# The Effects of Rosgen Style Trout Habitat Restoration on Trout Populations and Microhabitat Selection on Big Bear Creek

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# Abstract

The populations of Brook Trout, *Salvelinus fontinalis*, and Brown Trout, *Salmo trutta*, of Big Bear Creek, a tributary of the Loyalsock Creek in Lycoming County have declined over the past 100 years. To counteract large amounts of sediment pollution, 176 Rosgen style boulder structures were added from 1999 to 2002. These structures were intended to help stop bank erosion and to create fish habitat. In addition to this, stocking of trout was ended in 1999.

This study determined the affect of these structures on the trout populations and trout microhabitat choice and availability. Since implementation, trout populations were shown to rise and reach equilibrium between the two species. In addition, dominant trout were shown to prefer depths ranging from 0.39 to 0.54 meters, mean velocities from 0.28 to 0.41 meters per second, and focal point velocities from 0.13 to 0.26. Preferred substrate was also found to be cobble or boulder.

# Introduction

Modern man often degrades his environment. Toxic gasses are released into the air, forests are clear-cut and waterways are degraded with a variety of introduced pollutants. These are all direct consequences of human activities. In addition to these obvious examples, degradation can occur in many ways that are not often noticed by the untrained eye. For example, in Pennsylvania the 16,000 stream miles suffering from unnaturally high sediment loads make this sediment problem the number one form of water pollution in the state (Worobec, 2000). These sediment deposits are often the byproduct of human activity such as deforestation, bridge and highway construction, elimination of riparian buffers and dam construction. Since man has caused this disruption in stream sediment, it seems logical that man should also be the one to repair the problem.

Big Bear Creek is a fourth order stream located in northern Lycoming County, Pennsylvania. It is a tributary of Loyalsock Creek and encompasses a 17 square-mile watershed. The actual location of Big Bear Creek in the Big Bend Watershed can be seen in Figure 1. The stream itself runs approximately 5.2 miles and is part of the property belonging to the Dunwoody Sportsmen's club. The Dunwoody Club attained exclusive rites to the stream in 1884 and has monitored fishing conditions there since. The ground was originally purchased because of the pristine steam and the high quality fishing the stream offered. Club members enjoyed great fishing in the area until around the 1920's when they started to notice a decline in the stream's tout populations. At this time the Club opened a hatchery on the property and began stocking trout in effort to restore the trout populations to the previous high numbers. This practice helped to rebound the trout numbers for a time, but was not a permanent solution to the problem.

The stream suffered extreme perturbations to the habitat in 1972 from Hurricane Agnes and again in 1975 from Hurricane Eloise. The extremely high flows from these hurricanes deposited large amounts of sediment in the stream channel and also caused much erosion along the banks of the stream. Big Bear again suffered a setback in 1980 when a dam was constructed downstream near the mouth at the Loyalsock Creek by a private landowner. This dam not only blocked the upstream migration of fish from Loyalsock Creek, but also contributed to the stream dropping a large amount of sediment in the upstream portions because it slowed the water velocity in order to create the desired pool. As water velocity slows, energy is lost and the stream can no longer carry the sediment that is suspended within the water and it is subsequently dropped, creating a shallower and wider stream. The stream was struck hard again in 1996 when a severe flood raised water levels and caused more bank erosion and the creation of three slide banks, which added much more sediment to the stream. In addition to these events, a dam was removed from the upstream portion of the club property in 1991 and all the accumulated sediment, more than 100 years worth, was distributed downstream (Worobec, 2000). The addition of several houses along a mile long stretch of the stream also added exceptionally high sediment loads that are often found when construction is underway in close proximity to a stream (Wolman, 1967).

The problem with all of this sediment deposition is that it makes the stream shallower and wider. These shallow stream conditions are not favorable habitat for trout, which prefer slower deeper water in order to reduce energy expelled to fight current

(Hayes and Jowett, 1994). The many natural and man made disruptions have kept the stream from naturally correcting itself and have suppressed the fish population.

In order to correct these habitat problems, The Dunwoody Club, in conjunction with a grant from the Pennsylvania Department of Environmental Protection and a partnership with the United States Fish and Wildlife Commission, decided to attempt to apply the fluvial geomorphologic streambed restoration techniques that were developed by Dave Rosgen (Rosgen, 1994). This technique operates on the idea that under natural, untouched conditions, a stream will eventually correct itself. This restoration style serves only to accelerate this process of the stream reaching a self -sustaining condition where it operates at its maximum biological potential. This is described as a dynamic equilibrium where the stream will adjust its dimensions, pattern and profile in order to allow the stream to endure climatic events such as the previous floods, without changing its general makeup as it did before. This process is observed naturally in untouched streams at a slow rate. This process is sped up in severely degraded streams by the addition of upstream facing structures that work with the natural flow of the water rather than against it as previous restoration structures have aimed to do.

This process is begun by first classifying the stream based upon a set of parameters that includes the number of channels, determination of bankfull depth and width, entrenchment ration, width to depth ratio, sinuosity, slope and channel material. Once the classification of the stream is determined, a specific combination of restoration structures is applied (Rosgen, 1996). These parameters and the possible classifications can be seen in Figure 2.

Big Bear Creek was classified as a B3 channel type based upon the parameters set by Rosgen. This channel type is matched with the addition of cross veins (seem in Figures 3 and 4), single veins, cross weirs and J hooks (seen in Figures 5 and 6) as valuable restoration structures. These structures serve to roll the flow of water to the center of the channel at a right angle. Focusing the flow on the center of the channel helps to take up the sediment that has already been deposited on the stream bottom and carries it downstream. It can also deposit sediment on the stream bank in order to help build it back up. This process helps to dredge the stream back to its previous depth and the sediment deposition on the banks helps to narrow it, reversing the erosion process that had been plaguing the stream banks. The structures are used to provide a series of riffle/pool channels, with riffles entering and exiting the meanders and pools at the inflection points. The pools are spaced about five to seven bank full widths apart and help to maintain slope and stability. These riffle/pool channels redistribute energy so not to erode the bank. At the same time, this series of riffles and pools creates optimal trout habitat in the pools and great macro invertebrate habitat in the riffles (Rosgen, 1994). Since the main goals of the club have always revolved around fishing, these structures provide a very desirable restoration project for the Dunwoody club.

In 1996, the members of the Dunwoody club built 14 Rosgen structures along the stream using large logs as a test to see if the project would be successful on their stream section and if it would be worth pursuing further. The success of these structures led to the addition of 42 more structures in 1999. They were built with large boulders over a 4000-foot section of the stream. Again in 2000, 120 more structures were installed for a total of 3.2 miles of stream restoration. These structures spanned from the Dunwoody

Club to the mouth of the stream where it joins the Loyalsock and only had a few gaps where private property owners would not comply.

Since the main project goal was to rebound fish populations, they also took other measures to attempt to do so. The most important of which was the decision made in 1999 to end the stocking practice that had been in place for over 75 years, in an attempt to bring about a high population of wild born trout both Brown Trout *Salmo Trutta* and Brook Trout *Salvilinus fontinalis*. Previous research has indicated that the addition of stocked trout leads to a decline in wild trout populations, which naturally would have a better chance of survival than the stocked trout (Dewald, 1992). This is due to the fact that the wild trout have feeding and hiding territories based on a dominance hierarchy that is generally based upon size. This means the larger fish occupy the optimal territory and have a better chance of survival to breed. These territories are defended simply by threatening postures such as fin flaring and are generally respected by wild raised trout. The addition of stocked trout raises a problem in that they do not have this territorial behavior and rather fight for territory. This is uncommon to wild trout and often results in the larger wild trout moving to less desirable habitat rather than fighting. The hatchery fish then do not utilize this territory well and dart after food, opening themselves to predators. These factors lead to a higher mortality of both stocked and wild trout (Goodman, 2000). The mixed breading of stocked and wild trout also leads to the genetically impure native offspring that have a lesser chance of survival than do wild trout (Dewald, 1992).

Another aim of the project was to rebound the native brook trout to the stream. The most common stocked trout in Pennsylvania are brown trout, a species not native to the state. These trout grow larger and are more aggressive than native brppl trout. They have similar food and habitat preferences and thus compete with each other (Cooper, 1983). Brook trout prey capture rates decrease, growth rates decline, and microhabitat locations are often altered when brown trout are introduced (Dewald, 1992). This causes the brown trout to take over dominance of the stream's desirable habitat. For both of these reasons the club ended the practice of stocking in hopes to rebound the populations of both total native trout and native brook trout. They also began a no harvest policy in order to allow the trout to rebound in population. It has been demonstrated that the elimination of stocking in conjunction with no harvest regulations drastically increase trout populations (Carline et al., 1991)

The goals of this project are to determine the affects of both the stream restoration and the cessation of shocking on the trout populations and habitat choice. These are to include Brook Trout, *Salvilinus fontinalis*, and Brown Trout, *Salmo Trutta*. Water chemistry and benthic macro invertebrate populations and densities will also be monitored in order provide feedback to changes in trout populations.

## Methods

Data was collected at four sites along the 3.2-mile stream section, including areas that underwent restoration as well as areas above and below the restoration site. Trout data was also collected at several other sites along the stream for population estimates. In addition, three sites were chosen on Ogdonia Creek, a nearby stream of comparable size and origin to Big Bear Creek, and were monitored for comparison and control. All sites were marked and measured as 200-meter sections. These sampling lengths comply with findings that specify the necessity for at least 150-meter study sites when comparing trout population estimates (Gregory et al., 2003).

Site 2 is just downstream from the end of the Dunwoody Club's pond and begins shortly after the first structure on the stream. Site 2 contains four J-Hook structures and three Cross Vein structures. This site has a well-stabilized riparian zone surrounded by a heavily forested area.

Site 11 is located downstream about 600 meters from Site 2 and begins with the first log structure added in 1999. This structure is still in place and is accompanied by four other Cross Vein structures and two J-Hook structures. This site contains a bridge and was subject to massive riparian disruption because of the bridge and construction road that runs along the stream. The riparian zone has since been replanted but is slow to rebound.

Site 14 is located about 500 meters downstream from Site 11 and is also in a heavily forested area further away from the access road and includes little riparian disruption. This site contains two Cross Veins and four J-Hooks.

Site NDS is at the downstream end of Big Bear Creek where it feeds into Loyalsock Creek. This area was part of the restoration project from 2001. NDS contains two Cross Veins and three J-Hooks and is of importance because the restoration was just recently finished in 2002 at this site. The riparian zone in this section is not well developed.

In addition to these sites, trout population estimates and physiochemical data were collected from site 16 which is located about 100 meters after site 14 and includes two

Cross Veins and one J-Hook, site END which is located at the very end of the original boulder restoration project before the private landowner property begins and contains one Cross Vein and two J-Hooks, site Kirk 1, which is located just before the restoration structures begin again at the route 87 bridge, and site 87 which begins where site Kirk 1 ends at the Route 87 bridge and contains two Cross Veins and two J-Hooks. All site locations can be seen in Figure 7.

Physiochemical data was collected during times when fish and invertebrates were sampled. Water was collected in 500 ml bottles before any other data was collected and stored on ice until it was analyzed. In addition, water temperature in degrees Celsius and dissolved oxygen in parts per million were taken on site using a YSI 55 DO meter and velocity was taken with a Swiffer Model 2100 velocity meter. Stream width in meters and depth in meters per second were also noted at the sites for total flow calculation. Water samples were returned to the lab and tested for pH using a Corning pH meter 440, alkalinity in parts per million using sulfuric acid titration. Conductivity in microsemens per square centimeter and total dissolved solids in parts per million were determined using a Hanna Conductivity/TDS meter. Nitrate and nitrite as well as orthophosphate, and total phosphorous concentrations were determined in parts per million using a Hach DR/4000 spectrophotometer. Physiochemical data was collected in the Summer 2001 and Summer 2002 and compared in order to ensure comparable stream conditions each year.

Benthic macroinvertebrates were sampled in the summer of 2002 at sites for comparison with historical data (Kratzer, 2000). Kick Samples were taken for diversity and similarity analysis. Kick samples were done with a D frame kick net by disturbing an area up to approximately one meter in front of the net and collecting the invertebrates on the net. All invertebrates gathered at each site were preserved in 95 percent ethanol and later identified to genus. These samples were used to calculate the Simpson Diversity, the Shannon Diversity Index and a percent similarity index using the Ecological Analysis Programs Plus computer program published by Oakleaf Systems (Wetzel, 2001). Surber samples were collected using a one square foot surber sampler in order to compute the invertebrate density for the stream segment. A riffle area was selected within each study segment and three separate Surber samples were collected within each. These samples were then preserved in 95 percent ethanol and returned to the lab where they were counted. These numbers were then used to determine the number of benthic macroinvertebrates per meter for each site.

Trout sampling was done using a combination of snorkeling and electro fishing techniques. This was done to the differing aims of this project for both population estimates and microhabitat selection. Electro fishing was used for Brook and Brown Trout population estimates. This was done because when multiple pass samples are taken, a linear regression can be used to accurately calculate total site populations (Wetzel, 2001). Snorkeling was not used for population estimates because smaller fish are often overlooked and it is noted to be less effective in population estimation than electro fishing. Compared with electro fishing, snorkeling estimates are only 40-80% of that of electro fishing (Mullner and Hubert, 1998).

Electro fishing was done using multiple passes at each site with a pulsed-DC Smith-Root Model 15-A backpack Electro fisher using 1000V and 60Hz settings. A crew of approximately four that followed the individual with the electro shocker collected the trout. All trout were anesthetized with clove oil and then counted, weighed, measured and released after all passes were finished. In addition, trout larger than 200 mm were tagged for future migration and growth studies and scales were removed for aging. Population Estimates were made using a three-pass depletion method and analyzed using Microfish Software. These estimates were collected for the Summer 2001 and Summer 2002 and compared to historical data from a previous project by Judd Kratzer (Kratzer, 2000)

Snorkeling was used for microhabitat analysis because unlike during electro fishing, fish are generally not disturbed during snorkeling sampling and thus their microhabitat selection is easily marked (Pert et al, 1997). In addition, since larger fish are easily observed during snorkeling runs, and only trout greater than 149 mm are of interest when examining microhabitat, snorkeling was used for microhabitat analysis. Only trout greater than 149 mm in length are considered dominant trout and are of interest because dominant fish defend the most energetically profitable positions and the most desirable microhabitat (Pert and Erman, 1994).

Snorkeling microhabitat examinations were done at Sites 2, 11, 14 and NDS in the summers of 2002 and 2003. Each site was snorkeled using either two individuals in two straight lines or one sampler in a zigzag pattern. This practice is shown in Figure 8. Each time a trout was noted a fluorescent painted and numbered rock was dropped on the exact spot of observation and the trout's size class, position in water column, species and focal point were noted. Any trout that were disturbed to the point were their exact location could not be determined were not noted and were ignored. After each site was snorkeled, other microhabitat measurements of stream width in meters, depth in centimeters, maximum depth along the transect in centimeters, mean stream velocity in meters per second, maximum stream velocity along the transect in meters per second, stream velocity 0.5m and 1m on either side of the trout in meters per second in order to calculate sheer velocity, focal point velocity in meters per second, distance to nearest structure in meters, dominant substrate type, and another substrate measurement were taken at each marker. Dominant Substrate was visually estimated and classified as: sand (0-2mm), gravel (3-64mm), cobble (65-264mm), and boulder (>264mm). The other substrate measurement was taken using a clear acrylic sheet divided into 25, 5x5 cm squares. The grid was placed over the marker and the number of squares that each rock covered was recorded. The number of squares covered by the rock was the category. This is shown in Figure 10. A substrate index was developed using the formula $I = \Sigma nR^2$. For this formula n is the number of rocks in each category and R is the actual category. For the purpose of this study, average focal point velocity, mean velocity, depth and dominant substrate were averaged for the trout over 149mm at each site and compared to data from literature and also compared to the percent composition of each site that fits into these ranges.

To calculate the percent composition of each site in these categories each site was divided into 15 transects equally spaced apart and stream width, mean depth, maximum depth, and velocity at the deepest point along each transect were measured. In addition, at five equally spaced spots along the width of each transect, mean velocity, bottom velocity, depth and substrate index were recorded as is suggested in Simonson et al. (1994). This practice is shown in Figure 9. In addition to this, Big Bear was walked and segments were categorized by macro habitat category, riffle, run and pool. Each segment was measured for length and width and the entire stream was evaluated for percent riffle, run and pool. This was used in comparison with the makeup of the stream as measured in 1999 prior to restoration. This procedure was replicated on Ogdonia Creek.

## Results

Physiochemical data was collected mostly for comparison across the sites and with historical data in order to rule out chemical influence on trout populations. Table 1 and Table 2 show physiochemical data from June of 2001 and 2002, respectively. Chemical parameters were very similar at sites at both ends of the stream. Total dissolved solids increased as the stream neared the mouth at site NDS. Chemical data remained similar from 2001 to 2002 with the exception of conductivity, orthophosphate, total dissolved solids and dissolved oxygen, all of which increased.

Invertebrates sampled belonged to a wide verity of taxa. Tables 4 and 5 show taxa lists for Big Bear Creek and Ogdonia Creek, respectively. These taxa contributed to the diversity scores of the separate creeks that are shown in Tables 6, 7, and 8. Diversity scores on Big Bear showed little change from 1999 to 2002 and were slightly less than the scores from Ogdonia Creek. Ogdonia Creek had more taxa than did Big Bear. Similarity Indexes calculated from the comparison of Sites 2 and 11 on Big Bear, sites 2 and END on Big Bear and the total of sites 2, 11, and 14 from Big Bear and the total of sites 1,2, and 3 on Ogdonia Creek are presented in Table 9. Sites on Big Bear were shown to be more similar to each other in taxa composition than they were to sites on Ogdonia Creek.

The number of organisms per square meter at each site along Big Bear from 1999, 2002 and 2003 are presented in Table 10 and the same type of data for 2002 and 2003 on Ogdonia Creek is given in Table 11. From 1999 to 2002 sites on Big Bear showed an average increase of 74 percent in macro invertebrate density across the stream. The stream showed only slight fluctuation form 2002 to 2003 and even slight decreases at some sites. This is also seen on Ogdonia from 2002 to 2003. In addition, with the exception of site 3 on Ogdonia, sites on Big Bear showed much higher densities than did sites on Ogdonia in both 2002 and 2003.

Electro fishing population estimates from all sites from 2002 are shown in comparison to historical data in Table 12. The actual populations of Brook Trout and Brown Trout over the past four years are given for Sites 2, 11, and 16 in Figures 11, 12, and 13 respectively. All sites show a general trend of increased trout populations for Brook, Brown and Total Trout on a yearly basis from 1999 to 2002. An increase in total trout of more than 75 at Site 2, 60 at Site 11 and 15 at Site 16 can be seen. This is with the exception of a high number of Brown Trout caught at site 11 in June of 2001. This is possibly due to high conductivity experience during this time and thus causing a higher catch per unit effort, which caused a higher population estimate.

Tables 13 and 14 show the size classes of Brook Trout and Brown Trout observed during snorkeling estimates form 2001 to 2003. This data is also presented to be compared across the stream in Figures 14 and 15 for Brook and Brown Trout respectively. Population estimates were highest at sites 2, 14 and 19, reaching a maximum of nearly 75 trout at Site 2. The Estimates for each size class for Brook, Brown and Total Trout are given for 2001 in Figure 16, for 2002 in Figure 17 and for 2003 in

Figure 18. It can be seen that in 2001 the stream was dominated by Brown Trout in all size classes. By 2002 Brook Trout were able to assume dominance and by the summer of 2003 the numbers of both Brook and Brown trout were stabilized to nearly even numbers for all size classes.

Table 15 shows the preferred microhabitat selection as a mean with standard deviation for depth, mean velocity, and focal point velocity for all fish observed in 2001, 2002, and 2003. It should be noted that all data collected in 2001 was taken from a similar study done by Kirk Patten, a graduate student at Penn State University (Patten, 2001). Trout preferred depths ranging from 0.39 to 0.54 meters, mean velocities from 0.28 to 0.41 meters per second, and focal point velocities from 0.13 to 0.26. Preferred Substrate is also shown here,71.5% were found on cobble bottoms, 27 percent on boulder, 2 percent on gravel and 0.5 percent on sand. This data was only collected in 2002

Stream Microhabitat compositions are given in Figures 19, 20 and 21 for Depths, Mean Velocities and Substrate. In addition, the macro habitat date collected is given in Figure 22 for Big Bear Creek and Figure 23 for Ogdonia Creek. In 1999 Big Bear was 42 percent riffle, 7 percent pool and 51 percent run, with 6 percent underground flow. In, 2002 after remediation, the stream was 62 percent riffle, 15 percent pool and 23 percent run. In comparison, Ogdonia Creek was 49.6 percent riffle, 11.9 percent pool and 38.5 percent run.

## Discussion

As shown in Tables 1 and 2, the majority of the physical and chemical parameters that were monitored on Big Bear Creek stayed relatively constant from 2001 to 2002.

Total dissolved solids increased as the stream continued downstream, reaching a maximum value at site NDS. This could be caused by increased stream velocity created by the Rosgen structures, picking up sediment that had previously been deposited in the center of the stream. The increased velocity would then carry the sediment downstream rather than depositing it. In comparison, the total dissolved solids from 2001 remained more constant and were much lower than the 2002 measurements. This is likely due to the additional structures that were constructed between the summers of 2001 and 2002.

One major chemical parameter that could have had an effect on the trout populations of Big Bear is the low pH values that were recorded in 2002. For Big Bear, no sites recorded pH values higher than 5.5. Although these numbers are high enough to support adult trout populations (Leivestad, 1982), any pH values lower than 6.5 might inhibit the ability of Brook Trout to reproduce and values lower than 5.0 could inhibit Brown Trout reproduction (Peterson et al., 1982). Since Brook Trout seemed to have thrived in this stream in recent years, it appears that pH has not been a major factor in the survival and continuation of trout populations on Big Bear. This is likely due to the fact that over time, some populations of trout can develop a tolerance for lower pH conditions (Peterson et al., 1982). Although pH has not been a problem for this stream, it is a parameter that should be monitored in the future. In addition to pH dropping, dissolved oxygen measurements increased for all sites from 2001 to 2002. This is very profitable for Brook Trout since they require high levels of dissolved oxygen (Cooper, 1983).

Other than these two factors that fluctuated, it is unlikely that any of the other physiochemical parameters that were measured in this study had an affect on trout populations of Big Bear since all values remained within reasonable levels for the survival of both Brook and Brown Trout (Cooper, 1983). In addition, these parameters were consistent with those collected from Ogdonia Creek (Table 3), a similar sized stream that has incurred little disruption.

The actual macro habitat makeup of the stream can have a major affect upon both the invertebrate and trout populations of the stream. As can be seen in Figures 19 and 20, the restoration efforts had a drastic affect upon the macro habitat make up of Big Bear. The stream changed to create a run dominated stream, with a low percentage of pools, to a riffle dominated stream. In addition, the percentage of pools on the stream more than doubled over the 3.2-mile stretch that was restored. It is also important to note that the stream did not run dry in the summers of 2001, 2002 or 2003, in comparison to the summer of 1999, when 6 percent of the stream length went dry and ran underground. These macro habitats that were created can play a major role in the populations of the stream.

Most benthic macroinvertebrates prefer a riffle-dominated area where flow permits much organic material to pass by and where dissolved oxygen levels are highest. In addition, the cobble substrate percentage of the stream was made very high (70.5%) by construction, and cobble bottoms are the preferred form of substrate for benthic macro invertebrate colonization (Wetzel, 2001). This increase in suitable benthic macro invertebrate habitat is a good explanation for the sharp increases in benthic macro invertebrate densities from 1999 to 2002 and 2003 that can be seen in table 10. All invertebrate, trout and macro habitat data from 1999 was collected from research done by Judd Kratzer (Kratzer, 2000). Slight decreases in densities from 2002 to 2003 on Big Bear Creek can also be seen for Ogdonia Creek in Table 11. This data leads to the conclusion that the decrease in densities was not specific to Big Bear and likely caused by environmental factors that affected the entire watershed. Many heavy rainstorms that raised stream levels to near bank full conditions and raised stream velocities plagued the summer of 2003. These high flows could have been responsible for the slight decline in invertebrate densities.

The overall increases in benthic macro invertebrate densities could have a direct affect on trout populations of the stream. Both Brook Trout and Brown Trout feed primarily on macroinvertebrates and thus an increase in density of these invertebrates could promote trout population growth. The increased availability of macroinvertebrates leads to less competition between trout and also between trout species for food.

Species diversity scores for Big Bear Creek remained relatively constant across the stream from 1999 to 2002 as is apparent from Table 6 and 7, and were comparable to scores from Ogdonia Creek in 2002 as shown in Table 8. These comparisons indicate that species diversity of macroinvertebrates likely did not affect trout population changes.

In addition to affecting trout populations as a product of benthic macroinvertebrate composition, macro habitat can also have a direct affect on trout populations. As can be seen in Figures 11, 12 and 13, populations of Brook, Brown and total trout increased at all study sites (sites 2, 11, and 16) from 1999 to 2002. Although construction on the stream caused initial declines in trout populations (Kratzer, 2000), it can be seen that these populations have since rebounded and far surpassed previous populations. One explanation may be that trout prefer the slower and deeper water of pools with cobble substrates that were shown to be produced by the restoration structures (Hayes and Jowett, 1994).

In addition to a rise in populations of both Brook Trout and Brown Trout, an equal portion of the overall trout population is now represented by each of the two species. Figure 16 shows that in 2001 Brown Trout dominated the stream at all size classes. Figure 17 shows that in 2002, a drastic increase in the Brook trout population occurred. This is likely due to an increase in available habitat and thus less competition between Brook and Brown Trout, leading to an increase in Brook Trout populations. Since brook trout are generally the less dominant species, this increased habitat composition allows for less competition and thus population increases. This spike in Brook Trout populations was followed by a rise in Brown Trout populations in 2003 to a point where populations of the two species were relatively equal for all size classes.

Hayes and Jowett (1994) explained that the most important microhabitat parameters monitored are depth, mean velocity, focal point velocity and substrate, because these have been found to be the most important factors in habitat selection by trout. In examining if the micro habitat that was created by this restoration project was the habitat that was utilized by the trout in Big Bear, Table 15 shows that preferred depths between 0.35 and 0.54 meters, mean velocities between 0.28 and 0.41 meters per second, and focal point velocities between 0.13 and 0.26 meters per second. In addition, the trout were also shown to favor cobble substrates. The difference in preferred mean velocities and focal point velocities is because dominant trout are drift feeders and prefer to stay in the lower velocity and more energetically profitable areas, but choose to be below higher mean velocities, which they monitor for feeding. The numbers of these parameters collected for Big Bear Creek are within the ranges of preferred microhabitat found in previous studies. The numbers for preferred depth were slightly lower in this study (0.39-0.54 meters) than were found in previous studies(0.67-0.86 meters) but still trout showed a preference for some of the deepest water available (Hayes and Jowett, 1994). All data collected for trout populations and microhabitat selection at site NDS was omitted due to faulty structures that are currently not functioning properly.

Sites on Big Bear Creek were shown to have around 16 percent of depths in the range found to be preferred, nearly 25 percent of mean velocities in preferred range, and over 70 percent of substrates in the preferred cobble classification (Figures 18, 19 and 20). These percentages of available microhabitat show a good proportion of the stream to be desirable habitat for dominant trout, and thus competition for this preferred habitat can be minimized.

It appears that the increased benthic macroinvertebrate densities, and increased preferred macro and micro habitat have both led to a decrease in competition between both individual trout and trout species, and have led to a rise in overall trout populations and allowed equilibration in the number of Brook Trout and Brown Trout on Big Bear Creek. Since these were two major goals of the restoration project, it is apparent that the project was a reasonable success. This agrees with the success of similar project applying Rosgen techniques in the western United States (Monde, 1998). This study shows the relative success of such restoration for the first time on the east coast and provides support for further restoration of other eastern streams experiencing sediment pollution.

These restoration projects and their effects are of importance to fisheries considerations and water management since the in-stream needs of these trout species are of prominent importance in water management decisions.

In completing this study, the need for further monitoring in several areas was seen. Invertebrate and trout populations need to be monitored in the future to examine if populations have actually leveled off or if they will continue to change with time. An examination of sites with non functional structures could also be done to see if these sites revert to lower populations as were seen before restoration. A continuation of the microhabitat project would also be beneficial to examine the other parameters that were monitored. The macro and microhabitat of the stream should be quantified again in the next few years in hopes to show stabilization in both parameters. The Big Bear Creek project will continue to be monitored for at least one more year in order to provide more complete conclusions about the effectiveness of the restoration project.

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**Figure 1: Location of Big Bear Creek**

# Big Bend Watershed

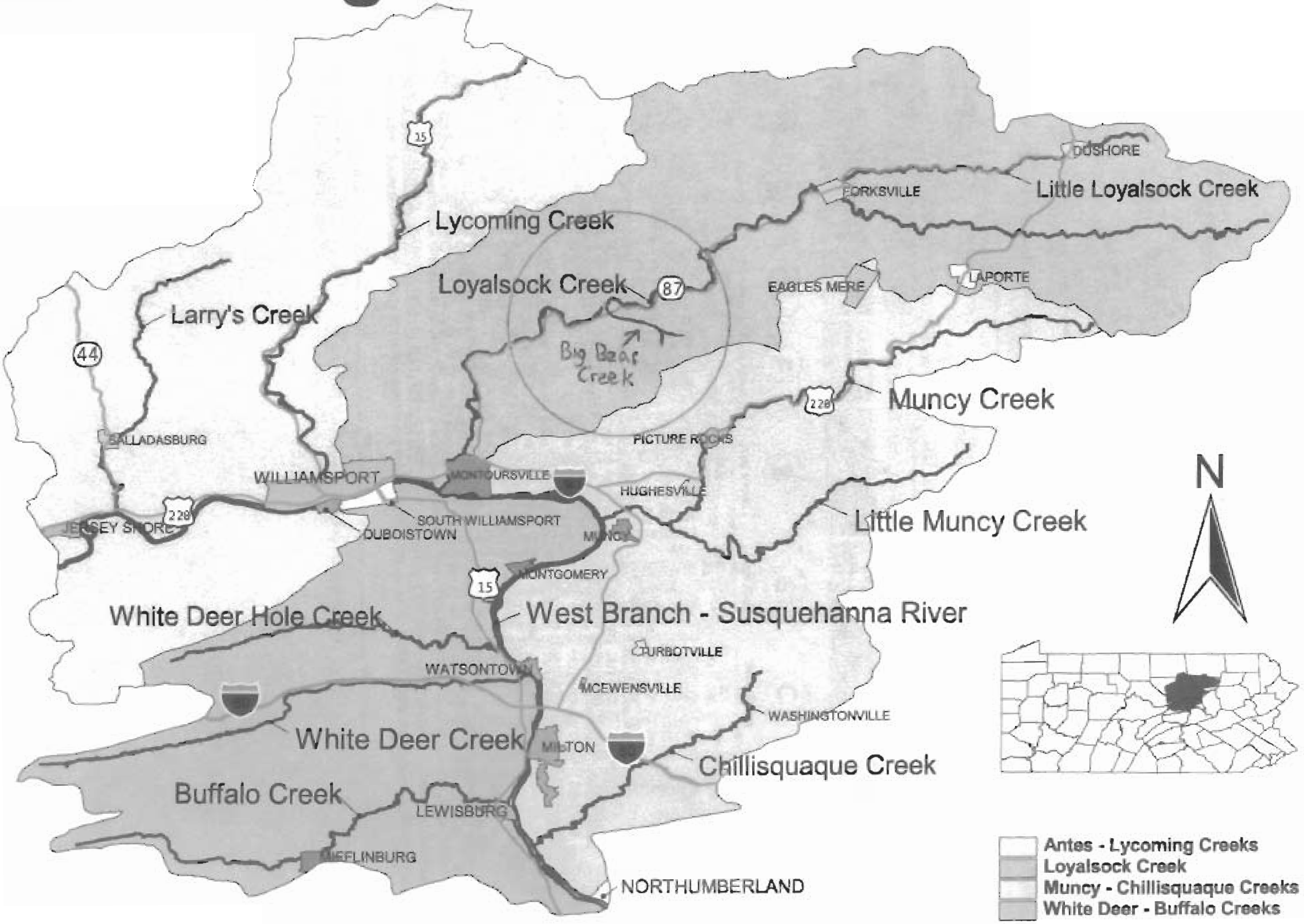
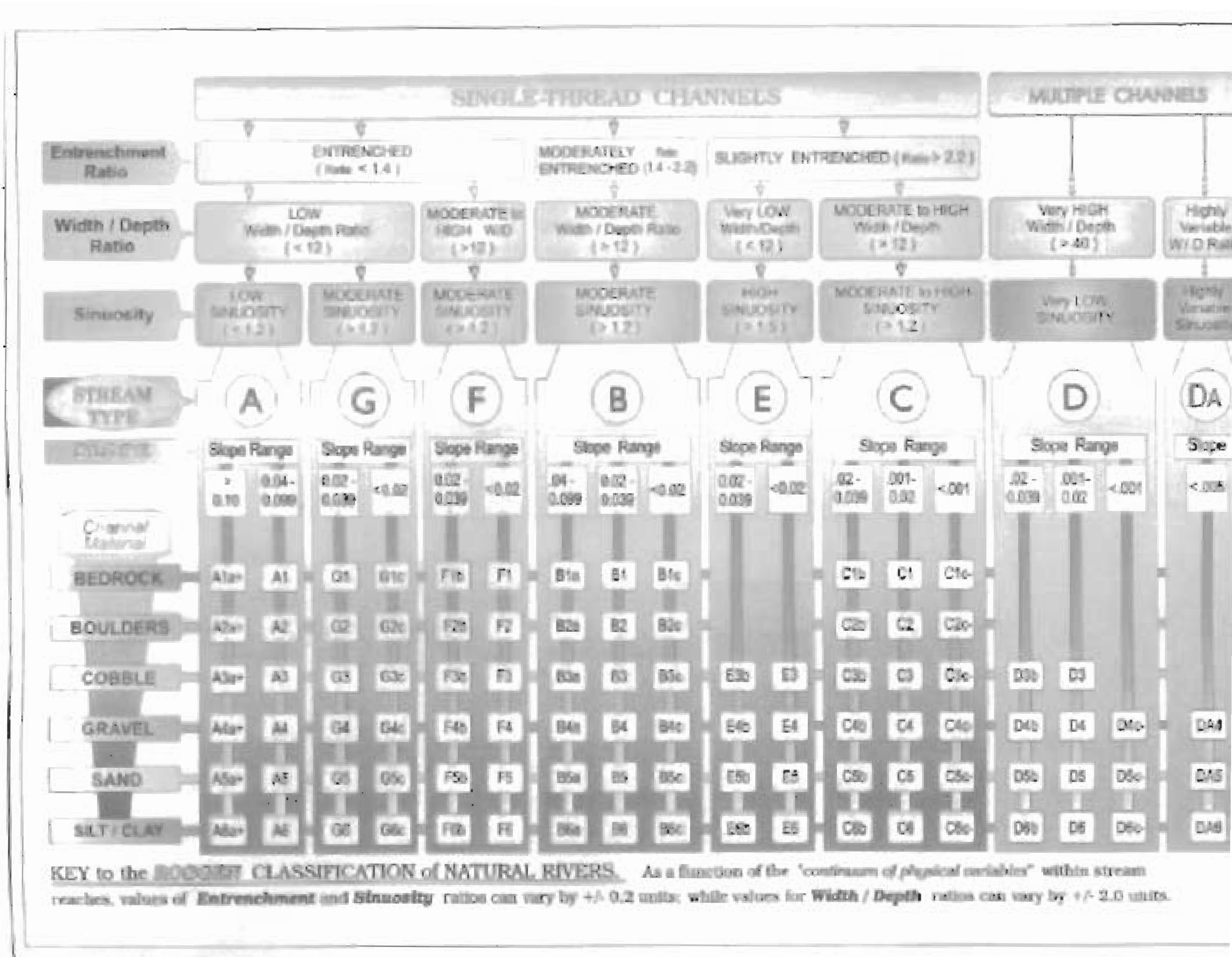


**Figure 2: List of Parameters for Rosgen Classification ( Table fromRosgen, 1994)**

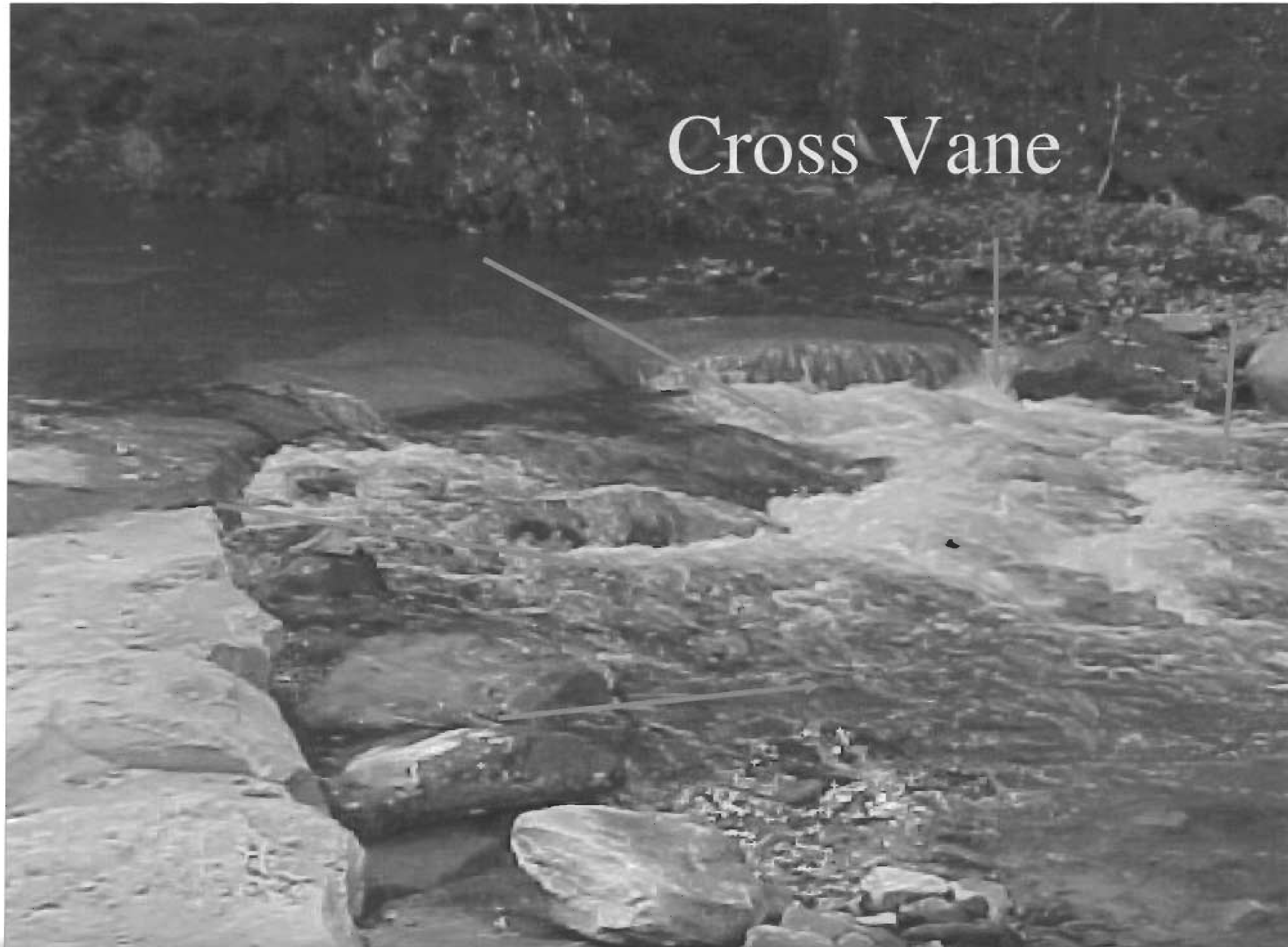


KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the "continuum of physical variables" within stream reaches, values of **Entrenchment** and **Sinuosity** ratios can vary by +/- 0.2 units; while values for **Width / Depth** ratios can vary by +/- 2.0 units.

FIGURE 5-3. Classification key for natural rivers.

Figure 3  Cross Vein Structure at Bankfull Conditions

Figure 4  Cross Vein Structure Under Normal Flow


Cross Vane