# LAND AND WATER RESTORATION OF THE COPPER BASIN OF TENNESSEE[1]

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**Abstract.** For more than 150 years, the Copper Basin in Tennessee was the site of copper mining and acid production. It is one of the most dramatically impacted mining areas in the US. As part of voluntary remediation efforts, Glenn Springs Holdings has committed to actions 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 mile$^2$) site. Two watersheds are chemically treated to protect and ensure the recovery of the Ocoee River; including treatment of acidic surface and underground mine drainage at perhaps the largest capacity AMD treatment plant in the world. Work in Davis Mill watershed has involved diversion of unaffected water around acid forming mine waste. In North Potato Creek, land reclamation, passive treatment systems, restored streams, tailings and mine waste reclamation, waste characterization and pit disposal, pit limnology and leak studies, lead cap, hazards fencing, subsidence monitoring, stream diversion, and stormwater studies are being implemented as the recovery of the watershed is documented with biomonitoring. Together, these chemical treatment plants protect the Ocoee as cleanup efforts in the Copper Basin progress. US Forest Service biologists confirm the Ocoee is responding positively to the effort. With this protection in place, Glenn Springs continues to implement its adaptive water management strategy: characterize drainage and influences, divert unaffected drainage, capture and treat affected drainage, sequester acid producing materials, mitigate remaining problems with passive systems, and evaluate with biologic indicators.

**Additional Key Words:** Ducktown TN, acid mine drainage, water management

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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. Sulfuric acid fumes from the process contaminated rainfall 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 a bright red spot in the otherwise green Smoky Mountains. Reforestation efforts began in the1920's and concentrated efforts began in the 1940's, which were carried out by the mining companies, academic institutions, and government agencies, particularly the TVA. Others have documented both revegetation (Cook et al., 2000) and reforestation (Muncy, 1986) research on tailings (Branson and Ammons, 2004) and eroded soils. Sulfuric acid production replaced Cu, Zn and iron mining as the primary industry in the 1980's, and the abandoned underground mines were inundated with acidic water. Portions of the mines have collapsed to the surface or are in danger of collapse, further challenging successful land reclamation.

## History

Drainage from the Tennessee Copper Basin's affected areas flows into the North Potato Creek and Davis Mill Watersheds of the Ocoee River. The Ocoee contains three TVA hydroelectric dams and exhibited water quality problems commencing with the mine developments in the 19$^{th}$ century. The sediment load to the Ocoee was estimated at 761,000 $m^3$ (617 acre feet) per year in the early 1920's and the dams were regularly sluiced to pass sediment downstream. Occidental Petroleum Corporation (now OXY USA) is alleged to have acquired liability for the site when it purchased Cities Service Company in 1982, after Cities had sold the site. Although it never owned the site, OXY, through its wholly owned subsidiary, Glenn Springs Holdings, Inc. (GSHI) signed a 2001 monumental Memorandum of Understanding with

the USEPA and Tennessee Division of Environment and Conservation to voluntarily remedy the site. The project involves 13 deep mines, 2 surface mines, 4 flotation plants, 3 smelters, 2 sulfuric acid plants, and over 1200 hectares (3,000 acres) directly affected by mining and processing. Risks to human health (at the time of the Memorandum) included physical safety hazards, PCBs, asbestos, and lead. Environmental impacts included poor water quality, sediment choked watercourses, poor riparian zones, and lack of aquatic and terrestrial habitat. The voluntary nature of this project has provided flexibility in the remedial approach. An *adaptive management strategy* has developed to:

- Characterize drainage and influences
- Divert unaffected drainage
- Capture and treat affected drainage
- Sequester acid producing materials
- Mitigate remaining problems with passive systems
- Evaluate success with Biologic indicators

## Safety First

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 and protect workers. At several of the mine collapses, GSHI has installed Time Domain Reflectometry technology (TDR) to monitor the subsurface caving similar to what is done when 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 shortening of the cable will reveal deformation of the rock, providing advance warning of additional collapse. Human health risks at the site were reduced by removing asbestos, PCB contaminated facilities and equipment, and the lead containment cap, along with the fencing project. A large slag facility proximate to the highway was also covered in place to reduce safety concerns and impact to air and water.

Early Water Quality and Revegetation Demonstrations

In 1998, GSHI demonstrated the adaptive management strategy in the McPherson Mine Area (Faulkner, 2002). It removed about 23,000 $m^3$ (30,000 cubic yards) of waste material proximate to the stream, which represented only a portion of the pyritic waste material in direct contact with the McPherson stream channel and strewn along the nearby transportation corridors. Because of high soil erosion in the watershed and elevated sediment load, an anaerobic wetland was constructed outside the flood plain and McPherson Branch was conveyed to the wetland behind a concrete dam. The wetland has successfully neutralized the acidic flow and sequestered the metals in the relatively small 46 hectare (114 acre) watershed. Additional removal actions upstream and the addition of aerobic wetland cells, a rock filter to remove manganese, and a demonstration restored stream segment have reduced the acid load and provided water quality and habitat suitable for aquatic life (Faulkner, 2004).

Over 17 million trees (mostly loblolly pine) have been planted in the Copper Basin, and site specific regrading, and revegetation practices have developed since early reclamation efforts in the Basin. At the time of the Memorandum, the London Mill Tailings Facility covered over 120 hectares (300 acres). The inert tailings exhibited good water quality but were a revegetation challenge. GSHI partnered with the University of Tennessee and demonstrated successful revegetation (Cook, 2000, Branson and Ammons, 2004) and used these findings to completely revegetate the area.

Waste Characterization

Beginning in 2002, Barge, Waggoner, Sumner & Cannon (BWSC as consultant to GSHI) performed a comprehensive waste characterization of the North Potato Creek drainage. In addition to analysis of mine wastes and affected soils and sediments, surface and shallow ground waters were also analyzed and compiled into a spatial database where sources and influences to surface waters could be identified and qualified. Typical of acid rock drainage, water quality standards for pH and heavy metals concentrations were exceeded throughout the watershed. This study and subsequent specific investigations confirmed that the underground mines and associated surface collapse features were not related to the stream contamination, as long as the mines were pumped well below the stream water level. Major sources were confined to wastes deposited along transportation corridors, old roast yards, and distinct waste

piles. The greatest water quality challenge in the Copper Basin is Davis Mill Channel. Source removal was not practical in Davis Mill, because the actual source of over 75% of the contaminant load has not been fully identified by either USEPA or Glenn Springs in separate, yet very thorough Remedial Investigations.

Immediate Interim Actions – Davis Mill Watershed

Remedial actions in the Davis Mill Watershed were designed to alleviate contaminant loading to the Ocoee River while the final remedy is being investigated. These actions will be consistent with the adaptive management approach and should satisfy final selected remedial alternatives. The existing Cantrell Flats Water Treatment Plant (CFWTP) was refurbished and put on line in 2002. An existing clean water pipeline diversion from the Gypsum Pond to Belltown Creek and through the worst contaminated reach of Davis Mill Watershed was supplemented with the addition of over 1200 meters (4,000 feet) of larger (1.6 meter or 63 inch diameter) pipeline in 2004. This pipeline diversion and refurbishing three in-stream dams provided the ability to pass clean water from a 10-year, 24-hour storm around the CFWTP intake while retaining and chemically treating stormwater in the affected watershed. The most recent extension of the Belltown diversion was completed in December, 2009 when the final 900 meters (3,000 feet) of up to 2.1 meter (84 inch) diameter pipeline was installed upstream of a dam/pump station at the watershed's confluence with the Ocoee River. This accomplishment means that all affected drainage is now captured and treated at the CFWTP before being released to the Ocoee (Fig. 1). Since 2002, CFWTP has removed over 13 million kilograms (30 million pounds) of acidity and over 8 million kilograms (18 million pounds) of metals from drainage to the Ocoee River. The Davis Mill Watershed Remedial Investigation and Feasibility Study is still ongoing.

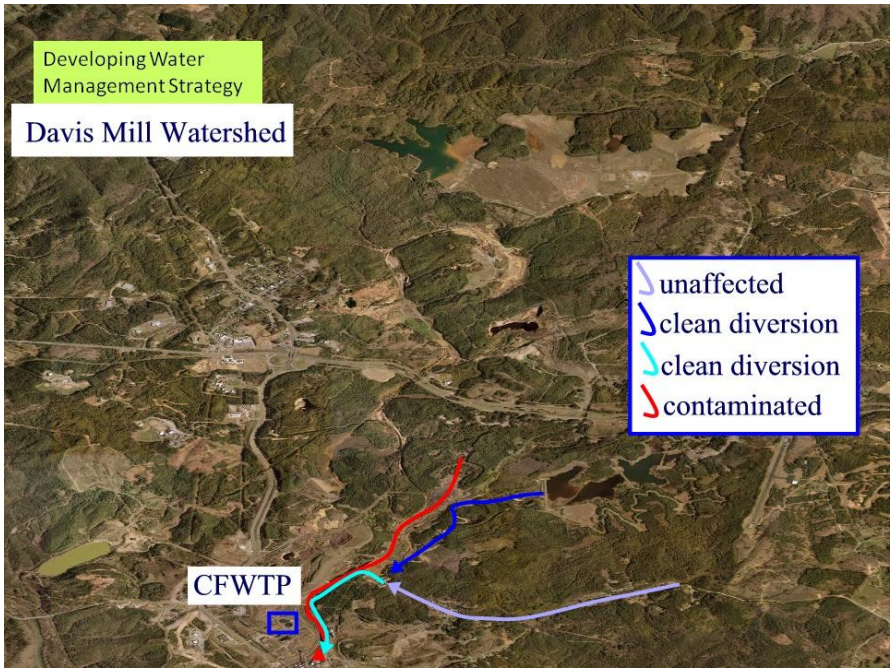



Figure 1. All contaminated drainage in the Davis Mill Watershed has been captured and treated since late 2009.

Immediate Interim Actions – North Potato Creek Watershed

Burra Burra Creek of North Potato Creek had been treated by GSHI at the London Mill Water Treatment Plant and predecessors since 1976. In addition to contaminated surface water, the plant received pumped discharges from the McPherson and Isabella Mine complexes. Despite effective acid neutralization and metal removal, the effluent from the plant became acidic within a short distance of the plant discharge into contaminated Burra Burra Creek. In the 1970's, the entire 3800 hectare (9,500 acre) drainage of North Potato Creek was diverted through a tunnel into the Davis Mill Watershed so surface mining could be conducted in the lower reach of North Potato Creek. When open pit mining was completed, regulatory officials required diverting North Potato Creek into the 8 hectare, 60 meter deep, 800 meter long (20 acre, 200 feet deep, 0.5 mile) open pit as a sediment trap in order to protect the Ocoee River from the on-going sediment in the drainage as the tunnel was closed. The flow attenuation provided by the diversion dam structure still in place allowed a unique opportunity for GSHI to place a new lime treatment facility upstream of the mine pit and treat the entire flow in North Potato Creek (up to a 10 year, 24 hour storm) and utilize the pit as an enormous clarifier. Acid

drainage from flooded deep mines flowing subsurface into the pit contributed substantial, yet unquantifiable loads to the drainage. A one year Engineering Evaluation and Cost Analysis (EECA) including modeling, limnological evaluation, bench and pilot scale evaluations of chemical treatment of the creek and mine pit provided confidence that water quality could be improved. The North Potato Creek Water Treatment Plant (NPCWTP) went on line in January, 2005 (Wyatt, 2005). Since then, it has neutralized the acidity in the creek and pit and dramatically reduced metals concentrations reaching the Ocoee River.

With the chemical treatment facility in place to protect the Ocoee River from contaminants in North Potato Creek, and building on demonstration remedial efforts in the headwaters of the watershed, GSHI utilized the information from the waste characterization effort to implement its iterative approach in diversion of unaffected drainage, and source reduction by removing acid producing materials from locations that negatively influenced water quality.

The London Mill Area underwent a dramatic transformation as drainage from the Tailings Pond area (supporting fish and other aquatic life) was diverted by dam and pipeline around the most contaminated reach in the watershed. Other surface water diversions and removal of contaminants to a permanent repository in the Isabella Collapse dramatically reduced the load in upper Burra Burra Creek (Stokes, 2008). A 4.5 hectare (11 acre) liner over the waste pile footprint and installation of a subsurface collection system (Infiltrator®) for the affected area allowed for the entire site to be regraded and revegetated. The remaining poor quality drainage captured in the retention pond and collected in the Infiltrator® flows by gravity pipeline with pumped mine water along the abandoned rail grade over 4300 meter (14,000 feet) to the NPCWTP inlet (Fig. 2). Other strongly acidic mine water from the Isabella Collapse is injected into the workings of the Central Mine, where it flows through the mine to the bottom of the South Mine Pit for treatment by the NPCWTP. The London Mill WTP was taken off line in 2009. This removal of contaminated water from the Burra Burra and North Potato Creek watercourse has dramatically improved water quality. The high acidity and metals loads before this remedial action masked more subtle sources of contamination along the stream which have since become evident. Removal of contaminants in two former roast areas (McPherson and Eureka) was necessary as storm water studies revealed that the first flush of contaminants increased metals concentrations above acutely toxic levels. Collection of zinc laden drainage

from slag piles in Ellis Branch and diversion via pipeline to the Isabella Collapse allowed for reduction of flow and metals in the regraded Eureka Plant site. Organic materials and limestone mixtures selected from extensive bench scale treatment efforts (Faulkner, 2007) were placed in subsurface vaults in this area to collect and treat remaining drainage.

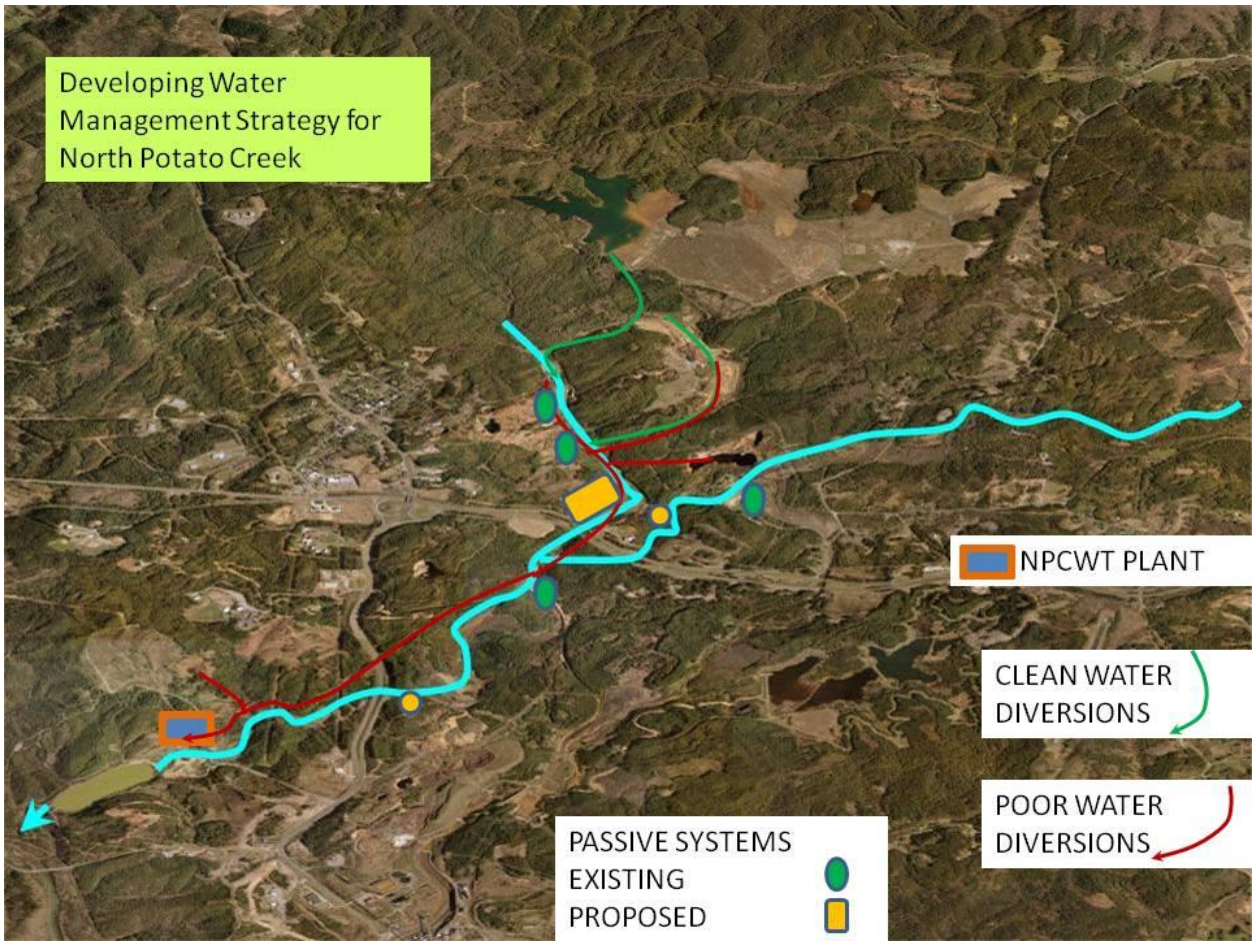
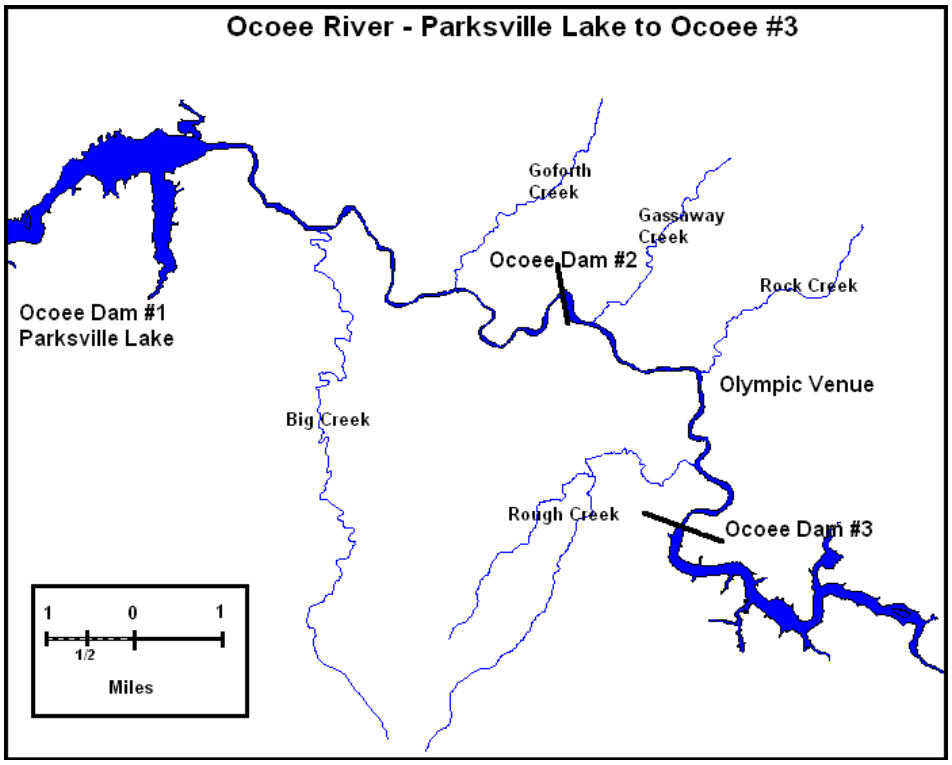



Figure 2. Most contaminated drainage in North Potato Creek. is diverted to the treatment plant

The Ocoee River

The Ocoee River's water uses have been compromised since before the river was first impounded in 1911. Its condition and recovery has been summarized by the US Forest Service (2008):




*"The Ocoee River has long been known as a "dead stream" supporting little to no aquatic life. Natural outcrops of highly acidified rock formations aggravated by historic unregulated mining (since the 1840's) rendered the stream devoid of fish and most other aquatic organisms. An intensive fish survey conducted prior to the 1996 Olympics revealed that the "dead stream" label was appropriate. The 5 miles {8 kilometers} of river from Ocoee Dam #3 downstream through the Olympic venue to Ocoee Dam #2 were surveyed using electrofishing and scuba. Three stonerollers were the only fish observed in this entire reach. Stream surveys by TVA downstream of Ocoee Dam #2 to Parksville Lake in the early 1990's produced few fish and no indication of reproduction in the river channel.*

*In 2001 Glenn Springs Holding, Inc. started a cleanup program on two streams, North Potato Creek and Davis Mill Creek, draining the Copper Basin. The US EPA and TDEC-Superfund cooperated in the cleanup. Preliminary results indicate that their efforts have been extremely effective. Heavy metals concentrations and pH readings in the effluent of the treated water are at or near acceptable levels for aquatic organisms.*

*These improvements to water quality in streams draining the Copper Basin have translated into dramatic improvements in the Ocoee River. Short segments of the Ocoee River in the vicinity of the Olympic Venue were snorkel surveyed by professional Aquatic Biologists from TVA and USFS on September 7, 2007. Thirteen native species of fish were documented…"*

USEPA's 2008 Remedial Investigation found that reduced erosion and sedimentation from the Copper Basin has generally improved water quality and ecological conditions in the Ocoee River. Prior to 2003, water quality in the river routinely exceeded Tennessee State Water Quality Standards (WQS) as mining wastes high in metals and acidity were allowed to erode and be transported to and down the river. Interim remedial actions in the Davis Mill and North Potato Creek watersheds have significantly reduced the concentrations and loads of metals and acidity to the river from mining areas and sources. As a result, the water quality in the river now generally meets Tennessee WQS, with some exceptions. These problematic areas are primarily along the right descending bank immediately below the confluences with Davis Mill and North Potato Creek or in locations within a few inches of contaminated sediment. The report concluded that if water concentration, vegetation, fish, and macroinvertebrate community trends continue to indicate improvement, then it will be concluded that the combination of source controls and natural recovery processes are continuing to have a beneficial effect and annual surveys will continue until other biological criteria are met.

In setting these goals, EPA fully recognizes the complexity of the Ocoee River and the remedial activities occurring in the watersheds of the Basin. It does not intend to adopt the Remedial Guidelines as strict clean-up standards. Rather, EPA intends to adopt an iterative decision process in evaluating goal achievement. An iterative process was suggested by OSWER Directive 9285.6-08 (EPA 2002), which recognized the recommendations made by the National Research Council in developing a risk management strategy for sediments contaminated by PCBs, but indicated that it would be applicable to most sediment sites. It is also consistent with an Adaptive Management (AM) approach that was recommended by the NRC in its review of the remedial decision processes used at another mining mega-site near Coeur d'Alene, Idaho (CH2M Hill et al. 2001). The AM process calls for well-reasoned iterative actions accompanied by a comprehensive monitoring program aimed at quantifying well-articulated performance-based measures.

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Note: The documents prepared by BWSC are work products prepared for GSHI and submitted to EPA Region 4 and TDEC in accordance with the Consent Orders and Commissioner's Order. 16 1 2

Copies of the documents can be requested by contacting the Ducktown, TN GSHI project office at 423-496-7900.