EPA Abandoned Mine Lands Innovative Technology Case Study

Copper Basin Mining District

Constructed Wetlands on McPherson Branch

ABSTRACT:

The Copper Basin Mining District is the former site of extensive copper and sulfur mining operations dating back for more than 150 years. In 1998, Glenn Springs Holdings, Inc. (GSHI) began installing a two-acre demonstration passive wetland system in conjunction with limestone dissolution and bacteria sulfate treatment. The anaerobic cell was completed in 1998, with two additional aerobic cells completed in 2003. The demonstration wetland system captured base flow water from McPherson Branch (a first-order watershed) with average influent flows of 291 gallons per minute (gpm). The McPherson Branch flow concentrations of iron, copper, zinc, and aluminum were reduced by an order of magnitude and acidity was reduced by 100 percent after flowing through the demonstrative wetland. The alkalinity was increased from 0 milligrams per liter (mg/L) to an average of approximately 160 mg/L. The pH of the treated water increased from 3.82 to 6.50. Flow capacity is limited, with treatment of only the base flow of the McPherson Branch through the wetland—higher flows bypass the passive treatment system. While diverting the base flow and improving water quality, GSHI completed construction of a 65-meter "restored stream segment" in 2003 to improve habitat and aquatic life of McPherson Branch (Faulkner, Ben B., and Miller, Franklin K., 2003).

SITE BACKGROUND

Copper Basin Mining District Site
CERCLIS ID: TN0001890839

An area rich in mining history, the Copper Basin Mining District is located in Polk County in southeastern Tennessee and in Fannin County in northern Georgia near the North Carolina border (see Figures 1 and 2). Mining of copper and sulfur began at the Copper Basin site soon after copper was discovered in 1843 in Ducktown, Tennessee. The only deep shaft mines east of the Mississippi River, mining and processing of copper occurred at the site until 1987, with sulfuric acid production continuing until 2000. During the more than 150 years of mining and processing activities conducted at Copper Basin, a total of more than 95 million tons of ore were mined from nine ore bodies (U.S. EPA, 2005).

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As a result of mining activities, degradation of the site and surrounding area was so catastrophic that the Copper Basin was once considered the largest man-made biological desert in the nation. The activities of the site impacted an area of more than 35 square miles, including the Davis Mill Creek Watershed, the North Potato Creek Watershed, and sections of the Ocoee River (U.S. EPA, 2006).

Figure 1: Location of Copper Basin Mine Site
(Source: U.S. EPA, 2005.)

Under legal agreements dating from 1990, various government agencies and private parties have taken steps to stabilize and partially revegetate the area. The site is currently being investigated and cleaned up through a collaborative three-party effort that was formalized on January 11, 2001 in a Memorandum of Understanding (MOU) and several related legal agreements among EPA, the Tennessee Department of Environment and Conservation (TDEC), and OXY USA (a subsidiary of Occidental Petroleum Corporation). The MOU provides an overall framework and establishes roles and responsibilities among the three parties for the investigation and cleanup work. Further, it provides assurance that the part of the federal government will not to list or propose to list the site on the NPL, as long as terms of the MOU are met. The enforceable agreements add details about the legally binding commitments made between OXY USA and the government. Glenn Springs Holdings, Inc. (GSHI), also a subsidiary of Occidental Petroleum Corporation, is conducting the remedial work at the site.

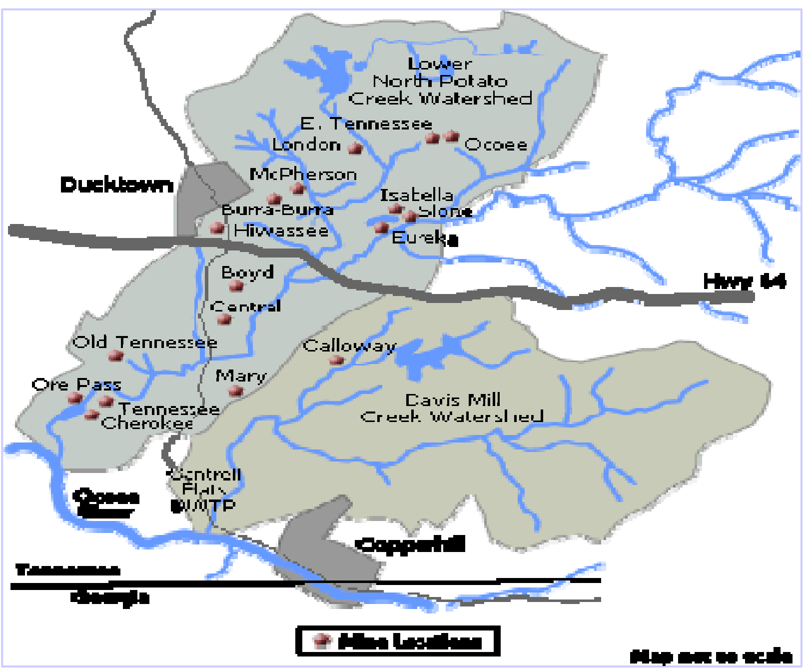

Figure 2: Overview of Watersheds within Copper Basin
(Source: Faulkner, Ben B., and Miller, Franklin K., 2003.)

In 1998, GSHI completed an anaerobic cell of the demonstration wetland on the McPherson Branch. As of 2003, GSHI completed two additional aerobic cells of the wetland, and restored 65 meters of habitat downstream of the wetland treatment system. The aerobic cells were added to aid in the reduction of manganese and aluminum concentrations. Today, the company continues to monitor the site and is proposing additional remedy activities to EPA, including additional wetlands and the use of compost as a sulfate-reducing bioreactor. GSHI is also in the process of refining the wetlands technology through bench-scale testing. However, there are additional sources of contamination at the site that are being addressed through separate remedies, such as removal of contaminated sediments and capping of upstream source materials (GSHI, 2003).

WASTE CHARACTERISTICS

Prior to the Civil War, open roasting was used to remove impurities from copper ore. This practice resulted in a denuded landscape as timber was cut for fuel for the roasting process. The open roasting process also produced sulfuric acid, which rained down on a 35-square-mile area. Soil conservation and reclamation practices, dramatically diminished the Copper Basin sediment load, but acid rock and mine drainage continue to pollute streams with acidity and high concentrations of iron, copper, manganese, aluminum, and zinc. The McPherson Branch is a first order tributary to North Potato Creek. It is typical of the tributaries of North Potato Creek and Davis Mill Creek of the Ocoee River, which drains the Copper Basin (U.S. EPA, 2005). The 410-acre McPherson Branch watershed contained mine wastes throughout the transportation corridors. Severe erosion and sediment deposition in the stream presented a challenge to any remediation technology or recovery of the stream. Prior to treatment, the McPherson Branch exhibited an average flow of 300 gallons per minute (gpm) and a pH of 4.0. The total iron, manganese, copper, zinc, and aluminum concentrations were 7.0, 1.2, 0.6, 1.7, and 4.2 milligrams per liter (mg/L), respectively (Faulkner, Ben B., and Miller, Franklin K., 2003).

TREATMENT TECHNOLOGY

Background

In 1998, GSHI started and completed the construction of the anaerobic cell of the demonstration wetland on the McPherson Branch near its convergence with Burra Burra Creek within the North Potato Creek Watershed (see Figures 3 and 4 for plan views of the wetland). The two-acre wetland was built at a former ore roast yard that contained acid drainage forming material within a highly eroded watershed. The high sediment load in McPherson Branch necessitated a unique design feature upstream of the constructed anaerobic wetland, including:

1. A liner (Fabriform blanket, see Figure 5) installed on the west bank 70 meters (m) upstream of the constructed dam. The liner minimizes infiltration into and drainage from mined waste rock under the roadway parallel to McPherson Branch;
2. A concrete diversion dam on the McPherson Branch to divert controlled flow to the wetland, and provide a settlement basin to remove silt from McPherson Branch before it entered the wetland (see Figure 5);
3. A sluice gate at the concrete dam to release the collected silt; and
4. A flushable sediment trap encased within the dam in the inlet to the wetland.

This design is intended to limit storm water flow into the wetland, limiting sediment and solids that would compromise the porous limestone bed and the wetland substrate. The wetland is lined with a Geosynthetic Clay Liner (GCL) covered with a 0.7 m thick agricultural lime-enriched soil layer; 0.7 m thick layer of crushed 2.5 cm limestone (minimum 75% $CaCO_3$ content); hay bales; and 0.15 m of spent mushroom compost. The wetland design also includes cattails and soil transplanted from a nearby borrow area with similar quality acidic drainage. Preferred flow is subsurface through the anoxic limestone bed. Concrete jersey barriers direct surface flow in a serpentine path through the cattails where it can drain into the limestone bed and be collected by a pipe manifold in the downstream section of the wetland. (Faulkner, Ben B., and Miller, Franklin K., 2003).

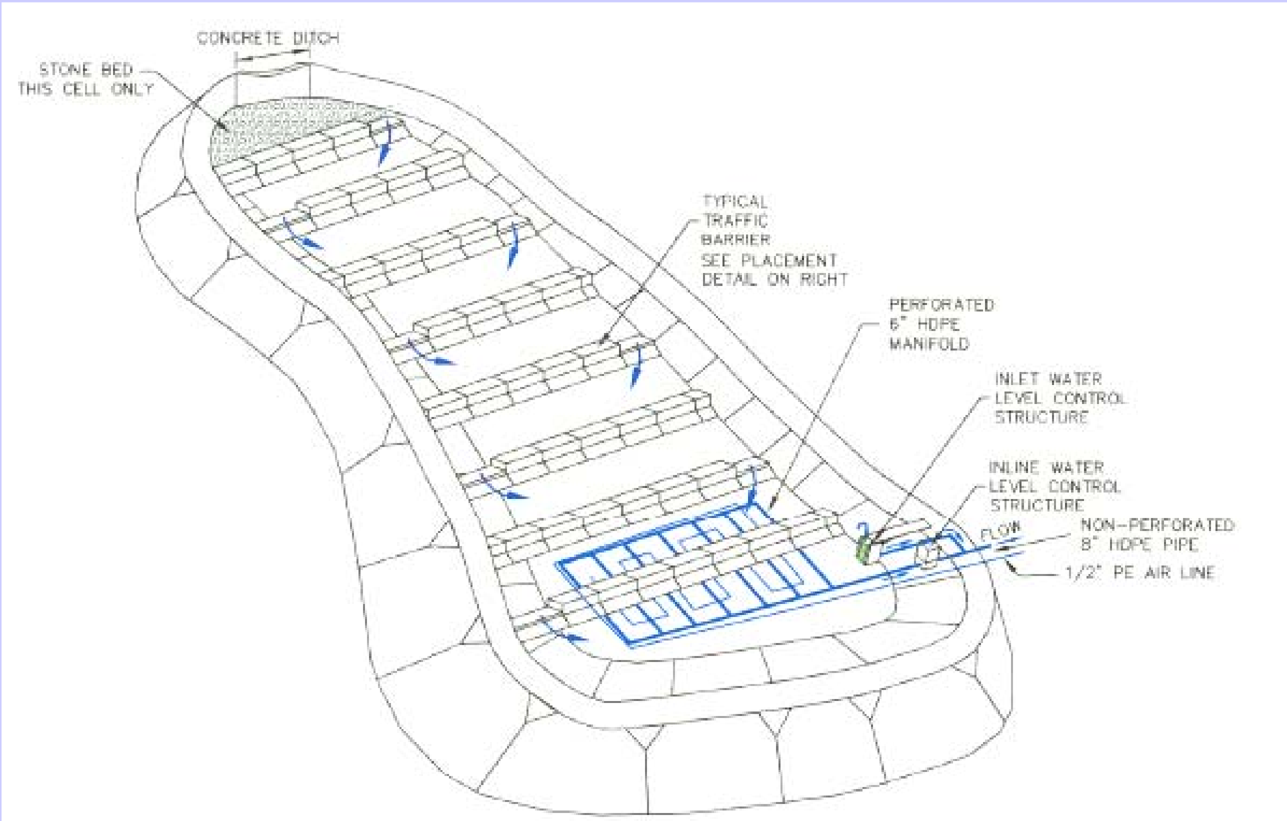

Figure 3. Wetland Basin Design

(Source: Marshall, Miller & Associates, 1998)

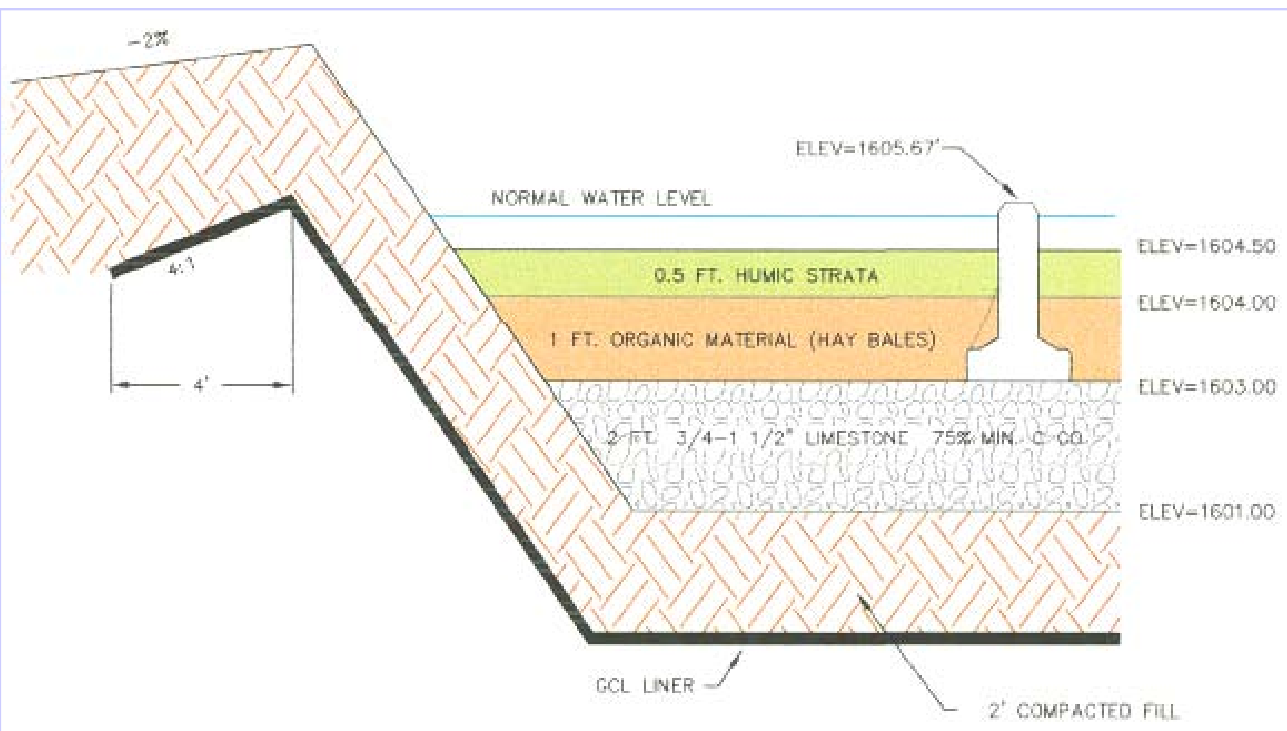

Figure 4: Cross Section of Wetland Design

(Source: Marshall, Miller & Associates, 1998)

Figure 5: Fabriform Blanket and Conversion Dam

To maintain water levels and periodically flush the limestone layer, a manufactured structure called the Agridrain was installed. The Agridrain unit was fitted to the six-inch, high-density polyethylene (HDPE) perforated pipe in the last two cells of the wetland system. Pulling flow from the limestone bed encourages subsurface drainage through the compost layer where microbial activity, removes oxygen and boosts the carbon dioxide concentration, promoting the dissolution of limestone. Since startup, the system has removed metals to concentrations below or near ecological screening values and has produced net alkaline drainage. (Faulkner, Ben B., and Miller, Franklin K., 2003).

It is a challenge to ensure deep subsurface flow in anaerobic systems, and a great deal of focus was placed on this part of the wetlands system. There are two mechanisms for acid neutralization: 1) sulfate reduction, and 2) limestone dissolution. There are seasonal variations in bacterial sulfide reduction, but very limited variation in limestone dissolution. As evidence, there is a higher negative redox potential during summer months; steady limestone dissolution is proven by consistent increases in dissolved calcium and hardness through the system.

Challenges, Adjustments, and Solutions

While flow from the anaerobic wetland oxygenated quickly as it returned to McPherson Branch, there were still concerns about introducing the reduced effluent into the stream. To remedy this, another phase of the demonstration was completed in 2003. Three successive aerobic wetland cells and a rock filter were constructed to provide for oxygenation, volatilization of hydrogen sulfide, and settlement of metal precipitates. A limestone-rock filter bed provided the media for colonization of manganese-reducing bacteria. While water quality in the effluent did not limit aquatic life, the overall habitat of the receiving stream was not suitable. In 2003, GSHI constructed 65 meters (215 feet) of restored stream segment to improve the habitat and demonstrate the McPherson Branch would support aquatic life after passing through the passive wetland treatment system (GSHI, 2003).

PERFORMANCE OF SYSTEM

Currently the base flow of the McPherson Branch flows through the passive treatment system. A study conducted from September 15, 1999 to February 5, 2003 found maintained reductions of acidity and metals, with the exception of manganese. The study also found an increase in water hardness with a decrease in sulfate from the limestone dissolution in the design of the wetland system (Faulkner, Ben B., and Miller, Franklin K., 2003). Later in 2003, the two aerobic cells were added to help decrease the manganese.

Overall, the restored stream segment exhibited improved habitat and increased macroinvertebrate populations. In fact, the stream's habitat became so successful that muskrats have since colonized the stream segment below the wetland treatment system. Unfortunately, their burrowing and feeding activity has dramatically altered the ideal constructed stream conditions. The highly erodable soils adjacent to the stream have since been pushed into the stream by the burrowing muskrats, reducing the available habitat for other aquatic life.

The McPherson Branch (a lightly buffered first-order stream) became contaminated with metals resulting in acidity from prominent waste piles near the stream. Removal of obvious waste in 1998 resulted in reduction of acidity and metals (except manganese). Beginning in late 1998, as the stream entered the anaerobic wetland, total metals were further reduced and the flow became net alkaline. Aerobic cells and rock filter were added in 2003 and flowed into a restored stream segment at the end of the system. Dissolved metals were also monitored. (See Tables 1 and 2.)

Table 1. Post-treatment Water Quality of McPherson Branch

	2004-2006		EPA MCL Standards
	Influent (mg/L)	Effluent (mg/L)	(mg/L)
pH	4.28	7.16	6.5-8.5
Al	1.423	0.055	0.05-0.2
Fe	0.211	0.133	0.3
Mn	1.148**	0.294**	0.05
Cu	0.197	0.017	1.0
Zn	0.640	0.197	5
Sulfate	110	104	250
Hardness	97	142	N/A
Flow (gpm)	294	241	N/A
Aciditiy	37	<1	N/A
Alkalinity	<1	45	N/A

Note: Numbers listed above represent the highest concentrations over the specified period of time. All concentration units, unless otherwise noted, are in mg/L (ppm) rounded to significant digits.

*These are secondary MCL standards for public water systems. These concentrations represent reasonable goals for drinking water. These are non-enforceable guidelines for regulating these contaminants. States may set higher or lower standards depending on the local conditions. (U.S. EPA, 2002)

**While all parameters are for total concentrations, Mn is listed as the dissolved concentration.

OTHER TECHNOLOGIES USED FOR WASTESTREAM

The North Potato Creek Watershed was used for many mining operations at Copper Basin, such as roasting, smelting, and acid production. Wastes containing strongly acidic material adjacent to and potentially impacting North Potato Creek, are currently being removed. GSHI is proposing to isolate this material from surface runoff and limit its exposure through diversions and capping. To prepare for construction of a new passive treatment wetland systems, GSHI is conducting phased bench-scale testing of various organic mixtures with strongly acidic mine drainage. Results of these bench-scale tests will provide information to help build effective compact passive systems for the treatment of small-flow, high-acidity seeps anticipated after effective land reclamation is accomplished.

KEY DATES

1847	Mining operations begin at Copper Basin.
1987	Copper mining operations cease on July 31. Sulfur replaces ore as raw material for acid production.
1995	Environmental study begins to identify problems caused by mining and smelting operations.
1998	GSHI constructs the anaerobic cell for the demonstration wetland on McPherson Branch near its convergence with North Potato Creek.
2000	Sulfur processing and mining operations cease.
2001	GSHI enters into a Memorandum of Understanding along with several enforceable agreements with EPA and TDEC on January 11 to clean up the North Potato Creek Watershed and Davis Mill Creek Watershed.
2003	GSHI completes two aerobic cells for the wetland, and restoration of habitat on McPherson Branch downstream of the demonstration wetland. Long-term monitoring of wetland and restored stream segment habitat begins.
2006	Proposal from GSHI submitted to EPA and TDEC for additional wetlands and compost bioreactor on other Copper Basin wastestreams (GSHI, 2003).

COST

In 1998, the cost of the anaerobic wetland and waste removal peaked at approximately $1 million.

In 2003, the cost of the aerobic wetland, rock filter, and restored stream segment was closer to $300,000. However, much more was spent on related waste removal at the site. The purpose of this wetland is to establish a better understanding of the longevity of passive systems. This passive wetland treatment system was constructed with a theoretical 20-year design life.

LESSONS LEARNED AND CONCLUSIONS

GSHI anticipated that simply removing obvious waste materials from the site would not be sufficient to allow timely restoration of aquatic life in the severely damaged receiving stream. GSHI successfully demonstrated that passive systems are a beneficial component to land reclamation in this small, isolated watershed under the right conditions. The constructed wetlands system at McPherson Branch is a model for remedies being developed and used at the rest of the Copper Basin site. Lightly buffered streams with natural acidity receiving drainage from highly erodable acid soils and unusually high precipitation presented unique challenges for reclamation, revegetation, and mitigation of water quality. Integrating the wetlands atop of the lined, acid-producing material outside the flood plain, which treats mild acid drainage from sources further upstream, is an effective method of acid prevention and treatment.

In anticipation of a high-sediment load from the poorly degraded and vegetated watershed, the demonstration wetland was intentionally placed outside of the flood plain. The sediment trap and pinch valve placed at the concrete diversion dam in McPherson Branch controls the amount of flow into the system by allowing only the base flow and a moderate volume of storm water to enter.

The demonstration wetland at McPherson Branch typically treats high flows of moderate pH and low metal concentrations. As remediation continues in the North Potato Creek Watershed, GSHI is proposing to EPA and TDEC to hydraulically isolate contaminated material that cannot be removed, using a passive treatment system that treats low flows of concentrated acid mine drainage.

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