
Total Score [1]	**0 - 240**	**204**	**201**	**213**	**197**	**151**	**152**	**157**	**180**	**160**	**182**	**167**	**180**	**206**	**160**	**179.3**	**75%**

Note: Not all monitoring sites are listed; only sites with completed habitat assessments

[1] Optimal: 181 to 240; Sub-Optimal: 121 to 180; Marginal: 61 to 120; Poor: Less than 60

Table 2. Laurel Run water quality data collected July 11-13, 2001.

Station Sample ID	LA1	UN1A	UN1BA	UN1BB	UN1BC	UN1C	UN1D	UN1E	LA2	UN2A	LA3	LA5	AMD1	LA6	LA8	UN5	UN6	UN7	AMD2	LA9
Field Parameters																				
Air T (^oC)	19.8	23.3	23.3	22.8	22.8	17.5	23.3	23.3	23.3	17.5	19.4	20.6	21.7	19.5	18.4	27	27	27	20.9	19
Water T (^oC)	17.3	18.5	22	19.4	17	15.6	18.6	20.4	18.2	17.5	16.3	17.1	N/A	16.4	13.1	15.7	14.2	11.3	10.4	15.4
pH	5.5	7	6.5	N/A	N/A	3.3	6	3.4	4.2	3.3	6	6.2	6	4.8	5.3	6.6	N/A	7.6	4.7	6.5
Cond (μmhos)	619	449	601	567	779	766	498	549	736	786	802	754	1180	751	605	600	761	764	942	107
Dissolved O_2	7.9	8	5.2	7.4	2.9	9.5	8.3	8.2	7.4	9.5	8.5	8.4	5.3	9.3	8.5	8.3	9.3	8.2	8.4	No Flow
Flow (L/min.)	4211	1591	57	113	57	122	467	189	2620	<1	1885	1734	397	1491	1120	15	101	98	170	<1
Laboratory Parameters																				
pH	4.9	6	6.5	4.2	6.7	3.1	5.6	3	4.1	3.1	5.7	5.5	6.1	4.7	4.7	N/A	6.8	6.5	3.0	5.9
Alkalinity	6.3	22	48	4.6	38	0	10	0	2.6	0	11.6	10.6	66	6.4	8.4	N/A	50	52	0	10.8
Acidity	42.2	33	0	61.8	0	122.8	45.6	61.8	41.8	122.8	53.2	52.4	52.4	54.9	49.2	N/A	0	0	202	6.8
TSS	4	14	<3	<3	16	44	24	12	4	44.9	8	8	12	4	12	N/A	18	8	5	<3
SO_4	276.7	190.6	245.1	442.1	236.7	194.2	211.6	135.2	359.7	194.2	318.6	478.6	540.6	328	356.1	N/A	470	341.3	449	<20
Fe - tot.	2.5	2.0	3.1	0.4	1.5	23.5	2.1	2.6	3.5	23.5	11.3	8.9	43.0	0.7	2.0	N/A	< 0.3	< 0.3	18.1	< 0.3
Mn - tot.	2.9	0.8	1.1	2.4	0.8	3.6	1.5	6.8	3.7	3.6	3.7	1.9	2.5	1.1	0.7	N/A	< 0.1	< 0.1	1.6	0.1
Al - tot.	0.9	0.8	< 0.5	3.5	< 0.5	7.3	1.1	3.1	1.0	7.3	0.9	1.3	< 0.5	2.0	4.2	N/A	< 0.5	< 0.5	14.1	< 0.5

Note: Parameters in mg/L unless otherwise noted.

sulfates, and total suspended solids were in healthy ranges with some buffering capacity.

Two unnamed tributaries enter Laurel Run before the second major discharge. Sample sites on these tributaries, UN3 and UN4, were not sampled due to dry summer conditions. Thus, LA7 was not taken since the water quality of Laurel Run would not have been affected. UN3 originates from several, old mining settling ponds.

By the time Laurel Run reaches sampling station LA6, less than 2 mg/L of metals remain in the water, having almost entirely precipitated within the stream. This station also monitors conditions of Laurel Run before AMD1. AMD1 is an alkaline discharge emanating from an abandoned highwall. This discharge increases pH, alkalinity, metals, sulfates, and specific conductance of Laurel Run, as seen from LA5. Even a third of a mile downstream at LA3, Laurel Run is still severely affected by the AMD1 discharge. UN2 is the last tributary prior to entering the steep valley of the lower portion of the watershed. It flows southwest with low flow and metals.

Figure 3: UN1A entering degraded Laurel Run.

At site LA2 there are decreases in pH, alkalinity, acidity, total suspended solids, aluminum, iron, and sulfates while manganese slightly increases. Again, this is due to the precipitation of the metals on the streambed. UN1A is the mouth of another impacted stream to Laurel Run (Figure 3). UN1BA, UN1BB, UN1BC, and UN1E are mine discharges that represent the majority of flow to this tributary. UN1C contains the lowest pH and highest concentrations of metals affecting this tributary to Laurel Run. Finally, LA1 is at the mouth of Laurel Run. In comparison with the upstream sample station of LA2, LA1 increases in pH and alkalinity and decreases in metal and sulfate concentrations.

<u>After Construction of Passive Treatment System</u>. Since the passive treatment system was placed online treating the AMD2 discharge, over a mile of Laurel Run has significantly improved.

Samples taken October 15, 2001 indicate that the passive treatment system is drastically reducing the amount of iron, aluminum, and manganese into Laurel Run (Table 3, Figure 4 and 5).

Table 3. Comparison of water quality data through passive treatment system.

Station Sample ID	AMD2	VFP	WL
Field Parameters			
Air T (^oC)	N/A	N/A	N/A
Water T (^oC)	9.8	11.0	13.4
pH	4.3	7.1	7.4
Cond (μmhos)	821.3	659.5	1721.5
Dissolved O_2	N/A	N/A	N/A
Flow (L/min.)	571	1061	1061
Laboratory Parameters			
pH	3.1	7.3	7.5
Alkalinity	0.0	228.0	284.6
Acidity	146.4	0.0	0.0
TSS	5.5	12.0	11.0
SO_4	369.8	650.3	777.7
Fe - tot.*	9.7	2.3	2.1
Mn - tot.*	1.1	1.2	1.5
Al - tot.*	11.4	1.3	1.1

Note: Parameters in mg/L unless otherwise noted. VFP = Vertical Flow Pond effluent, WL = Wetland effluent

Figure 4: View of flush pond and Vertical Flow Ponds looking south.

Figure 5: Vertical Flow Pond effluent entering unplanted wetland area to the south. Effluent of wetland enters Laurel Run.

In addition, the system is eliminating all acidity and producing over 250 mg/L of alkalinity. Further downstream, however, AMD1 and additional smaller AMD seeps reduce the amount of alkalinity to about 50 mg/L $CaCO_3$ at station LA3 (Figure 6).

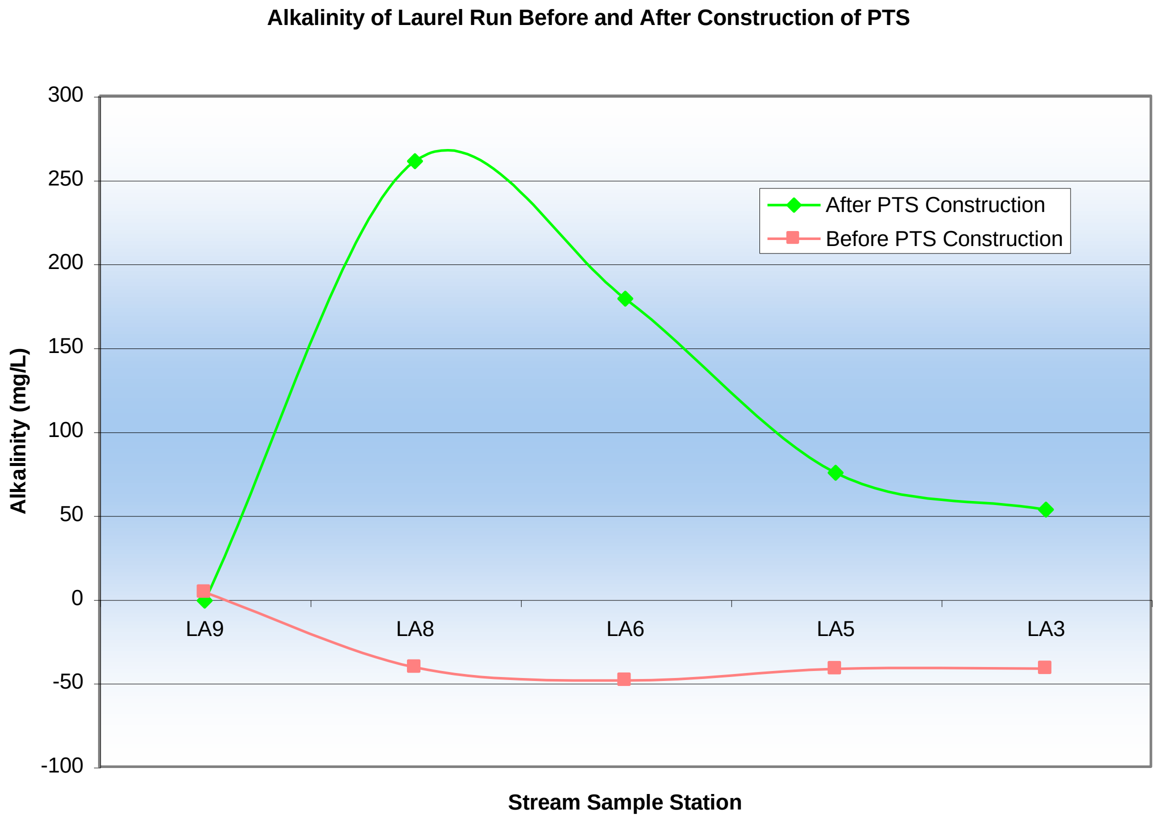

Figure 6. Comparison of alkalinity of Laurel Run before and after construction of passive treatment system.

Biological Characteristics

Potential aquatic insect habitat was sampled at all stations. The numbers of individuals and kind of taxa were lower than could be found in a physically similar, healthy stream. Iron and aluminum precipitate dominated the substrate at the majority of these stations. This precipitate has a direct affect on the macroinvertebrate populations by reducing viable habitat and food resources for macroinvertebrates (Gray, 1996).

At the time of sampling, the following stations were the only sites having populations of aquatic life: UN1D, UN6, and UN7 (Table 3). Two of these sites, UN6 and UN7, are in the headwaters of the watershed and are not affected by mine drainage. These streams contained several macroinvertebrates with a variety of tolerance levels. The other station, UN1D, is a small tributary located in the lower portion of the watershed, which was effected by several AMD discharges. Only three species of aquatic macroinvertebrates were found at this station, Corydalidae, Decapoda, and Hydropshychidae (Table 4). Corydalidae is an extremely sensitive macroinvertebrate, however, only one individual of this species was discovered. It is a predatory species capable of traveling large distances in search of food (Merritt and Cummins, 1996; Borror and White, 1970). Thus, it may not represent the quality of this portion of the stream. Decapoda and Hydropshychidae are mid-range tolerant organisms indicative of some impact (Barbour et al., 1999).

Table 4: Qualitative aquatic macroinvertebrate survey results.

Sample Station	Macroinvertebrate	Tolerance Index
UN1D	Corydalidae	0
	Decapoda	6
	Hydropshychidae	4
UN06	Decapoda	6
	Hydropshychidae	4
	Peltoperlidae	0
UN07	Decapoda	6
	Emphemerellidae	1
	Gastropid	6 to 8
	Hydropshychidae	4
	Peltoperlidae	0
	Polycentripodidae	6
	Tipulida	3

Aside from the obvious metal precipitation and poor water quality, Laurel Run has a high gradient, adequate dissolved oxygen, promising benthic habitat, and a predominately-forested watershed. UN6 and UN7 are an excellent background reference for water quality obtainable if stream restoration were to take place.

It should be noted again that Laurel Run does have the excellent potential for fish propagation with deep pools, undercut banks, boulders, submerged logs, and root masses. If restored, Laurel Run could be classified as a coldwater fishery.

Conclusions

A rapid assessment of the existing conditions within a watershed can be completed in a cost effective manner. This assessment was completed through a public-private partnership effort. Watershed groups with little financial resources can greatly benefit from an assessment of this type. Potential applications of the survey include future restoration and conservation planning, Total Maximum Daily Load (TMDL) studies, or can be a part of a larger watershed study.

Based on findings from this survey and a review of historical data:

1. The headwaters are generally spring-fed, have excellent forest and benthic habitat, and show a high potential for revitalizing water quality and biota upon stream restoration.
2. Two abandoned mine discharges are sources for the majority of metal and acid loading to Laurel Run.
3. Remediation of these discharges would restore miles of stream.
4. Many smaller discharges and seeps are found throughout the watershed.

The constructed passive treatment system at AMD2 has effectively eliminated the impacts of the underground discharge located in the headwaters of Laurel Run. There is a dramatic difference in low tolerant aquatic macroinvertebrates at the headwaters and no aquatic populations below, mainly due to AMD. Since the watershed has a forested area, a stable riparian buffer zone, an epifaunal substrate, adequate dissolved oxygen, and a high gradient the healthy upstream macroinvertebrate populations could inoculate the downstream reaches. Follow-up plans include post-treatment assessments, periodic monitoring, continued public participation, and prospecting other areas for complete watershed restoration.

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