CHANNEL DEVELOPMENT ON UNRECLAIMED SURFACE MINES IN THE BEAVER CREEK WATERSHED, TUCKER COUNTY, WEST VIRGINIA[1]

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Abstract: Mining in the early to mid 1900's has degraded streams within the Beaver Creek watershed in Tucker County, West Virginia. Channels have incised to bedrock and banks suffer from severe erosion. The sediment supply surpasses the stream's transport capacity, which has resulted in channel alterations. In a preliminary study, the headwater regions of two streams within the Beaver Creek watershed were assessed geomorphologically to define similarities in channel development on disturbed mine soils. These streams were composed of primarily aggradading sections and fewer degradating sections. Channel gradient and width were the primary factors used to separate the stream into distinct geomorphic units. Channel morphologies did not correlate consistently with the Rosgen Stream Classification System. Preliminary results indicate refinements to this system are needed to delineate streams on disturbed lands. Further research that quantifies and describes primary channel alterations that have developed since mining, may reveal the natural responses these streams are taking to reestablish equilibrium. Continued work on these streams may provide further information on how streams respond to comparable alterations.

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Introduction

Stream channels are developed, sustained, and altered by the water and sediment they transfer. The drainage basin is associated with hill slope processes that contribute water and sediment to the channel in accordance with regional climate, underlying bedrock, and land use by humans. Stream channels evolve to establish an equilibrium or stable state. A stream must be capable of consistently transporting its sediment load to remain stable. Fluvial networks counteract changes in sediment load and discharge by adjusting basin morphology to maintain equilibrium.

Surface mining activities have generated lasting alterations to the hydrologic conditions, ecological structure and functions of streams. Geology and stratigraphy of a drainage basin have the greatest effect upon stream drainage patterns and longitudinal profiles (Biedenharn, 1997). Consolidated geologic layers formally controlling topography and stream channel morphology are no longer present after surface mining occurs. Consequently, streams will not return to pre-mining conditions, but will rapidly adjust their morphologies to attain a new equilibrium compatible with conditions imposed by surface mining and reclamation (Tousinhthiphonexay and Gardner, 1984).

Two streams within the beaver creek watershed of Tucker County, West Virginia have been significantly impacted by surface mining that occurred in the 1960's. These adjacent streams are located on the south-east side of Rt. 93 just north of Davis West Virginia. Dominant vegetation surrounding the streams include white pines, red pines, autumn olive, and grasses. Channel morphology has been adjusting in attempts to regain equilibrium for the past 30 to 40 years. The streams have incised significantly creating, in some locations, steep banks reaching as high as 30 feet. Generally, these banks are sparsely vegetated and highly erosive.

The streams are primarily aggradating. Aggradation occurs when sediment supply is greater than the streams transport capacity. Channel width increases due to an increase in surface or subsurface fines. Aggradation increases channel width-depth ratio, sediment storage, bank erosion rates, loss of riparian vegetation and associated sediment availability from bank erosion, and overbank flooding with less than bankfull-flow magnitudes and decreases pool quality (Rosgen, 1996).

The streams are also comprised of fewer degradating sections. Degradation occurs when the sediment supply is less than the streams transport capacity. Degradation may cause erosion of channel beds and banks, channel incision, and removal of gravel or fines (armoring). Some channel adjustments associated to degradation include; oversteepening of the main stem and tributaries, acceleration of bank erosion, increased sediment supply and transport, floodplain abandonment resulting in the creation of new terraces, changes in vegetation and steepening of the water surface slope (Rosgen, 1996).

The objective of this study is to evaluate similar channel reaches and compare stream characteristics to stream types within the Rosgen Classification System. A channel reach is a stretch of stream, approximately 20 to 30 channel widths, comprised of similar channel materials. Reach morphologies are related to physical processes and environments that reduce the variety and quantity of possible channel responses to alterations in hydraulic discharge and sediment supply (Montgomery and Buffingham, 1997). Reach response potential is also influenced by external sources, such as channel confinement, vegetation, and large woody debris. Affects of isolated and cumulative disturbances on a specific reach depend on the reach position within the watershed and the succession of reach types upstream. Differences in reach morphology and physical processes produce different potential responses to similar alterations in discharge or sediment supply (Montgomery and Buffingham, 1997). Consequently, evaluating channel reaches may assist in determining channel disturbance and help predict how the channel will respond to future disturbances.

Methods

Two Beaver Creek Tributaries, Slaty Fork and an unnamed tributary, were drawn to scale in early August of 2003. Channel morphology including channel materials, bedforms, cut banks, channel width, bank height and degree of vegetation were all recorded. The same two streams were surveyed in late October of 2003. Longitudinal profiles in combination with stream sketches were the preliminary tools used to assess channel conditions and to establish stream segments with similar characteristics. Stream sketches were correlated to the longitudinal profile and used to assess channel width and present channel conditions. Conditions such as aggradation and degradation were determined from the sketches. Aggradating sections were determined through observation and were composed of fine and coarse materials, cobbles, and few boulders. These sections had a significant amount of sediment covering the channel bottom.

Degradating sections were determined through observation. The dominant, if not only, channel material present in degradating sections was soft shale bedrock. Sketches were used to establish sections when channel characteristics changed even though gradient was consistent. Degree of incision of each section was determined from stream sketches, while segment length was established using surveying data. Gradient, width, and present channel conditions were the primary factors considered when determining channel sections. Characteristics of channel sections were analyzed and compared to characteristics of stream types designated by Rosgen (1996). Bedforms, gradient, and physical processes were assessed to determine similarities.

Results and Discussion

The longitudinal profile and stream sketches correlated relatively consistently. Stream gradient proved to be the primary determinant when establishing sections, while sketches provided additional information on channel characteristics.

Stream One, the unnamed tributary, was divided into four sections according to channel gradient, width, and present channel conditions (Table 1). The entire stream section is steep, deeply entrenched and confined, and incised in heterogeneous minesoils. The channel is predominantly aggrading, however, there are actively degrading sections. Channel morphology is composed of irregularly spaced, structurally controlled bedrock steps and intermittent gravel bars. Some aggrading sections resemble a braided channel. Channel bed and banks are extremely unstable and highly erosive. The stream has a high sediment supply and a transport capacity that is incapable of transferring the significant amount of sediment. Transport capacity is further impeded by two culverts. Consequently, sediment has accumulated upstream of culverts, while the channel width immediately downstream has significantly decreased.

The longitudinal profile of Stream One reveals the four designated sections (Fig 1). Knickpoints are present at distances of 857 feet, 1314 feet, and 1704 feet from the initial point. A knickpoint is a short, oversteepened segment of the longitudinal profile indicating that channel gradient is actively re-adjusting (Ritter et al., 2002). Knickpoints were used in this study as initial indicators of changes in channel slope. The knickpoint present at 857 feet is the result of a road, which the stream flows over. At the knickpoint located at 1314 feet, the channel is in a transitional stage between aggrading section 2b and primarily degrading section 3a. Section 2b

Table 1. Sections established for Stream One.

Stream Section	Channel Description	Slope (%)	Length (ft)	Channel Width (ft)	Incision
1	Aggradating	8.3	792	10	moderate
2a	Aggradating	4.7	201	4	extreme
2b	Aggradating	3.2	206	10 to 20	moderate
3a	Primarily Degradating	8.6	151	10	slight
3b	Primarily Degradating	3.8	152	10	moderate
3c	Degradating	7.3	115	5 to 10	extreme
4a	Aggradating	5.3	195	15	None
4b	Primarily Degradating	5.3	118	7 to 10	slight
Total Stream Length	**Aggradating and Degradating**	**6.5**	**1930**	**4 to 20**	**moderate**

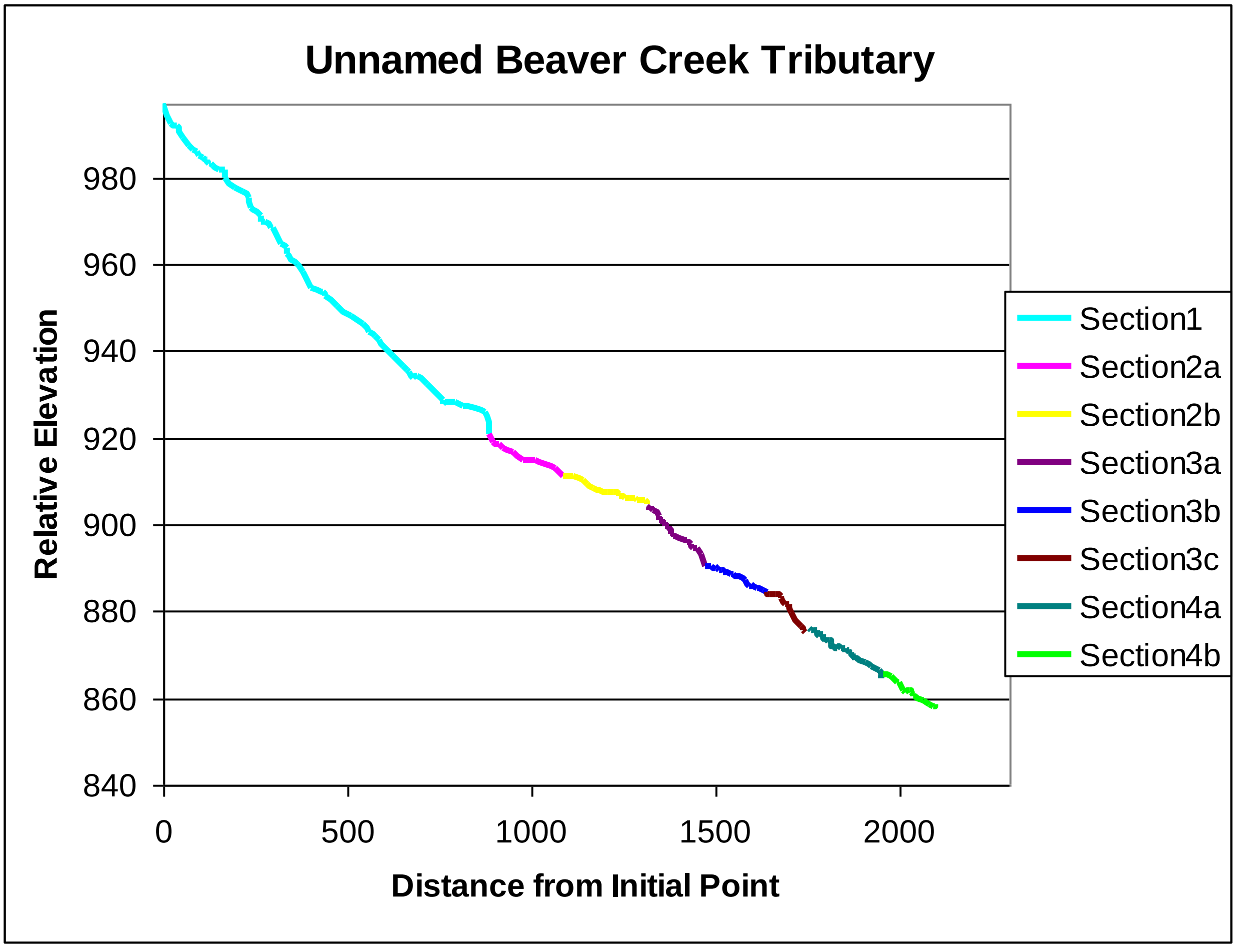

Figure 1. Longitudinal Profile of Stream 1, The Unnamed Tributary.

resembles a braided channel, has a 3.2 % slope, and a typical channel width of 20 feet. Section 3a has an 8.6 % slope, a typical channel width of nine feet, and soft bedrock is the dominant channel material. The knickpoint present at 1704 feet is located between primarily degrading section 3b and degrading section 3c. Section 3b has a typical channel width of 10 feet, a 3.8 % slope, and channel materials consisting primarily of soft bedrock with a small degree of fine to large sediment. Section 3c has a 7.3 % slope, a typical channel width of 10 feet, soft bedrock as the dominant channel material, and severely cut banks.

Stream Two, Slaty Fork, was divided into six sections according to channel gradient, width, and present channel conditions (Table 2). The entire stream section is moderately steep, deeply entrenched and confined, and incised in heterogeneous minesoils. Although the slope is moderately steep, the channel is predominantly aggradating. Extremely unstable and highly erosive channel bed and banks may be the primary reason for the stream's aggradating state. Stream section 1 is surrounded by minesoil banks as high as 30 feet, is aggradating, and has a 7% slope (Fig. 2). Some aggradating sections resemble a braided channel. There are fewer actively degrading sections. Section 6 represents a degradating section with soft bedrock as the dominant channel material (Fig 3). The stream has a high sediment supply and a transport capacity that is incapable of transferring the significant amount of sediment. The transport capacity is further impeded by one culvert. A large amount of sediment has accumulated upstream of this culvert. Channel morphology is composed of irregularly spaced, structurally controlled bedrock steps and intermittent gravel bars.

Table 2: Sections established for Stream Two, Slaty Fork.

Stream Section	Channel Description	Slope (%)	Length (ft)	Channel Width (ft)	Incision
1	Aggradating	6.8	400	5 to 20	extreme
2	Primarily Degradating	5.5	313	5	extreme
3a	Primarily Aggradating	4.4	342	15	moderate
3b	Aggradating	3.3	413	10 to 25	slight
4	Primarily Degradating	4.3	73	10	extreme
5	Aggradating	2.9	264	10 to 20	extreme
6	Degradating	7.1	216	10 to 20	moderate
Total Stream Length	**Aggradating and Degradating**	**4.9**	**2021**	**5 to 25**	**extreme**

Figure 2. Section 1 of Slaty Fork: Aggradating section with 7% slope.

Figure 3. Section 6: Degradating section of Slaty Fork.

The longitudinal profile of Slaty Fork reveals the six designated sections (Fig 2). Due to a surveying error there is a sharp increase in slope, noted by the red area of the profile in section 3b. To decrease error, the red area was omitted when calculating gradient of section 3b. The knickpoint located at 1440 feet, is due to the surveying error. The knickpoint present at 1900 feet from the initial point, indicates that channel gradient is actively re-adjusting. The knickpoint is located between aggradading section 5 and degrading section 6. Section 5 resembles a braided channel, has a 2.9% slope, and a typical channel width of 15 feet (Fig 4). Section 6 has a 7.1% slope and a typical channel width of 15 feet.

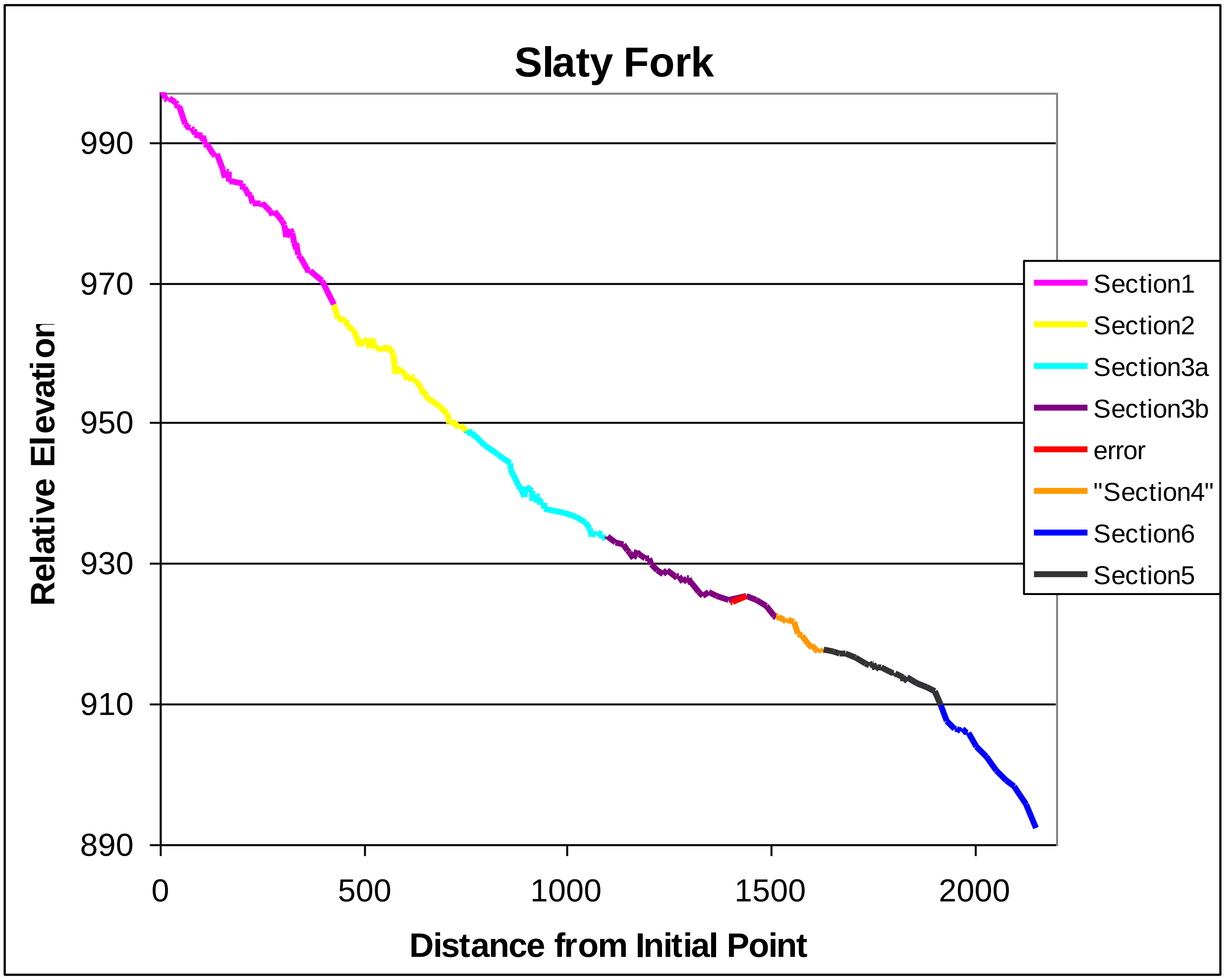

Figure 2: Longitudinal Profile of Stream 2, Slaty Fork

Figure 4. Aggrading section 5 of Slaty Fork.

Similar sections between the two disturbed streams were determined by comparing present channel conditions, gradient, and channel width. Streams from the Rosgen Classification System (Rosgen, 1996) were analyzed and stream types with characteristics similar to the disturbed streams were chosen (Table 3).

Similar sections among the disturbed streams were compared to stream types designated by Rosgen (Table 4). Sections were correlated by gradient, degree of incision, and bed materials. Rosgen's D-type streams are described as braided streams that receive a high sediment supply and are not entrenched. Rosgen's A and G-type streams are generally the same except for channel gradient. A-type streams occur on much steeper slopes (4% to 10%), while G-type streams occur on gentler gradients (< 4%). Stream types G1 and A1 are the only streams that are underlain by bedrock however they both have a low sediment supply and are considered stable. The remaining A and G stream types all have high sediment supply, however they are not underlain by bedrock. Consequently, it was difficult to characterize degrading sections present in the two disturbed tributaries of Beaver Creek.

Table 3: Characteristics of Rosgen stream types.

Stream Type	Slope (%)†	Morphology	Sediment Supply	Entrenchment	Channel Materials	Stability
A1	4 to10r	Falls and irregularly Paced step-pools	Low	Incised Ratio: < 1.4	Bedrock with some cobble, gravel, and boulders.	Stable
A3	8.4a 4 to 10r	Cascading or step pools	High	Very Incised Ratio: < 1.4	Cobble with some small boulders, gravel and sand	Unstable
A4	5.7a 4 to 10r	Cascading or step pools	High	Deeply Incised Ratio: < 1.4	Gravel with some boulders, cobble and sand	Unstable
A5	4 to10r	Actively degrading channel	High	Entrenched Ratio: < 1.4	Sand with some gravel, silt, and clay	Unstable
G1	< 4r	Step-pool with low sediment storage	Low	Deeply Incised Ratio: < 1.4	Bedrock with some cobble, gravel, and boulders	Very Stable
G3	2.5a < 4r	Step-pool	High	Deeply Incised Ratio: < 1.4	Cobble with a mixture of gravel and sand	Very Unstable
G4	2.2a < 4r	Step-pool	High	Deeply incised Ratio: < 1.4	Gravel with some sand and cobble	Very Unstable
D3	< 2a 2 to 4r	Multiple channel system, braided	Very High	Not Incised Ratio: NA	Cobble with strong bimodal sand distribution, actively eroding	Unstable
D4	< 2a 2 to 4r	Braided, close series of rapids and scour pools	Very High	Not Incised Ratio: NA	Gravel with strong bimodal sand distribution, actively eroding	Very Unstable

† Values are followed with (r) or (a) indicating range or average, respectively.

Table 4: Correspondence of Similar Disturbed Stream Sections with Rosgen Stream Types.

Similar Sections of Stream One	Similar Sections of Stream Two	Corresponding Stream Type
1	1	A3, A4
2a	NA	A4, A5, G4
2b	3a and 5	A5, G3, G4
3a and 3c	6	A1, A3
4a	3b	D3, D4
4b and 3b	2 and 4	A1, A4, G1

Conclusions

Stream gradient was an efficient tool for the preliminary evaluation of the two Beaver Creek tributaries. The two streams appeared to be very similar, having similar gradients, widths, and present channel conditions. Comparable sections between the two disturbed streams were established. Correspondence between sections of disturbed streams to stream type designated by

Rosgen was difficult. Characteristics of sections of disturbed streams did not correlate consistently with stream types designated by Rosgen. Some sections were entrenched in bedrock and had an extremely high sediment supply. Rosgen stream types G1 and A1 are incised in bedrock but both are associated with low sediment supply. The degrading sections of the disturbed streams are underlain by bedrock, have similar channel gradients, but are associated with very high sediment supply. Consequently, the designated sections of the disturbed streams do not correspond efficiently to the Rosgen Classification System. Preliminary results from the study indicate that further refinements are needed in the Rosgen Classification System to identify and describe streams on disturbed sites. Additional research is necessary to characterize sites where streams are underlain by bedrock and have a high sediment supply.

More information is needed to define similarities in channel development of these two streams. A more detailed geomorphic assessment is essential to determine information on the responses of stream channels to disturbance. Future work involves longitudinal and cross sectional surveying of the designated sections. Impending work consists of determining dominant channel materials, sinuosity, soil sampling and analysis, and stream power calculations. By quantifying and describing primary channel alterations that have developed since mining, data may reveal the natural responses these two streams are taking to reestablish equilibrium. Continued work on these streams may provide further information on how streams react to comparable alterations.

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