Abandoned Mine Land Restoration in a North Idaho Stream: A Geomorphological Perspective

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Abstract

Pine Creek (drainage area 80 mi^2), a tributary to the South Fork Coeur D'Alene River, was heavily impacted by metals mining in the 20^{th} century. By 1960, more than 156,000 ft of mine tunnels had been excavated. In excess of 260,000 yd^3 of rock waste had been dumped, much of which made its way into the East Fork of Pine Creek. The increased sediment load destabilized the stream and resulted in more than a 50% widening of the channel of the East Fork of Pine Creek since 1933. Consequent erosion of stream banks of metals-laden tailings in the floodplain contaminated Pine Creek.

Following large-scale flooding in 1996, the Coeur d'Alene Field Office of the Bureau of Land Management (BLM), Idaho and partners undertook efforts to accelerate mined-land reclamation and floodplain stabilization on affected public lands, including Pine Creek. Project work, originally enabled through emergency flood funds, has since been supplemented with funding from the Department of Interior's Central Hazardous Materials Fund and BLM's Abandoned Mine Land (AML) program.

Using sequential historical aerial photos that dated from 1933 to present, a reconnaissance-level geomorphic assessment of sediment sources, channel-morphology trends, and riparian vegetation provided a basis for selecting restoration strategies. Additional field investigations were used to develop site-specific recommendations for channel and floodplain restoration, including: stabilization of waste-rock piles, tailings removals, bank armoring, floodplain revegetation, and channel realignment. Possible applications at other AML sites are suggested.

Substantial coordination with EPA, the State of Idaho, and the local county public works department was helpful on a variety of issues. Though the Pine Creek Restoration Project is ongoing, approximately 80 percent of the priority waste-rock piles have been stabilized through a combination of grading, armoring, or channel realignment.

Introduction and Background

In the Pine Creek watershed, extensive mining and milling activities and timber harvesting have dramatically impacted the fluvial geomorphic cycle. Pine Creek, a tributary to the South Fork Coeur d'Alene River, was heavily impacted by metals mining in the 20th century.

The Bureau of Land Management (BLM) is committed to restoration of public lands that have been impacted by environmental and physical hazards that affect water quality and public health and safety. As part of this effort, BLM and its partners are investigating and cleaning up priority abandoned and inactive mine sites.

Purpose and Scope

Mine waste removal and stabilization actions are key to removing heavy metal inputs from watersheds (see Fortier and Moore, 2002, in this volume). Once the mine waste has been managed, returning the stream to a stable condition pre-mining condition can be approached. This paper focuses on stream-stabilization efforts that have been pursued in the Pine Creek watershed. The methodology of this restoration effort has been based on concepts and recommendations developed in field observations and geomorphic research of (Kondolf and Matthews, 1996; Matthews, 1996; and Kondolf and others, 2000, 2002).

BLM has been involved with investigations, mine-waste removal and stabilization, and stream restoration efforts on most of these mines during the past few years. In the Pine Creek watershed, more than 156,000 ft of underground mine workings had been excavated by 1960, (Kondolf and others, 2002). Based on the extent of underground mine development, in excess of 260,000 yd^3 of rock waste was generated and deposited in streamside waste dumps. Much of this waste made its way into the East Fork of Pine Creek and has adversely affected the stream functionality.

The bulk of the mine waste was generated during the period of 1941-1952, coinciding with wartime metals needs for lead and zinc. Most of the mine waste rock from and flotation mill tailings were deposited in along the floodplains of Pine Creek, East Fork and their tributaries making the sediment easily accessible to erosion and transport. Large volumes of mine waste was input into the drainages particularly during the numerous flood events of from 1917 – 1996 (Matthews and Kondolf , 1996).

The Pine Creek watershed includes a mountainous area of approximately 80 mi^2 that drains northward through the town of Pinehurst into the south Fork of the Coeur d' Alene River. Elevations range from approximately 2,200 to 6,400 ft in this watershed that has very little flat land, with the exception of the alluvial valley bottomlands along the East and West Forks of Pine Creek. Pine Creek has a West Fork and an East Fork, which merge 6 miles upstream from Pinehurst. Bedload in Pine Creek streambeds is dominated by coarse material consisting of resistant, coarse quartzite cobbles and boulders. Due to the nature of the source materials, an organic component is largely absent from the stream sediments.
Several major events have influenced the fluvial geomorphic processes in the watershed (Kondolf and Matthews, 1996). Near the turn of the century, large cedars from the valley floors were extensively harvested. In 1910, the Coeur d' Alene Basin fire of 1910 burned the East Fork drainage down to the channel. From the 1920's to the 1950s, the ridgetops were extensively

grazed. From the 1950s to the present, steep slopes of the West Fork have been logged. During the early part of the century, intensive mining has affected much of the watershed resulting in a large input of tailings and waste rock into the East Fork and its tributaries. Channelization has also occurred in the lower 2.3 miles of the West Fork.

Several major floods have occurred in the Pine Creek watershed during the 20th century, the most recent in 2002. Prior to that extensive flooding occurred in 1996, resulting in significant channel modification and erosion. Because of all these influential events, the channel morphology and functionality has been severely impacted in the 20th century.

Analysis of Sediment Sources and Channel Morphology

Kondolf and Matthews (1996) provided a reconnaissance-level investigation that has revealed insights on changes in channel morphology that resulted from increased input of sediment from mine wastes in the watershed. Matthews and Kondolf (1996) found that the removal of the mature bottomland cedar forest in combination with increased sediment loads, allowed a geomorphic threshold to be crossed during moderate to large flood events (in 1917, 1933, 1938, 1964, 1974, and 1996). This led to destabilization of alluvial valley floors. Particularly in the East Fork, the mining activities resulted in increased sediment loads that accelerated the evolution from a stable, narrow, sinuous channel form to an unstable, wide, braided, and shifting channel. Similar changes in channel form have not been noted in unmined reaches of the West Fork of Pine Creek.

Field Observations of Sediment Sources, Sediment Delivery, and Channel Destabilization

Many of the existing sediment sources in the East Fork watershed were obvious from field inspection, where large rock waste piles were visibly contributing coarse sediment to the channels. Effects of the 1996 flood were compared on two tributaries, Douglas Creek and Highland Creek. They are comparable in drainage area (6.3 vs. 5.0 square miles), relief, basin aspect, and fire history, but they differ in two respects: the presence of sediment storage sites in downstream reaches of Douglas Creek and in mining history. The Douglas Creek basin has not been subject to extensive mining or road construction, while the Highland Creek basin has been heavily mined, involving removal of vegetation, construction of roads and industrial development, and most importantly, discharge of waste rock into the channel. Thus, Douglas Creek illustrates the sediment transport regime likely prevailing in Highland Creek prior to mining and the resultant increased sediment yield, although with a lower reach in which deposition is more likely before reaching the East Fork channel.

Field observations indicate that during the 1996 floods, with an estimated return period of 100 years, the upper reaches of Douglas Creek were actively transporting bedload and reworking channel deposits. The channel remained narrow and stable, with fresh sediment deposits only in protected sites behind obstructions, low gradient reaches above controls, and spread out on wooded floodplains (Kondolf and Matthews, 1996).

In contrast to Douglas Creek, the active open channel of Highland Creek occupies most of the canyon bottom. The width of freshly deposited sediment varies, but is commonly 40- to 80- feet wide. Cedar stumps were buried under aggraded sediment (typically about 2-feet thick) along the length of the Highland Creek channel downstream of the mines. The fresh deposits included a large fraction of dark Prichard Formation lithologies, implying that much of this sediment was derived from mine rock waste dumps. In contrast, the channel upstream of the Highland Surprise Mine is narrow (typically 10-15-feet wide), with a continuous, dense riparian corridor along the bank, similar to the channel of Douglas Creek.

The channel morphology and evidence of aggradation downstream of the mines indicates a greatly increased sediment load in Highland Creek. This increased load has overwhelmed the sediment storage capacity of the valley bottom, and is being transported through the reach to the mainstem of the East Fork, forming an alluvial fan at the confluence. Significant aggradation, lateral migration, and fan building were again evident in April 2002, following a moderate flood with an estimated return period of 10-15 years.

Mine wastes have obviously played a key role in increasing bedload and destabilizing channels and bottomland deposits. However, the coarse sediments in the bed of Pine Creek consist primarily of white quartzite while the mine rock wastes are composed principally of the predominately dark-gray- to black-laminated argillites. The overwhelming dominance of white quartzite in the bed material of the East Fork implies that despite large inputs of rock wastes near the point sources, these wastes do not constitute a large fraction of the sediment in the East Fork.

It is hypothesized that mine-derived sediment served to destabilize the channel, and that much of the sediment transported downstream was simply reworked from pre-existing bottomland deposits. This suggests that progressive destabilization of the channel does not reflect the downstream propagation of a wave of coarse sediment, but rather propagation of channel instability, such that most of the sediment visible at one point in the channel is probably derived from erosion of bottomland deposits a short distance upstream (Matthews and Kondolf, 1996). Another supporting observation is that relict cedar stumps, where present, are not buried by sediment as might be expected in the event of massive aggradation. In addition, photo analysis indicates that the increase in area of exposed, unvegetated, active channel did not progress downstream from the point sources of mine-derived sediment. Instead, the downstream reach of Highland Creek began to destabilize first, and the destabilization propagated upstream.

Restoration Project Development

As previously noted, the first step in the development of conceptual restoration designs for Pine Creek was a reconnaissance-level investigation of sediment sources and geomorphic history. This investigation was conducted soon after the flood of 1996 and the subsequent report (Kondolf and Matthews, 1996) was used by BLM as first step in defining several flood-related issues: problem assessment; restoration feasibility; and additional informational needs. The second step was to have aerial photography flown for the entire Pine Creek watershed. The stream corridor photos were enlarged to a scale of 1 inch= 100 feet. Mylar overlays were also generated at the enlarged scale and used to produce blue-line prints for field use and design.

With the aid of the post-flood stereoscopic photos, enlargements and blue-line prints, an additional field investigation was conducted. Resulting from that investigation, a more detailed report outlining conceptual designs for stream restoration projects was produced for BLM (Matthews, 1996). This report includes conceptual design guidance for use in the planning and design of projects within the Pine Creek system. Additional site-specific investigation by BLM, including analysis of longitudinal profiles, cross-sections, channel hydraulics, and pebble counts were used to develop specific design and construction drawings.

Overview of Conceptual Design Framework

The design framework is based on two primary strategies: (1) the control of sediment sources; and (2) in-place stabilization of sediment deposits by channel restoration and re-establishment of the riparian forest. The recommendation to stabilize sediment in place was based upon the hypothesis that a geomorphic threshold was exceeded in the East Fork first, then was followed by the West Fork. This was a result of decreased bank and floodplain stability resulting from loss of the floodplain forest, and increased loads and a number of large-flow events in the last fifty years. The potentially long wait necessary for flushing the sediment, as well as the potential impairment of flood control infrastructure downstream in Pinehurst are both arguments for stabilizing deposits in place upstream. The design framework from Matthews (1996) incorporates the following concepts:

1. Relocate the channel away from active hill-slope failures that are sediment sources.
2. Create a more meandering channel.
3. Implement actions to train stream towards a single-thread channel.
4. Minimize channel grading by identifying areas with acceptable geometry.
5. Minimize efforts to adjust longitudinal profile.
6. Identify and incorporate existing stable floodplain surfaces.
7. Incorporate bedrock outcrops as locations for channel bends.
8. Stabilize bends with bio-technical log/root-wad/boulder structures.
9. Consider risks to existing development.
10. Revegetate channel toes and slopes.
11. Revegetate floodplain surfaces.

Preliminary Results and Lessons Learned

Long-term monitoring is the only way to qualitatively determine changes in stream trends. BLM is monitoring the effects of restoration efforts using numerous reference cross sections, sampling sites, and photo points. After three field seasons, roughly 90% of the streamside rock dumps and tailings piles have been treated. This has involved a range of treatments including: regrading and toe armoring of steep waste rock piles in narrow tributaries; relocating the channel away from two rock dumps, one tailings pile, and three active hill-slope failures; and physical removal of tailings at five sites.

<u>Treatment of Sediment Sources</u>

1. Based on visual inspection and cross-section analysis, reduction of sediment loading from rock-pile stabilization appears to be successful, though additional toe stabilization is still needed at the steepest rock piles. This work is scheduled to be implemented this fall.

2. In the three cases where the channel has been moved away from sediment sources, two appear to be vertically and laterally stable. The other site, on lower Highland Creek is

vertically stable, but will require additional bank stabilization due to lateral migration caused by the high sediment load upstream. The channel design width appears to be too narrow to accommodate the sediment load.

3. Following physical removal of floodplain tailings deposits, several of the sites have been regraded, covered with topsoil, and revegetated with grasses and willows. Vegetative success has been promising, particularly following the second year after planting.

Channel and Floodplain Restoration

During moderate to large floods, Pine Creek, particularly the East Fork, has repeatedly washed away hundreds of feet of paved county road, plugged or washed away undersized culverts, and scoured around bridges. BLM has replaced three major culverts and stabilized the adjacent channels upstream. Following a 2002 flood event with a 15-year return period, the culverts performed well, while other tributary culverts, on both forks of Pine Creek, required maintenance by the county.

On a larger scale, the overall restoration efforts towards channel stabilization and floodplain revegetation on the mainstem and the lower East and West Forks of Pine Creek appears to be working. Approximately six miles have been graded, following the concepts developed in the previously described reports. Where stable geometry exists, the channel was not graded at all and bedrock outcrops have been incorporated for channel bends where feasible. Stable floodplain surfaces have been planted and revegetation efforts, which are relatively inexpensive, will continue as funding permits.

Lateral erosion of floodplain surfaces has been reduced by the comprehensive grading, revegetation, and bank-stabilization projects. Qualitative, short-term results have been positive in many reaches where planted vegetation was recently covered by thin deposits of fine sediments, and bedload deposition at bridges and culverts following a ten year-event was about equal to or less than previous two-year events. Revegetation has varied by stream reach, but in general, trenched willows have been very successful. Containerized plantings have been successful also, particularly the one-gallon size alders and dogwoods. Trenching with a small excavator, or planting with a Bobcat equipped with a six-inch auger, have been the most efficient methods for planting container stock. Because of cost and the extensive area of floodplain to be revegetated, use of topsoil has been limited primarily to priority areas on top of mine tailings removal sites. Topsoil has worked well for establishing grasses when applied four- to six-inches deep.

The major lesson learned from stream-restoration activities along Pine Creek is that a thorough understanding of the geomorphic processes is necessary for the restoration project design. Without proper consideration of the overall stream system, interim channel modification measures may be only temporary. In addition, a careful consideration of realistic timelines for recovery is essential. While land management agencies are often compelled to demonstrate short-term results, we recognize that recovery will take decades and that land use, and abuse, in the watershed may impact restored floodplain.

References Cited

Bennett, E.H., 1996, History of the Coeur d' Alene mining district, Idaho: Idaho Geological Survey manuscript.

Kondolf, G.M., Piégay, H., and Landon, N , 2000, Channel response to increased and decreased bedload supply from land-use change since 1900: contrasts between catchments in the Rocky Mountains of Idaho and Pre-Alps of France, 22p. plus illustrations.

Kondolf, G.M., Piégay, H., and Landon, N., 2002, Channel response to increased and decreased bedload supply from land use change: Contrasts between two catchments: Geomorphology, Elsevier, v. 45, June 2002, p. 35-51.

Kondolf, G.M., and Matthews, W.V., 1996, Reconnaissance-level investigation of sediment sources and channel morphology, and recommendations for management, Pine Creek, Shoshone County, Idaho: Report prepared for Bureau of Land Management, Coeur d' Alene Field Office, June 20, 1996, 15p. plus illustrations.

Lewis, R.S., Burmester, R.F., Kauffmann, and Frost, T.P., 2000, Geologic map of the St. Maries 30 x 60 Minute Quadrangle, Idaho: Idaho Geological Survey, Geologic Map 28, scale 1:100,000.

Matthews, G.M., 1996, Recommendations for channel management, Pine Creek, Shoshone County, Idaho, Report prepared for Bureau of Land Management, Coeur d' Alene Field Office, September 9, 1996, 14p. plus illustrations.

Matthews, W.V., 1996, Conceptual designs for stream restoration projects, Pine Creek, Idaho: Report prepared for Bureau of Land Management, Coeur d' Alene Field Office, September 12, 1996, 16p. plus illustrations.

Mitchell, V., 1996, History of selected mines in the Pine Creek area, Shoshone County, Idaho: Idaho Geological Survey Special Report (Prepared for the Bureau of Land Management), July 1996, 309p.