Structure and function of streams in the Pigeonroost Branch watershed, and the influence of mountain top removal and valley fill on southern West Virginia watershed-ecosystems

Prepared for·

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This report was prepared by Dr. Benjamin Mortimer Stout III, Ph.D. and contains his opinion relevant to the litigation related to proposed mountaintop removal and valley fills in Pigeonroost Branch watershed, other drainage basins in West Virginia, and the effect of such valley fills on the ecology of West Virginia forests and streams. The opinion of a technical nature has been made using generally accepted scientific practice or methods to a reasonable degree of scientific certainty.

____________________	March 30, 1999
Ben M. Stout III	Date

Background of Dr. Ben M. Stout III

I have been retained by Mountain State Justice, Inc to prepare a report analyzing the structure and function of streams in the Pigeonroost Branch watershed, and the influence of mountain top removal and valley fill on southern West Virginia watershed-ecosystems. For this work I have an agreement for compensation at my standard rate of $500/day less a 30% discount in consideration of non-profit status of the West Virginia Highlands Conservancy.

I am a West Virginia resident (resume' appended). I was born December 21, 1957 in Morgantown, WV, and currently reside in Wheeling, WV. I earned a Bachelor of Science degree in Agriculture and Forestry from West Virginia University in 1980. My curriculum at WVU was Wildlife Resources with an emphasis on aquatic ecology including coursework in Limnology (study of lakes), Fisheries Biology, Ichthyology (study of fishes), Aqueous Geochemistry, Groundwater Hydrology, and Stream Ecology.

I graduated from Tennessee Technological University in 1982 with a Masters of Science degree in Biology. My thesis title was Leaf Litter Processing by Aquatic Invertebrates in Lotic and Lentic Waters Near Soddy-Daisy, Tennessee. My advisor, Dr. C. B. Coburn, Jr., and I published a paper from this work entitled "*Impact of highway construction on leaf processing in aquatic habitats of eastern Tennessee*" which appeared in the international journal *Hydrobiologia*.

I taught at Southern West Virginia Community College as Instructor for the Biological Sciences for three years. During that time I taught courses on the Williamson and Logan campuses. I also conducted studies of the benthic macroinvertebrates in Miller Creek, Mingo County, and Hominy Creek, Nicholas County, WV. These studies were not published.

I began doctoral work in 1985 in the laboratory of Drs. Fred Benfield and Jack Webster at Virginia Polytechnic Institute and State University. I conducted one year of field research at Coweeta Hydrologic Laboratory, a U.S. Forest Service research facility near Franklin, North Carolina. I also conducted one year of laboratory work rearing aquatic insects on diets consisting of leaves from various tree species. My dissertation title was Effects of Forest Disturbance on Shredder Production in Headwater Streams. From this work the paper *Effect of a forest disturbance on shredder production in southern Appalachian headwater streams* was published in Freshwater Biology, the leading international journal in aquatic sciences. I also published papers relating to the ecology of aquatic insects with several co-authors.

I began teaching at Wheeling Jesuit University in 1990. At WJU I have taught courses in general biology, process of biology, methods of biology, general ecology, ecology laboratory, physiological ecology, and physiological ecology laboratory. Working with 14 colleagues beginning in 1993, I led development of a Bachelor of Science degree in Environmental Studies. I have served as Director of Environmental Studies since 1995. I was tenured in 1996 and promoted to Associate Professor in 1997.

I have conducted research in wetland and stream ecosystems and attracted over one million dollars in private, state, and federal research funds. I have conducted studies in every major watershed in West Virginia, sampling thousands of stream and wetland sites. I have served as reviewer of articles submitted to the Journal of the North American Benthological Society, the second-leading impact journal in freshwater biology. I have also served as Associate Editor and reviewer for articles submitted to the Journal of the West Virginia Academy of Science, reviewer for Entomological News, and reviewer for the Journal of the Pennsylvania Academy of Science.

Summary of prior testimony by Dr. Ben M. Stout III

This case:

February 9, 1999. US District Court, Southern District of West Virginia, Charleston Division, Federal Courthouse, Charleston, WV. Expert testimony before Honorable Charles H. Haden II, Chief Judge, regarding water quality surveys and status of Pigeonroost Branch streams.

February 25, 1999. Pigeonroost Branch watershed. Tour with Honorable Charles H. Haden II, Chief Judge, US District Court, Southern District of West Virginia, Charleston Division. Expert testimony regarding benthic macroinvertebrate structure and function in Pigeonroost Branch.

Other cases:

March 17, 1999. Holiday Inn, Fairmont, West Virginia. Expert testimony before West Virginia Surface Mining Review Board regarding the impact of ferric hydroxide deposits on the biological community of a small stream near Fairmont, WV.

Reports reviewed by Dr. Stout:

Sturm Report (not dated). *An evaluation of mountaintop mining and valley fill construction effects upon the surface hydrologic and benthic systems* by Sturm Environmental Services, Inc.

Fisher, 1998. Letter from David W. Fisher, Sturm Environmental Services, Inc., to John McDaniel, Hobet Mining, Inc. July 30, 1998. With attachments relating benthic sampling involved in the Spruce #1 mining area.

Fish and Wildlife Service, 1998a. *A survey of the aquatic life and terrestrial habitats on the proposed Spruce No. 1 surface mine in Logan County, West Virginia* by The United States Fish and Wildlife Service, December, 1998.

SAIC, 1998. *Analysis of valley fill impacts using benthic macroinvertebrates. Draft final report.* September 30, 1998. by Science Applications International Corporation. McLean, VA, USA. EPA Contract No. 68-C4-0034.

Review of the report: *An evaluation of mountaintop mining and valley fill construction effects upon the surface hydrologic and benthic systems* by Sturm Environmental Services, Inc., not dated.

I reviewed the report "*An evaluation of mountaintop mining and valley fill construction effects upon the surface hydrologic and benthic systems*" by Sturm Environmental, Inc., not dated, hitherto the Sturm Report. The primary purpose of the Sturm Report was "to provide a summary of available surface water quality and benthic data to those agencies involved in regulating mining activities in West Virginia" (page 4). The Sturm Report summarizes the available data, however, the data available are insufficient to justify the ambitious title of the report.

The second stated purpose of the Sturm Report was to "outline and verify that detailed water quality and benthic programs have been and are being conducted pre-, during, and post-mining on many West Virginia mines"(p. 4). The Sturm Report fails to accomplish this purpose because of 1) inadequate experimental design, 2) lack of scientific controls, 3) inadequate benthic sampling frequency, 4) discrepancies in the time of year when benthic sampling was conducted, and 5) differences in sampling methodology during different sampling events.

The Sturm Report is simply a compilation of existing data, rather than a carefully designed study. The data used in the Sturm Report were collected for the purpose of meeting permit requirements for the National Pollution Discharge Elimination System requirements. Re-interpreting existing data for a new purpose, in this case for evaluating mountaintop removal and valley fill impacts on streams, is nearly meaningless. Statistics were never designed into the study nor could they be employed for the data collected. It is impossible to determine if statistically significant differences existed "before and after" valley fill. Therefore, it cannot be determined if any changes that may have taken place were due to anything other than chance alone.

The Sturm Report lacks a scientific control. In aquatic impact studies, the most common practice has been to establish a control site upstream of a disturbed area (Resh and McElravy, 1993). The best studies are those that employ an above and below, before and after experimental design. In the case of valley fill, an upstream control site is not possible because the entire upstream area is buried. To ascertain the effects downstream of the fills a suitable scientific control would be a nearby "reference" stream in a relatively undisturbed watershed. A reference stream would allow investigators to determine if the potential effects they measure in a study stream were caused by a treatment (*e.g.* valley fill) or some outside influence (*e.g.* El Nino). In a chapter entitled "Contemporary Quantitative Biomonitoring" (the use of benthic organisms to ascertain water quality conditions), authors Resh and McElravy (1993) point out: *"the establishment of suitable spatial and/or temporal controls is an essential component of sampling design for any biomonitoring study."*

Although the benthic data were interpreted as if the Sturm Report was a long-term study, in reality, benthic macroinvertebrates were sampled only three times over an eleven year period. In the majority of stream biomonitoring studies published before 1989 benthic samples were collected at monthly intervals (Resh and McElravy, 1993). For this study to portray before and after impacts three samples collected over an eleven year period is entirely inadequate. To be meaningful, benthic samples should have been collected, at the very least, at monthly intervals over the entire eleven-year period.

For studies where budgets permit only annual or semi-annual sampling, Resh and McElravy (1993) state that the *"choice of sampling time is critical and should follow logically from the questions being asked."* For the Sturm Report the time of year when the sampling was conducted was different for each sampling event. For instance, Rockhouse Creek was sampled May 6, 1986, April 30, 1993, and July 28, 1997. The two or three month difference in the time-of-year that samples were collected may have had a greater influence on the results than the seven- or eleven-year lapse between subsequent sampling events. For instance, most of the mayflies and stoneflies living in these streams emerge as adults in May and early June. Caddisflies emerge primarily in Fall. Mayflies and stoneflies dominated April and May samples, whereas caddisflies dominated the July sample. This study was in effect measuring different populations of organisms, another example of how the Sturm Report cannot properly evaluate impact.

Finally, the results of the Sturm Report are predicated on sampling that was conducted using different methodologies. For instance, the May 6, 1986 sampling was conducted using a square foot sampler described by Surber (1937). The April 30, 1993 sampling was conducted by hand picking the stream bottom for 20 minutes. The July 28, 1997 sampling was conducted by hand picking the stream bottom for 30 minutes. The differences in sampling method and sampling effort make it impossible to interpret abundance data with any accuracy.

The Sturm Report bases conclusions about the impact of mountain top mining and valley fills on "streams" using seven benthic samples collected over an eleven-year period. With no scientific control, no *a priori* experimental (including statistical) design, and inconsistent sampling methods, the results of this study have no scientific value. Additionally, the Sturm Report makes no mention of the obvious permanent impact to benthic communities in the streams that were actually buried by valley fill.

Review of the letter from David W. Fisher, Sturm Environmental Services, Inc., to John McDaniel, Hobet Mining, Inc. July 30, 1998. With attachments relating benthic sampling involved in the Spruce #1 mining area.

The letter from David Fisher with accompanying benthic data sheets describes a paucity of macroinvertebrate taxa in Pigeonroost Branch. However, the macroinvertebrate taxa that are identified include Stenonema mayflies and other taxa that are sensitive to pollution and intolerant of human disturbance. It is difficult to envision a stream community that contains taxa that are indicators of excellent water quality, but with only a few taxa.

In this letter the statement that "the proposed development of Spruce #1 mine should not pose a permanent threat to these systems" is incorrect. My understanding of the proposed mine is that these streams and their inherent biological communities would be buried under valley fills. I do not to see how these streams will "recover upon completion of the reclamation phase" (paragraph 6). Furthermore, I disagree with the statement that mining in the area would not pose long-term or permanent problems "because of the collected benthic populations, flow data, and water chemistry, and the absence of any recognized sensitive, threatened, or endangered benthic groups." The fact that some data were collected doesn't mean that the system won't be harmed.

Sturm's benthic survey does not attempt to study the impact of mountaintop mining and valley fill on Pigeonroost Branch streams. Additionally, the repeated statements (paragraphs 2 & 6) regarding extractive industry activities such as prior mining and oil and gas exploration don't appear to be representative of the Pigeonroost Branch watershed. The Sturm report contains no data to support statements that prior mining has influenced Pigeonroost Branch or any other watershed. Because they are near the bottom of the hollow, abandoned home sites and cars affect less than 10% of the watershed area. Additionally, abandoned cars are temporary impacts that are easily removed and have little influence on water quality.

Review of the report: A survey of the aquatic life and terrestrial habitats on the proposed Spruce No. 1 surface mine in Logan County, West Virginia by The United States Fish and Wildlife Service, December, 1998a.

The Fish and Wildlife Service Report (1998a) provides a snapshot of the quality of the benthic macroinvertebrate fauna in Pigeonroost Branch streams and surrounding watersheds including Oldhouse Branch and White Oak Branch in July of 1998. Sampling was conducted in these streams within a narrow window of two days, allowing for site comparisons and contrast without having to compensate for seasonal variation. Unfortunately, as in other reports, sampling was conducted in late July. July is a time of year when leaf accumulations are approaching an annual low and many species of aquatic macroinvertebrates are in the adult or egg stage.

Because of the July sampling dates many species of leaf shredding macroinvertebrates that would be expected to be present in these streams were absent or nearly absent from samples. For instance, leaf shredding cranefly larvae Tipula abdominalis are early stage larvae in July and only five were collected in Pigeonroost Branch samples. Leaf shredding caddisfly larvae Pycnopsyche gentilis and Pycnopsyche scabripennis are primarily in the adult or egg stages in late July and none were collected from any of the streams sampled. These caddisfly species have annual life cycles and typically dominate the fall, winter, and spring macroinvertebrate communities in headwater streams of the southern Appalachians. The only leaf shredding macroinvertebrates of any significance in July samples from Pigeonroost Branch were pteronarcid and peltoperlid stoneflies, both of which are hemivoltine. Hemivoltine insects complete their life cycles in 2 or more years, thus representatives of these leaf shredding insects were collected because they over-summer in these streams at an intermediate stage of development.

Regardless of temporal sampling limitations, the Fish and Wildlife Report (1998a) listed 45 taxa of aquatic macroinvertebrates that were collected in Pigeonroost Branch streams. All of the taxa identified have been previously reported from West Virginia streams (Tarter, 1976). The sampling conducted by the Fish and Wildlife Service was obviously much more comprehensive than sampling conducted by Sturm Environmental. The report of the Fish and Wildlife Service provides information that is representative of the organisms living in Pigeonroost Branch streams.

I disagree with two minor points in the Fish and Wildlife Report (1998a). First, the designation of Pigeonroost Branch as a second order stream near the confluence with Spruce Fork ignores viable benthic communities in first order streams that were identified as "isolated seep areas," but were not sampled. By definition, seeps represent the origin of headwater streams (Hynes, 1970). Second, the Fish and Wildlife Service Report (1998a) states that Pigeonroost Branch near the confluence with Spruce Fork is designated as intermittent on USGS Topographic maps. Pigeonroost Branch is designated as perennial from the confluence of the Left and Right Forks to the confluence with Spruce Fork on the USGS topographic maps (Figure 1, appended to back).

Review of the report: *Analysis of valley fill impacts using benthic macroinvertebrates. Draft final report.* September 30, 1998. by Science Applications International Corporation. McLean, VA, USA. EPA Contract No. 68-C4-0034.

This was a well-designed proposal for a study that, unfortunately, was never carried out as designed. Conclusions rely on existing data from questionable sources such as the Sturm Report (1998). The "difficulty in drawing any real conclusions" (p. 40) was attributed to 1) lack of pre-mining land use data, 2) differences in sampling methodology, and 3) limited sampling effort. In addition, the valley fill sites selected were relatively small fills in comparison to the currently proposed valley fill projects in West Virginia. Most of the sites were impacted by contour mining, not mountaintop mining. Although this paper is inconclusive, and although the study proposed by the paper was never carried out, it does provide valuable recommendations regarding the design of a potentially comprehensive research project (p. 41).

Field survey of benthic fauna in the Pigeonroost Branch watershed

Purpose

I examined the Pigeonroost Branch watershed on January 11, 1999. The purpose of the site visit was to determine which of several reports most accurately described water quality and the benthic macroinvertebrate fauna in Pigeonroost Branch and tributaries. The following report details my review of these reports in the context of my field observations and literature in stream ecology. My examination was not intended as a research project suitable for publication.

Method

During my first site visit, I surveyed benthic macroinvertebrates by hand-picking the benthic fauna at two sites on the main stem of Pigeonroost Branch, two sites on the Left Fork, one site on the Right Fork, and one site each on five small tributaries. Approximately 5 to 10 minutes was spent at each of 10 locations in the watershed. The entire watershed was traversed by vehicle using jeep roads, with the exception of the upper 1km of the (river) Left Fork, the southern most fork of Pigeonroost Branch. I also drove up Beech Creek to the Hobet Office and viewed Rockhouse Fork and Beech Creek without sampling.

Study area

The Pigeonroost Branch watershed is greater than 90% forested, as accurately portrayed on USGS topographic maps (Figure 1). Forest canopy coverage was present over all stream segments except active or abandoned home sites in the lower 3km near the confluence of Pigeonroost Branch with Spruce Fork. In some areas, there appeared to be selective timber harvest within the past decade as evidenced by partially decayed stumps and less than pole-sized timber. Most of the forest appeared to be 20-40 years post-harvest as evidenced by medium-size timber and absence of decaying stumps. The forest was mixed-mesophytic in composition with species such as sycamore, red maple, yellow birch, and tulip poplar occurring near streams, and American beech, black cherry, black oaks, and chestnut oak on steeper slopes.

Stream ordering method

Stream ordering is a hierarchical system of stream classification described by Horton (1945) that provides a method for identifying streams based on their relative size (Figure 2). The confluence of two first order streams results in second order status for the stream segment downstream of the confluence. The union of two, second order streams results in a third order stream. Stream order does not change when different order streams merge. For instance, when a first order stream enters a second order stream the stream segment below the confluence remains second order. Stream order increases only when two streams of equal size merge. Therefore, an increase in stream order by one represents an order of magnitude increase in stream size.

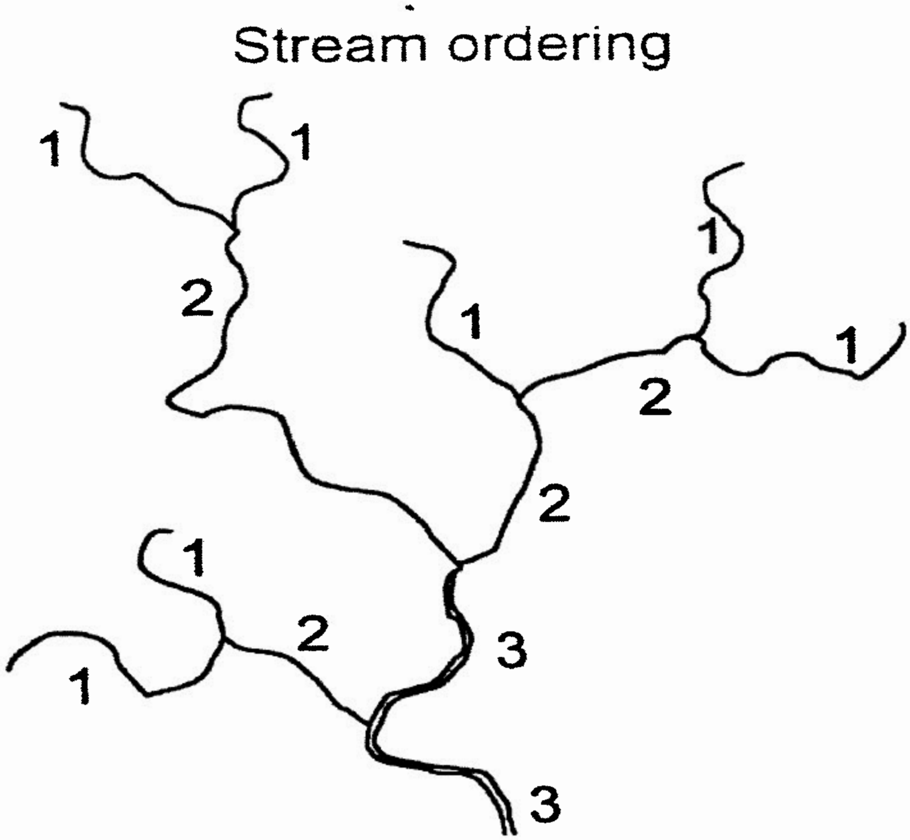

Figure 2. Conceptual stream ordering diagram.

Identification of first order streams is the most critical step for determining stream order of Pigeonroost Branch near the mouth. In the classic work The Ecology of Running Waters, H. B. N. Hynes (1970) suggests with regard to designation of first order stream status that "for the biologist the most useful criterion would seem to be perennial streams or those that persist at least long enough to develop biota." More recently, first order streams have been defined as the smallest stream segments with perennially flowing water (Allan, 1995).

Stream ordering in Pigeonroost Branch watershed

During my site visit, first order tributaries of Pigeonroost Branch were identified based on the presence of characteristic benthic fauna, primarily aquatic insect larvae that undergo development through larval stages in fresh water. Streams harboring a cohort of advanced stage peltoperlid larvae, in addition to other associated species of aquatic insects described below, were determined to be perennial streams for a period of more than one year prior to the January 1999 survey.

Stonefly larvae from the family Peltoperlidae in Pigeonroost Branch were particularly useful in designating first order streams because the larvae are purely aquatic (not semi-aquatic or terrestrial) and have a two-year life cycle in streams (Stewart & Stark, 1988). A two-year life cycle results in the presence of two distinct cohorts (ie year classes) of larvae being present in the stream from fall to spring. In January, smaller, first-year class larvae have resided in the stream for 4-6 months, whereas larger, second-year class of larvae have been in the stream for 16–18 months. Given that peltoperlids are cold water organisms requiring well-oxygenated water (Surdick & Gaufin, 1978), the presence of second-year larvae indicates that water quality conditions within the stream were suitable for development of this and associated aquatic insects for 16 months prior to the January sampling.

Pigeonroost Branch is a third order stream near the confluence with Spruce Fork. Third order status is the result of the convergence of the second order Left Fork with the second order Right Fork of Pigeonroost Branch. Each of the second order branches are fed by two or more first order tributaries.

Quality of Pigeonroost Branch streams

My survey of the Pigeonroost Branch watershed revealed a benthic macroinvertebrate fauna typical of exceptionally high quality, undisturbed forested streams in the southern Appalachians. The presence of three year-classes of the stonefly Pteronarcys indicates excellent water quality conditions in the Left Fork, Right Fork, and main Pigeonroost Branch over the past 2.5 years. An abundance and diversity of mayflies (insect order **E**phemeroptera), stoneflies (**P**lectoptera), and caddisflies (**T**richoptera), often referred to as **EPT** taxa (Resh & Jackson, 1993), indicates exceptional water quality throughout the basin. From observation, Pigeonroost Branch appeared to be one of the higher quality streams in the region.

Macroinvertebrate fauna identified by Sturm Environmental Services, Inc. (Fisher, 1998) versus the Fish and Wildlife Service Report (1998a) give conflicting views of the benthic communities in Pigeonroost Branch. A comparison of the three samples collected for each report illustrates the difference in sampling effort by different organizations (Table 1). Whereas 45 taxa were identified by the Fish and Wildlife Service, only 8 were identified by Sturm. A total of 18 EPT taxa were collected by the Fish and Wildlife Service, but only 4 EPT taxa were collected by Sturm. In addition, 20 taxa were identified in White Oak Branch by the Fish and Wildlife Service, whereas Sturm said the stream had no flow. In Oldhouse Branch, the Fish and Wildlife Service found 20 taxa and Sturm found four taxa. Both Oldhouse Branch and White Oak Branch are high quality streams. After surveying Pigeonroost Branch it is clear that the Fish and Wildlife Service survey is reliable and the Sturm report is not reliable.

Table 1. Comparison of total macroinverebrate taxa in Pigeonroost Branch as represented by The US Fish and Wildlife Service Report (1998a) and Sturm Environmental Services, Inc. (Fisher, 1998).

Taxonomic category	Fish & Wildlife (1998a)	David Fisher (1998)
Total taxa collected	45	8
Mayfly taxa (**E**phemeroptera)	6	1
Stonefly taxa (**P**lecoptera)	6	1
Caddifly taxa (**T**richoptera)	6	2
Total **EPT** taxa collected	18	4

Pigeonroost Branch is one of the best quality streams in the region. The presence of 45 taxa during a time of year when benthic populations are species-poor indicates that this stream is exceptionally diverse. Two independent reports were used to compare Pigeonroost Branch (Green & Passimore, 1998) with Caney Fork of Twelvepole Creek (SAIC, 1998). Caney Fork is located 24 miles West of Blair, WV. Caney Fork is an EPA regional reference stream representing the "best attainable current conditions" in the ecoregion (SAIC, 1998). A total of 262 organisms were collected by each report, indicating comparable sampling efforts.

A comparison of the total number of taxa collected shows that Pigeonroost Branch has more macroinvertebrate taxa and more EPT taxa than the reference stream (Table 2). This indicates that Pigeonroost Branch has a better macroinvertebrate fauna than the regional stream selected by EPA as having the best attainable current conditions. Therefore, the quality of the benthic macroinvertebrate fauna in Pigeonroost Branch is among the best, if not the best, for streams in the region.

Table 2. Comparison of total macroinverebrate taxa collected by the US EPA in Pigeonroost Branch (Green & Passimore, 1998) and Caney Fork of Twelvepole Creek, an EPA regional reference stream representing the best attainable current conditions (SAIC, 1998).

Taxonomic category	Pigeonroost Branch	Caney Fork reference
Total taxa collected	19	16
Mayfly taxa (**E**phemeroptera)	4	3
Stonefly taxa (**P**lecoptera)	4	3
Caddifly taxa (**T**richoptera)	3	3
Total **EPT** taxa collected	10	8

Benthic macroinvertebrate functional feeding groups

Macroinvertebrates are the major macroconsummers in streams and their feeding strategies are indicative of the energy and nutrient resources available to them (Cummins & Klug, 1979). Cummins (1974) first described the concept of functional feeding groups for aquatic macroinvertebrates. In this scheme macroinvertebrates are assigned to one of **four functional feeding categories** based on their primary mode of ingestion. **Shredders** are organisms that feed on decaying leaves and other large particles of organic matter. **Collectors** filter or gather fine particles of organic matter from the water column or stream bed. **Grazers** scrape or brush biofilm (a matrix of algae, fungi, and bacteria) from rocks, sticks, leaves and other structural components of the stream bed. **Predators** consume other macroinvertebrates.

River Continuum Concept

Stream ecosystems are organized like other ecosystems to fend-off entropy (energy loss) and conserve nutrients. The River Continuum Concept (RCC) is the accepted model of how streams are organized as ecosystems (Allen, 1995).

The basic premise of the RCC is that biological processes respond to a continuously changing gradient of physical features from headwaters to mouth (Figure 3). Water flows from small headwater streams to large river systems through a continuously changing landscape of increasing stream width, depth, volume, and land surface drainage area. Small streams are closely intertwined with the surrounding forest ecosystem, and as streams increase in size their interrelations with the surrounding terrestrial ecosystem change proportionately.

As depicted in Figure 3, headwater streams (first through third order) are narrow and well shaded by the surrounding forest in most regions of the world. Shading reduces the ability of a stream to harbor organisms that utilize sunlight to capture energy (*ie* plants and algae). In headwater streams the ratio of photosynthesis to respiration is less than one (Figure 3, $P/R<1$). The significance of P/R being less than one is that headwater streams decompose more biomolecules than they synthesize. Streams must import energy in the form of biomolecules, and are therefore dependent on a net influx of biological materials to maintain energy balance.

In the Hubbard Brook Experimental Forest, New Hampshire, 99% of the annual energy available to macroconsummers in a small woodland stream was derived from the surrounding forest (Fisher & Likens, 1973). Bacteria, fungi, and macroinvertebrate consumers in streams utilize leaves and sticks from the forest, convert them to fine particles through feeding activities, and eventually release fine particles downstream where they become available to collectors. In Hubbard Brook, 65% of the energy that entered the stream was eventually exported downstream (Fisher & Likens, 1973).

Larger rivers and streams are poorly shaded yet shallow enough for sunlight to reach the stream bottom. Physical changes from headwaters to larger streams result in an increase in production by periphyton (attached algae) and other primary producers such as emergent plants. The result is a net increase in the importance of in-stream photosynthesis as a source of energy for macroconsumers living in larger streams.

However, organic matter budgets constructed for large rivers draining forested watersheds indicates that the bulk of energy even in large river systems originates in the forest (Allen, 1995).

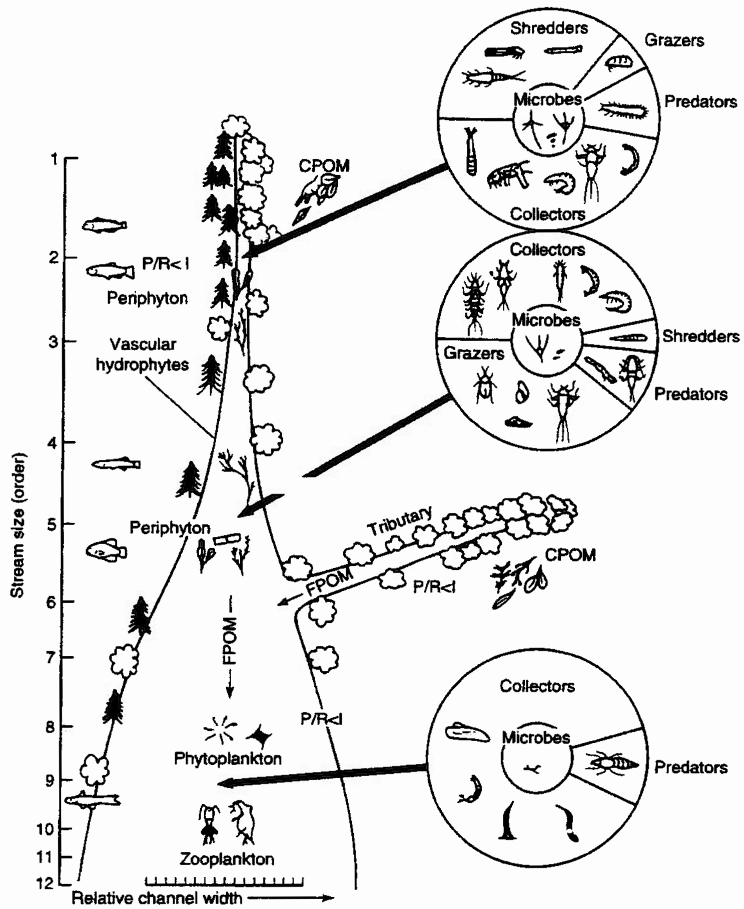

Figure 3. Conceptual model of the River Continuum Concept illustrating changes in physical and biological characteristics along a stream gradient from headwaters to mouth (adapted from Allen, 1995).

Since publication in 1980 the River Continuum Concept article has been cited 814 times in the primary literature (WebofSci®, personal communication, March 16, 1999). The large number of RCC citations is indicative of widespread use of the RCC by a variety of investigators worldwide. The RCC provides commonality that reaches across the aquatic sciences and serves to unify efforts to understand stream ecosystem structure and function. In the most widely recognized textbook in stream ecology author J. David Allen reiterates *"the biota of a stream reflects the nature of organic matter inputs"* (Allen, 1995).

The RCC is applicable to most, but not all river systems. Rivers in the eastern deciduous forest generally follow the tenets of the RCC (Allen, 1995). Headwater streams draining watersheds perched above tree-line (Minshall, et al, 1983) or where deciduous trees are absent (Winterbourne, Rounick, & Cowie, 1981) rely more on photosynthesis than would be predicted by the RCC. Impounded rivers are not as likely to follow the RCC (Statzner & Hilger, 1985) compared to free-flowing rivers (Minshall, et al, 1992). River systems in the eastern US, where much of the RCC precursory work was done, are the most likely of the world's rivers to follow the RCC (Allen, 1995).

The structure and function of Pigeonroost Branch headwater streams

First order streams in the Pigeonroost Branch watershed

Peltoperlid stoneflies observed in Pigeonroost Branch headwater streams (first through third order) are leaf shredders that derive their nutrition and energy by "skeletonizing" leaves, that is, by peeling epidermal and mesophyll tissue from leaves while leaving vascular (veins) tissue intact (Wallace, Woodall, & Sherberger, 1970). The bulk of their diet consists of leaves and an associated fungi/bacterial matrix colonizing the leaves. Their primary energy source is leaf tissue, but they also derive energy and nutrients from the associated microbial matrix (Allan, 1995).

Other obligate leaf shredding species (Merritt & Cummins, 1996) that I found along with peltoperlids in first order Pigeonroost Branch tributaries included nemourid stoneflies, the cranefly Tipula abdominalis, and the caddisfly Pycnopsyche gentilis. Amphipods (freshwater shrimp), Isopods (scuds), and Decapods (crayfish) are crustaceans that were observed in some first order streams. These crustaceans are omnivorous, functioning as leaf shredders, fine particle collectors, and scavengers.

Other benthic macroinvertebrates oberved in first order streams in the Pigeonroost Branch watershed included the mayfly Stenonema, an organism that grazes rock surfaces and feeds on a biofilm matrix of fungi, bacteria, and algae, mostly diatoms. Another mayfly, Ephemerella, collects fine particles of organic matter from the stream bottom. Predatory species observed in first order streams included Nigronia (hellgrammite), Hexatoma (cranefly), and perlodid stoneflies. Overall, the organisms present in first order Pigeonroost Branch streams were indicative of high quality, cold water streams and are typical of the benthic macroinvertebrate communities in high quality southern Appalachian headwater streams.

Larger streams in the Pigeonroost Branch watershed

In the larger second-order Left and Right Forks of Pigeonroost Branch the leaf shredding stonefly Pteronarcys was abundant as was the case-building caddisfly Pycnopsyche scabripennis. As noted in the US Fish and Wildlife Service Report (1998a), Pteronarcys is a pollution sensitive organism indicative of flowing water conditions. The size discrepancy among Pteronarcys identified by the Fish and Wildlife Service Report (1998a) can be explained by the presence of three distinct year-classes (cohorts) because Pteronarcys has a three-year life cycle in streams.

I observed all three year-classes of Pteronarcys in second and third order Pigeonroost Branch streams. The water quality requirements including temperature, dissolved oxygen, pH, and flow described for Pteronarcys (Surdick & Gaufin, 1978) are similar to those for brook trout (Salvelinus fontinalis) in West Virginia streams (Stauffer, Boltz, & White, 1995). Maps of the distribution of Pteronarcys in West Virginia streams (Tarter, 1976) are nearly identical to those of brook trout in West Virginia streams (Stauffer, Boltz, & White, 1995). I agree with the Fish & Wildlife Service Report (1998a) that Pteronarcys is an indicator of excellent water quality and that the absence of trout from Pigeonroost Branch is due to physical habitat limitations. Furthermore, the third year class of Pteronarcys indicates excellent water quality conditions during their residency in Pigeonroost Branch for a period of 2.5 years prior to January 1999 sampling.

Pteronarcys is abundant in debris dams and mid-stream leaf packs in Pigeonroost Branch streams. Their large size and abundance indicates significant production in second and third order Pigeonroost Branch streams. A healthy Pteronarcys population also indicates successful microbe-mediated conversion of terrestrially-derived leaves into insect forage. Like most shredders, Pteronarcys is only 10-15% efficient in converting leaf tissue into animal mass (Perry, et al, 1987). The majority of the leaf material consumed is eggested as frass (feces and leaf fragments). Pteronarcys is therefore indicative of a healthy leaf shredding community that has a primary function of converting leaf material into fine particles that eventually wash downstream and feed downstream collector communities.

The cranefly larvae Tipula abdominalis consume whole leaves and were found primarily in leaf packs within the streams. This is one of the most abundant leaf shredders observed in Pigeonroost Branch streams as, confirmed by the data from (Fisher, 1998) and the Fish and Wildlife Report (1998a). This species is an obligate leaf shredder as best evidenced by its ability to produce cellulolytic enzymes, those capable of breaking down cellulose molecules (Allen, 1995). It is difficult to understand why this organism was not referred to as a leaf shredder in field testimony (February 25, 1999) given the plethora of research conducted on this species (Merritt & Cummins, 1996, 3rd edition). Even the out-dated reference used by Sturm Environmental, Inc. identifies Tipula as a leaf shredder (Merritt & Cummins, 1984, 2nd edition). Algae is not prominent Pigeonroost streams and will not support a grazer-based community. Only 7 of the 45 taxa collected by the Fish and Wildlife Service (Fish and Wildlife Service, 1998a) are predators as described by the current literature (Merritt & Cummins, 1996).

Some of the Caddisfly species observed in Pigeonroost Branch consume leaves and also cut leaf disks. These caddisflies spin silk and use the silk to arrange leaf disks into a constructed "case." Early stage Pycnopsyche gentilis begin case construction using leaves and then add small (0.25-5mm) stones to complete the case. Pycnopsyche scabripennis use leaves initially and then adds twigs and bark to the case. As caddisfly larvae mature the case eventually becomes a secure chamber within which they will pupate and from which they will emerge as an adult. Leaf quantity and quality thus influences the survival and production of leaf shredding caddisflies in southern Appalachian headwater streams (Stout, Benfield, & Webster, 1993).

Role of headwater streams in the health of larger streams and rivers

Keystone role of shredders in river and stream ecosystems

Of the four macroinvertebrate functional groups, leaf shredders are the key linkage between terrestrial and aquatic environments. Leaf shredders are a keystone community because their removal from the ecosystem would cause failure of headwater streams to efficiently break down terrestrially derived leaf tissue into small particles that are washed downstream and subsequently feed energy and nutrients into the downstream collector community. At Coweeta Hydrologic Laboratory in North Carolina, experimental elimination of shredders from headwater streams significantly reduced leaf breakdown rates as well as the quality (size) and quantity of fine particulate material exported downstream (Wallace, Webster, & Cuffney, 1982).

Leaf shredding is *not* an efficient process. In fact, studies of a variety of leaf shredders indicate that shredders assimilate (capture) only 10-20% of the total energy they ingest (Allen, 1995). The bulk of the energy shredders consume is lost as frass (mostly feces). Therefore, their primary role in the ecosystem is to convert vast quantities of large particulate organic matter (leaves and sticks) into fine particles that wash downstream. For instance, the stonefly Pteronarcys yields 15.8% of it's body weight per day in feces (McDiffett, 1970). Presence of Pteronarys in streams significantly increases the amount of fine particulate organic matter available to downstream communities (Short & Maslin, 1977). Dr. Robert Leo Smith, Professor Emeritus at West Virginia University, has written the second most popular text in general ecology. Using the RCC as an example of how ecosystems are organized, Smith (1996) explains: *"throughout the downstream continuum, the lotic* (flowing water) *community capitalizes on upstream feeding inefficiency."*

Larger streams are dependent on headwater stream processes

Benthic macroinvertebrate communities inhabiting larger streams and rivers world-wide are dependent on the export of energy and nutrients from headwater streams (Allen, 1975). Collectors dominate the macroinvertebrate abundance and biomass in rivers and streams (Vannote, *et al*, 1980; Allen, 1995). Energy budgets for large rivers reveal that most of the energy needed to drive the ecosystem comes from outside, as opposed to in-stream, sources. For instance, in the New River near Blacksburg, Virginia (upstream of the New River Gorge, WV), production by algae and emergent plants yielded 40% of the energy budget whereas energy from outside sources contributed 60% of the total energy budget (Hill & Webster, 1982; Hill & Webster, 1983).

Export of fine particulate organic matter from headwater streams is essential to health and balance of large rivers. Wallace and Merritt (1980) reviewed the literature on suspension-feeding macroinvertebrates and discussed the tremendous variety of mechanisms that collectors use to filter or gather fine particles of organic matter. Collectors dominate the functional feeding groups of river ecosystems (Allen, 1995). Winterbourne, Cowie, and Rounick (1984) used stable carbon isotope analysis to determine that collectors fed mostly on fine particles that originated from the terrestrial ecosystem.

Influence of mountain top removal on mountain state rivers and streams

Headwater streams (first through third order) make up >80% of the total stream length of the world's rivers and streams (Hynes, 1970). Whereas cumulative stream volume (discharge) and stream surface area remain relatively constant, greater stream length accompanied by smaller stream size in headwaters is indicative of a much greater contact of headwater streams with the surrounding landscape when compared to larger streams. Physical features of headwater streams provide a template for much greater contact and therefore interactions with terrestrial ecosystems as compared to larger streams.

Foundation Papers in Ecology published by the Ecological Society of America (Real & Brown, eds., 1991) includes a paper by Likens *et al* (1970) that was the first to described a watershed as an ecosystem. Through careful experimentation, Likens *et al* (1970) found that forest canopy removal profoundly effected the hydrologic balance and export of materials from deforested headwater streams compared to undisturbed reference streams in the Hubbard Brook Experimental Forest in New Hampshire. The significance of the watershed-ecosystem concept is that the physical and chemical conditions of large river and streams are directly influenced by the interactions of headwater streams with the management of the surrounding forest ecosystem.

The River Continuum Concept and subsequent experiments have shown that biological processes in rivers and streams are intimately linked with headwater stream functionality. The pathway of energy and nutrient flow from forest to headwater streams to larger rivers is mediated by thousands of bacterial, fungal, and macroinvertebrate species and billions of individual organisms in a given river system. Each of the species involved has a slightly different strategy for capitalizing on the resources available. The function of each species involved is critical to the efficient processing of nutrient and energy resources along the river continuum. Ultimately, production by benthic macroinvertebrates serves to support organisms that are higher-level consumers such as fish and amphibians. In turn, higher-level consumers support top level predators such as mammals (*e.g.* mink, otter, humans) and birds of prey (*e.g.* osprey, eagles).

Rivers and streams contribute energy and nutrients back to the forest ecosystem. Emergence of insects from rivers and streams represents not only a significant quantity of energy and nutrients, but also a significant quality. Tissue of adult insects contains a tremendous proportion of protein and lipids (fats). These highly labile ecosystem products are in sharp contrast to the recalcitrant lignin and cellulose molecules of the forest from which they originated. Additionally, the export of high quality food to the surrounding forest ecosystem comes in a form that can be consumed by a plethora of forest species, and at a time when forest species require high energy foods for the successful production of ensuing generations.

The burial of headwater stream ecosystems by mountaintop removal and valley fill practices in the southern Appalachians is troubling. In five counties of southern West Virginia alone, it has been estimated that 469.3 miles of stream in five watersheds have been buried (U. S. Fish and Wildlife Service, "permitted stream losses", 1998b). This figure represents only one-half of the watersheds in West Virginia where mining is occurring. In the Mud River watershed, it is estimated that 39% of the headwater reaches have been buried. This level of disturbance within a watershed is unprecedented and is potentially devastating to downstream river and stream ecosystems.

There have been no valid studies showing the impacts of mountaintop mining and valley fill practices on forest and stream ecosystems. The few studies that have been conducted to date have been poorly designed or poorly executed, revealing no information of scientific value (SAIC, 1998). By removing forests and headwater streams, energy and nutrients will non longer feed downstream ecosystems. Significant impacts to downstream communities will result from the loss of upstream keystone functionality. The River Continuum Concept clearly indicates that there will be significant, irreversible, and far-reaching consequences of mountaintop removal and valley fill impacts on watershed-ecosystems of the southern Appalachian Mountains.

Loss of forests from mountain top mining and valley fill

Deforestation has well known consequences (Smith, 1996). Canopy removal results in the disruption of basic ecosystem-level functions including temperature moderation, water balance, nutrient recycling, and energy flow. Mountaintop removal is not as benign as deforestation. Before mountaintop removal begins the tree roots are "grubbed" and the topsoil is removed and dumped into valley fills. The landscape is permanently altered with steep slopes buried under hundreds of feet of fill material. The impact of mountaintop removal and valley fill on forest ecosystems is devastating.

Ecological succession is an orderly and predictable recolonization of species following a disturbance. After timbering a typical mature northern hardwood forest it is expected that forest succession will proceed at a rate that would yield replacement of the mature forest species (*e.g.* beech, sugar maple) within a century (Smith, 1996). Herbacious plants and grasses (forbes) dominate for the first decade after timbering. Intermediate successional tree species (*e.g.* poplar, yellow birch, red maple) dominate the regenerating forest canopy after one or two decades, and drop out as the forest matures. Mature forest species become important as saplings in the successional forest within one or two decades.

It is questionable whether forest succession is proceeding as would be expected on two mountaintop removal sites reclaimed by Hobet (Michael, 1998a, 1998b). If succession fails to proceed as expected forest edge species (Smith, 1996) such as the gray catbird and the American robin may prosper. However, forest interior species such as the ovenbird and worm-eating warbler will disappear, and the ancestral forests of the region will be reduced to mere islands of their original form. A terrestrial habitat survey of Pigeonroost Branch watershed states that "*if the forest were allowed to mature, more mast would be produced, further enhancing its wildlife value* (Fish and

Wildlife Service Report , 1988a, p. 20)." However, discussions of habitat evaluations for both reclaimed Hobet properties include identical statements in both reports that "*ecological succession has occurred in a pattern that might have been predicted in certain portions of the reclaimed study site; forbes invaded the areas seeded with a grass seed mixture and shrubs and trees invaded the areas planted with locust. However, in other portions of the reclaimed study sites there has been little, if any, ecological succession* (Michael, 1998a, p.11; Michael, 1998b, p. 12)."

The interpretation of habitat values prepared by Hobet for reclaimed Hobet properties is misleading. John McDaniel of Arch Coal, in an October 12, 1998 letter to Dan Sweeney of the US EPA, points out that wildlife habitat evaluation scores for reclaimed sites were much greater than habitat evaluation scores for undisturbed sites in the surrounding forest. The notion that wildlife habitat is enhance by replacing forests with poorly vegetated grasslands in southern West Virginia is absurd. Higher wildlife habitat evaluation scores for reclaimed sites are purely methodolgical.

The methods for the Habitat Evaluation Procedures used to evaluate Hobet reclamation sites were developed during a period when Appalachian forests were in peak re-growth, 50-100 years after the nearly complete deforestation of the ancestral Appalachian forests. Because re-growing forests were relatively even-aged, openings, breaks, and fields were an asset for wildlife in an otherwise unbroken forest. This is like comparing apples to oranges. The methods used to evaluate the Hobet properties gave highest scores to areas that are easier to walk through, contain 60-80% herb and grass cover, and are overgrown with dense shrubs and small trees. Areas with shrub and tree cover exceeding 80% of ground cover were given the lowest possible scores (Michael, 1998a, Appendix 1).

Conservation Biology has emerged in the past two-decades as a science that addresses loss of plant and animal species worldwide. Conservation Biology "*addresses the problems of gross habitat destruction and a great reduction in the population size of species* (Smith, 1996, p. 11)." Metrics of Conservation Biology include measures of habitat fragmentation, connectivity between remnant habitat "islands", and the ability of species to migrate over distances between habitat islands. One concern of large-scale disturbance by mountaintop mining in southern West Virginia is the ability of "area sensitive" species, such as neotropical migrant forest birds, to survive in fragmented forests.

The Fish and Wildlife Report (1998a) points out that "*many of the area-sensitive neotropical migrant forest bird species found in southwestern West Virginia, such as the wood thrush, cerulean warbler, black and white warbler, Acadian flycatcher, and worm-eating warbler, are species of special concern to the Service because of declining populations.*" These species require large expanses of unbroken forest to survive. Grasslands will not support forest interior species. As described in the Fish and Wildlife Report (1998a), *"this portion of West Virginia has been recognized as one of the largest areas of contiguous forest remaining in the Northeast."* Furthermore, the Fish and Wildlife Report (1998a) describes southwestern West Virginia as a *"hot spot for forest interior bird species of special concern in the Northeastern United States."*

Invasion of ecosystems by exotic species is an urgent concern in the United States (Department of Interior, 1999). In many cases, introduced exotic species have *"outcompeted native community members and altered community structure"* (Campbell, 1996, p. 1132). Displacement by exotic species introductions has been implicated as at least partially causative in 68% of the listings of extinct, endangered, and rare species (Campbell, 1996, p. 1166). The most prominent plant species inhabiting reclaimed Hobet properties are exotic, introduced species that are not native to the Appalachians. Kentucky-31 tall fescue (Festuca arundinacea) is an exotic species introduced from Europe that is common along highways and waste places throughout West Virginia (Strausbaugh & Core, 1970). Both of the species of Lespedeza used to seed reclaimed Hobet sites are native to Asia. Given the fate of multiflora rose, autumn olive, and Japanese knotweed in West Virginia, it is not surprising that management recommendations for increasing habitat value on Hobet sites include controlling Kentucky-31 fescue (Michael, 1998a, 1998b).

The scale of current mountaintop mining operations in southern West Virginia is enormous and the impacts to the contiguous forest ecosystem are potentially far-reaching. If these mining operations continue displacing native species, future habitat values are likely to include measures of the continuity of forest stands, availability of hard mast producers, presence of standing dead trees, availability of nesting sties for neotropical migrant songbirds, and connectivity between islands of remnant hardwood forest in southern West Virginia.

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with Dr. Trevor Harris, West Virginia University.
1994-1995 Burroughs-Wellcome Apaalachian Regional Fellowship, Appalachian College Association, Lexington, KY, $12,600
with Dr. Trevor Harris, West Virginia University.
1995-1996. US EPA, Philadelphia, PA, $ 540,000 (WJC $114,581)
with 5 co-investigators, West Virginia University.

Wheeling Creek water quality assessment: monitoring protocol for Ohio River watershed studies

1993-1994 Virginia Environmental Endowment, $26,121
and West Virginia Water Research Institute, $19,601
1994-1995 Virginia Environmental Endowment, $29,608
and West Virginia Water Research Institute, $21,948
with Dr. Trevor Harris, West Virginia University.
1995-1996 Virginia Environmental Endowment, $35,173
and West Virginia Water Research Institute, $16,912
And Wheeling Heritage Area Corporation, $10,000
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Figure 1. Map of the Pigeonroost Branch watershed (USGS).