THE COPPER BASIN RECLAMATION PROJECT[1]

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Abstract. For more than 150 years, the Copper Basin in southeast Tennessee was the site of extensive copper and other metal mining and sulfuric acid production. It is one of the most dramatically impacted mining areas in the eastern United States. As part of voluntary remediation efforts at the site, Glenn Springs Holdings has committed to remedial actions within the affected tributaries of the Ocoee River with long-range goals of restoring biodiversity and biointegrity. This work follows decades of land reclamation and reforestation efforts on the 9,000 hectare (35 square mile) site by industry, TVA, and other interests. Accomplishments in the comprehensive program include on-going and proposed chemical treatment of acidic surface and underground mine drainage, demonstration land reclamation, demonstration passive treatment systems, restored stream segment, tailings and mine waste reclamation, waste characterization, surface water and storm water study, pit limnology and leak study, PCB removal, lead cap, hazards fencing, subsidence monitoring, stream diversion, and future land use planning.

Additional Key Words: Ducktown TN, acid mine drainage, Ocoee River

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Introduction

The Tennessee Copper Basin is located where Tennessee, North Carolina, and Georgia meet and where the Ocoee River is formed. It is an area with a rich history rooted in copper mining (Daniels, undated). Copper was shipped out of the basin as early as 1847 and underground mining continued until 1987. The Basin's mines are the only deep shaft copper mines east of the Mississippi River. Limited surface mining was conducted within the Basin in the 1970's. Open roasting of the copper ore to remove impurities began prior to the Civil War, resulting in a denuded landscape as timber was cut for fuel for the roasting process and sulfuric acid from the roasting process rained down within a 9,000 hectare (35 square mile) area. Severe erosion of the native soils gave the appearance of un-reclaimed surface mines, and the unique area was discernable from outer space as late as the 1970's. Reforestation began in the 1920s and concentrated efforts began in the 1940s that were carried out by the mining companies, academic institutions, and government agencies, particularly TVA. Approximately 16 million trees have been planted. Others have documented both revegetation (Cook et al., 2000) and reforestation (Muncy, 1986) research on tailings and eroded soils.

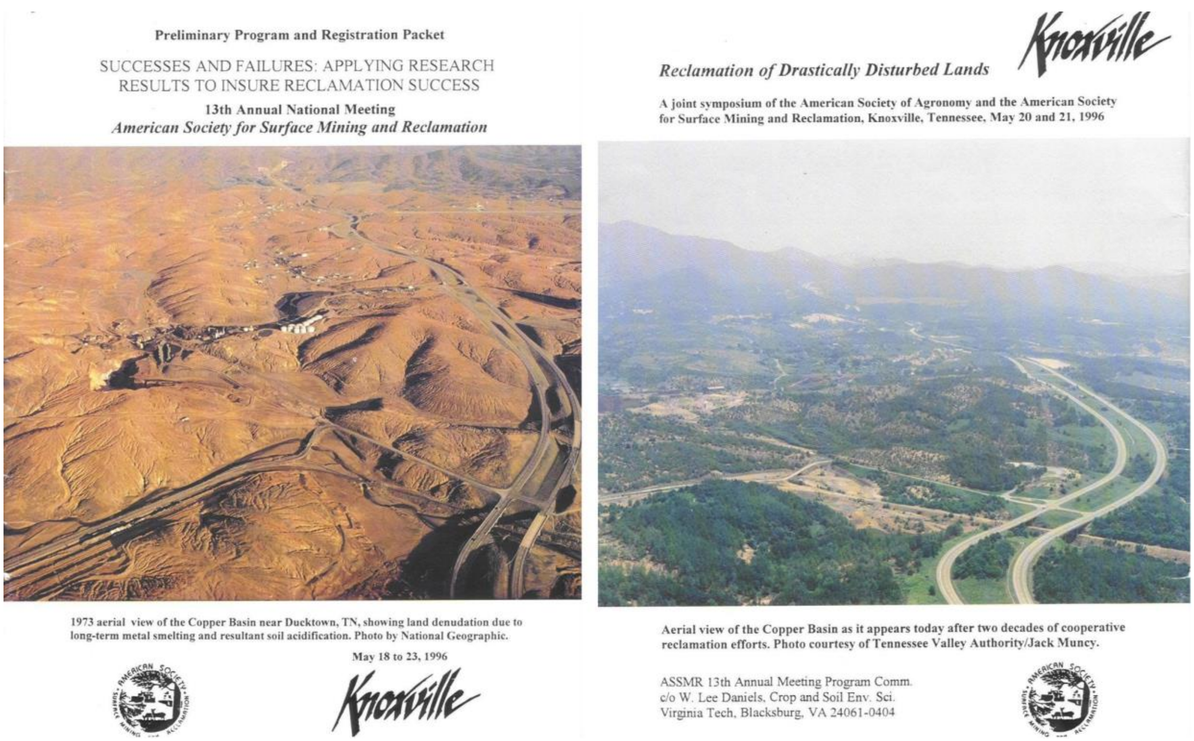

Figure 1. The Copper Basin served as the cover for the 1996 ASSMR Proceedings

Sulfuric acid production replaced copper, zinc and iron mining as the primary industry in the 1980's, and the abandoned underground mines were inundated with acid water. Portions of the mines have collapsed to the surface or are in danger of collapse, further challenging successful land reclamation. Acid drainage emanates from the ore wastes scattered within the two affected tributaries of the Ocoee River; North Potato Creek and Davis Mill Creek. Even the areas not directly affected by mining or waste disposal are severely eroded and contribute acidic runoff to the streams in the Basin. (BWSC Inc., 2000).

In January 2001, Glenn Springs Holdings, Inc. (GSHI – a subsidiary of OXY USA) entered into agreements with the Tennessee Department of Environment and Conservation (TDEC) and the US Environmental Protection Agency (EPA) to restore the North Potato Creek Watershed and alleviate contaminant discharge to the Ocoee River. The voluntary agreements included a TDEC Commissioner's Order. The project boundaries encompass nearly 1290 hectares (3200 acres). GSHI, with the cooperation of TDEC and EPA, has successfully completed several important interim steps toward meeting the goals of those agreements.

Project Work

Waste Characterization

Waste characterization along transportation corridors and other waste piles in this and other areas identified by historic photos and stressed or failed vegetation will provide information as to the appropriateness of disposal of mine wastes in the collapse and elsewhere. Testing includes paste pH, acid base accounting, and mineralogy, as well as synthetic precipitation leaching procedure. Included with the extensive field reconnaissance and field and laboratory testing of the waste characterization is an evaluation of interstitial water proximate to the stream channels. Soil vapor tubes pushed into the alluvium of the creek banks and flood plain are evacuated with a peristaltic pump, yielding shallow groundwater which is field and laboratory tested to confirm the movement of contaminants from the waste to the streams. Focused monthly stream sampling, and drought and storm event water sampling in the Isabella and London Mill design units further identify and quantify contaminants of environmental concern.

<u>The McPherson Branch Demonstration Site</u>

In 1998, GSHI constructed a demonstration passive wetland that captured water from McPherson Branch, a small (165 hectare / 410 acre) first-order watershed with a monoculture of pine growing on the eroded soils. Near its confluence with North Potato Creek, this stream exhibited low pH, moderate acidity, and elevated metals. Additionally, stream remediation was challenged by the high sediment load from the eroded areas upstream. Even paved roadways located well above the creek channel were regularly inundated and covered with sandy silt from the barren areas. The relatively low concentrations of metals and acidity indicated the drainage was a good candidate for passive treatment. Evidence of very high flows and obviously high sediment loads required an innovative approach to implementing passive treatment. This project was detailed in a 2002 ASMR presentation (Faulkner, 2002).

Figure 2. McPherson Demonstration

Figure 3. Aerobic Wetland

In that same year, GSHI removed a 7600 cubic meter (10,000 cubic yard) pile of mine waste proximate to McPherson Branch, and documented a rapid acceleration of the improvement in water quality in the branch that had been slowly occurring since the mines became idle decades ago (TDEC, 2002). Since October of 1998, the two-acre anaerobic passive treatment system has successfully routed base flow from McPherson Branch through the cattail dominated wetland, and by limestone dissolution and bacterial sulfate reduction has converted the acidic, metal-laden stream to an alkaline discharge with greatly reduced concentrations of problem metals. GSHI has recently completed an adjoining one-acre, three-cell aerobic wetland (Fig. 2 & 3) that increases dissolved oxygen in the flow and provides retention time for sulfide volatilization and oxygen demanding processes to occur. While increasing alkalinity and hardness, the rock filter system also provides habitat for manganese reducing bacteria. An additional benefit of the geosynthetic clay lined system is to limit the recharge of seepage under the McPherson roadway from the old roaster yard where the wetland system was constructed. Additional regrading and revegetation of the area surrounding the wetland has also recently been accomplished.

A biosurvey in 2002 indicated that the most important limiting factor for aquatic life in McPherson Branch downstream of the wetland was not any chemical problem with the stream, but lack of habitat. Years of sediment deposition and poor vegetation survival in and along the stream provided poor habitat for aquatic insects. A 65 meters (215 feet) "restored stream segment" was constructed in 2003 to improve habitat and to demonstrate that McPherson Branch, having passed through the treatment wetland, will support aquatic life. Shrubs and plants native to the area were placed alongside recovering species. Rocks, cobbles and aquatic insects were "transplanted" to the stream from nearby Belltown Creek and tributaries of North Potato Creek. Annual biomonitoring in this restored stream segment will evaluate changes in habitat, macroinvertebrate populations, and water chemistry. GSHI biologists are carefully monitoring the performance of the wetland and the aquatic life in the restored stream segment to refine plans for stream recovery efforts elsewhere in the basin. In addition, bench scale tests of passive systems are being conducted to determine the optimum components and sizing for future passive applications at other sites in the Basin.

London Mill Water Treatment Plant and Burra Burra Creek.

In 1996, GSHI began operating the London Mill Water Treatment Plant under an earlier agreement with EPA. The lime plant treats water pumped from the McPherson Mine, the Isabella Collapse and upper Burra-Burra Creek. Pumping from the mines prevents gravity discharges to the stream. The treated effluent from the lime plant was relocated in 2002 from Burra-Burra Creek to McPherson Branch upstream of the wetland outlet.

Ruins of the London Mill flotation plant and adjacent waste areas dominate the stream banks of Burra-Burra Creek upstream and downstream of the retention pond where runoff is collected. Upstream of the mine ruins, Burra-Burra Creek exhibits good water quality, including water impounded on the 120 hectares (300 acres) of tailings located on the north-western corner of the site. The tailings were the site of soils and revegetation studies by UT Knoxville (Cook, 2000) and were recently revegetated with warm and cool season grasses and several thousand tree and shrub stems.

Restricting Access to Physical Hazards

GSHI has completed an extensive fencing project to control access to existing and potential mine collapses, and other physical hazards on the site. Over 8 kilometers (5 miles) of chain link fence, specially constructed to withstand the acidic environment, have been installed to restrict access of the public (Fig. 4).

Figure 4. Burra Burra Collapse from Museum observation deck

Subsidence Monitoring

GSHI, with the assistance of Agapito Associates, has installed Time Domain Reflectometry technology to monitor sub-surface caving, similar to monitoring subsidence in longwall coal mining. The TDR method involves grouting a coaxial cable in a borehole located over a mine void. The cable is interrogated by sending an electrical impulse down the cable. Any deformation of the cable will reveal any deformation of the rock, providing advance warning of additional collapse. These monitoring devices have been installed near the Isabella/Eureka Mines, the Mary Mine, and the Tennessee/Cherokee Mines, all identified as areas having significant potential for future collapse.

Isabella/Eureka Mining and Processing Area

Operations in the Isabella/Eureka area included mining of the nearby ore body, smelting and roasting of ores, acid production by the chamber and contact methods, and metals concentration by flotation. These operations began in the 1850s and continued with only short interruptions until the mid 1980s. Investigations of the surface materials (largely mining and processing wastes) and the nearby streams have identified sources of continuing contamination to North Potato Creek.

The Lead Chamber Acid Plant, which operated from 1909 until 1941, was disassembled in 1942. Some of the more than 1270 metric tons (1,400 tons) of lead from the plant remains as contaminants in the soil over several acres of the former site. In 2003, GSHI constructed an impermeable cap over more than three acres of the site to isolate contaminated soils from human contact and exposure to the environment. GSHI has also begun remediation of the Isabella process areas to remove human health and ecological risks posed by the waste materials along Ellis Branch and North Potato Creek.

Analysis for PCBs has been included in most sampling within the project. PCB contamination at action levels is limited to a small area near the Isabella Mine which is being remediated.

The Isabella Pit, located between the Isabella and Eureka shafts, was formed by a series of collapses beginning in 1960 and continuing to 1972. The irregularly shaped pit measures approximately 300 meters (1000 feet) long by 100 meters (300 feet) wide and extends to a depth of about 85 meters (280 feet) below the surface of the water. The water in the pit is highly contaminated and is pumped to the London Mill Treatment Plant for removal of metals and acidity. As part of the remediation plan for the entire site, GSHI is studying the use of the pit as a sub aqueous disposal site for as much as 380,000 cubic meters (500,000 cubic yards) of mining and processing wastes. Disposal under water would provide a chemically stable disposal site where continued production of acid and metals from the wastes would be prevented. TDEC will approve this disposal method if it can be shown that the method is at least as protective as a lined landfill and the pit does not leak into North Potato Creek.

South Mine Pit

Two surface mines were developed in the lower portion of the North Potato Creek Watershed – the North Mine Pit and the South Mine Pit. After completion of mining, the North Mine Pit was filled with spoil from the South Mine Pit. Today what remains of the South Mine Pit is an 8.1 hectare (20 acre) impoundment that is approximately 60 meters (200 feet) deep and contains approximately 20 million hectoliters (550 million gallons) of water. North Potato Creek was diverted into the South Mine Pit in 1991 to act as a sediment trap. The quality of the water in the South Mine Pit and in North Potato Creek as it enters and exits from the Pit is degraded. The agreement with EPA required GSHI to conduct a study to determine the appropriate remedial action to alleviate contaminant discharge from North Potato Creek into the Ocoee River. As part of the study, a streamlined risk assessment based on human health risk based screening values determined that current conditions posed no human health risk. Consequently, ecological impacts were the principal focus of the study and chronic and acute ecological screening values were used to determine that aluminum, cadmium, cobalt, copper, iron, manganese, lead, and zinc were the contaminants of potential ecological concern.. Bench and field scale treatability studies determined that removal efficiencies for these metals averaged 95% and that the generated sludge would settle to the bottom of the pit through its strongly stratified layers.

A year-long limnology and surface water study, including bench tests and a full-scale pilot study, determined that a lime treatment plant that drew anaerobic, highly mineralized water from the bottom of the pit (which is permanently stratified thermally and chemically) mixed with the flow from North Potato Creek would settle its precipitates in the pit before discharging from the pit to the Ocoee River. Acid neutralization and metals precipitation through conventional lime treatment was selected as the appropriate remedial action, and the plant, scheduled to be on line in 2004, will be capable of treating the 10-year, 24-hour storm in the 4,000 hectare (10,000 acre) watershed of North Potato Creek. This capacity of 27,000 lps (972 cfs or 436,000 gpm) makes this arguably the largest AMD treatment facility in the world.

The selected alternative presented in the study's findings will protect the Ocoee River while long-term work and study are proceeding upstream in the North Potato Creek watershed.

<u>Davis Mill Creek – Cantrell Flats Water Treatment Plant and Belltown Diversion</u>

Under the agreement with EPA, GSHI has refurbished the Cantrell Flats Water Treatment Plant in the Davis Mill Creek Watershed Since completion of the refurbishment in November of 2002, the plant is operating much more efficiently and is removing much more of the contaminant loading of Davis Mill Creek, which flows directly into the Ocoee River. At present, it removes iron and other metals weighing more than a full-size car each day. Over 900,000 kilograms (two million pounds) of metals were removed in the first year of operation. This dramatic reduction of metals loading to the Ocoee River translates into clearer water with less visible staining downstream at the Olympic Whitewater Center. This significant reduction in metals loading should soon be reflected in improvements in the biologic community.

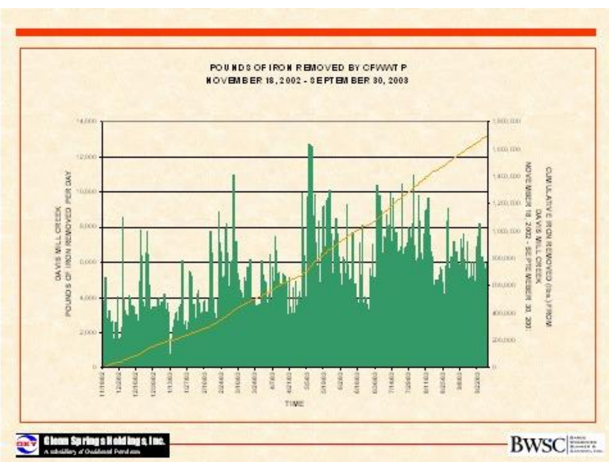

Figure 5. Removal of metals from Davis Mill Ck.

Figure 6. Davis Mill Creek

Under that same agreement, GSHI is diverting Belltown Creek that has good water quality upstream of its confluence with Davis Mill Creek. Construction has begun on the diversion that will use a 160 cm (63 in.) polyethylene pipe to carry up to the peak flow of a 10-year, 24-hour storm. Removing this flow of clean water from Davis Mill Creek will allow the Cantrell Flats Water Treatment Plant to operate more efficiently during storm events, and consequently remove even more of the potential contaminants to the Ocoee River (Fig. 7).

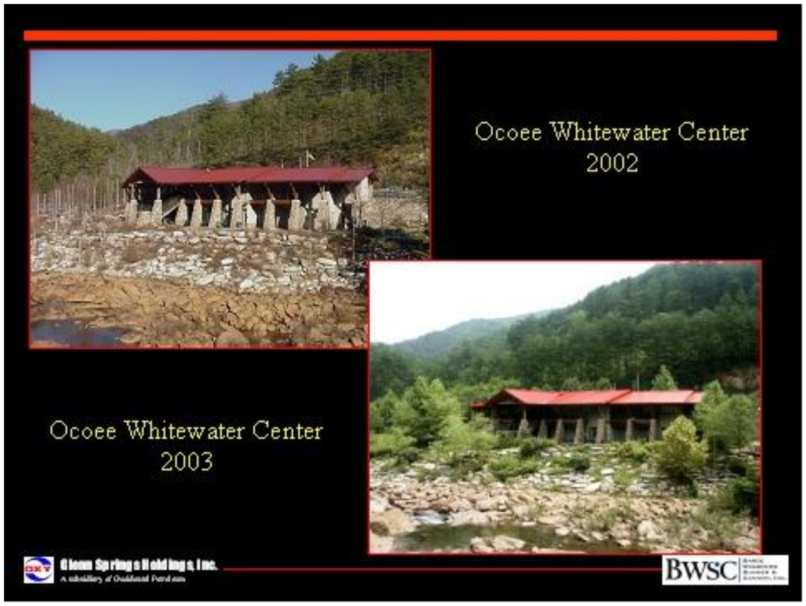

Figure 7. Removal of contaminants from Davis Mill Creek shows in the Ocoee River.

<u>Future-Use Plans</u>

Since the environmental work that could affect development activities is ongoing, the future-use plan must be viewed as preliminary in nature. Future-use improvements are designed to provide an economic and recreational asset for the Ducktown/Copperhill region and the State of Tennessee. The improvements would encourage cultural, historic, and environmental tourism through enhancements of historic mining features, and would be important to the region’s economy. Plans within the next 10 years include expanding the Ducktown Copper Basin Museum as the center of walking/bicycle trails that connect with local and regional trail systems, interpretive trails and outdoor classrooms designed to educate the visitor about mining operations, post-mining land stewardship practices, and the natural history of the area.

Figure 8. The Copper Basin Project Area

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