

Revegetating Highly Acidic Mine Spoil on the Big South Fork National River

By Ed Buckner, Michael Rikard, and Sam Kunkle

The Big South Fork River and Recreation Area (BISO) in north-central Tennessee, established in 1976, is a relatively new project for the National Park Service. Development of BISO is currently the shared responsibility of the U.S. Army Corps of Engineers and of NPS. Full administrative responsibility will be assumed by NPS once development is completed. Of primary public interest in BISO is the Big South Fork of the Cumberland River and the gorge it has carved into the Cumberland Plateau.

Most of the land under development is U.S. Forest Service land acquired in 1937 from the Stearns Coal and Lumber Company. During the company's ownership, essentially all of the marketable timber was cut. In 1936-37, exercising their mineral rights, the company began coal mining operations that continued for 25 years. These lumbering and mining activities left marks on the landscape that still are visible today.

The coal-bearing strata were too deep for surface mining but were accessible for deep mining at points where they outcropped along the gorge wall. A seam of highly acidic, pyritic shale that overlies or is mixed with the coal in this region had to be removed with the coal and disposed of as tailings. Since no reclamation laws applied to this region at that time, the shale was simply dumped at the mine entrances. The resulting spoil banks extend from the mine openings, most of which are situated about halfway up the north wall of the gorge, down to the river. Many once extended into the river, but flooding has truncated these at the high-water line.

Although much of the area has been abandoned for more than 30 years, and despite the availability of seeds from trees growing on bluffs above, these spoil banks have remained essentially devoid of vegetation. It is evident that growing conditions on these south-facing embankments with their dark, heat-absorption surfaces, are not suitable for natural revegetation. Such barren, eroding embankments are of particular concern since they are situated just upstream from Devils Jump, a popular rapid with white-water enthusiasts.

The existence of pine plantations established during a USFS reclamation program in the mid-1960s on spoil just upstream from the study area indicated that spoils in the area could be revegetated. Soil tests confirmed that these fully-stocked and reasonably vigorous stands were growing on spoil essentially identical to that on the problem sites. Further investigation

revealed that the Forest Service program was terminated because of the extreme cost of the project. For each seedling planted, a hole large enough to accommodate approximately one cubic foot of topsoil had to be dug. Thus, a less expensive means of revegetation was needed.

Our study was started in the fall of 1983 to establish techniques and guidelines for permanently revegetating these spoil banks to reduce water pollution and erosion and to improve the aesthetic quality of the gorge.

Soil testing revealed that extremely acid conditions still prevail, with average pH values of 2.6 at the spoil surface and 2.3 at the 10-15 inch depth (Table 1). This is considerably below the lower limit recommended for even the most acid-tolerant trees used in surface mine reclamation, according to Fribourg et al. 1981.*



Pine plantation stands on an old mine spoil area in the Big South Fork NRR. Author Michael Rikard stands in front.

Grading was considered to better regulate water movement across the spoil banks, but there was concern since any spoil disturbance would expose the higher acidity at the 10-15 inch depth. Weathering at the spoil surface apparently had ameliorated the very low pH. But of even greater consequence to plant establishment and growth was the high conductivity below the spoil surface: such high conductivity is generally toxic to plants.

A preliminary grading test was established in the fall of 1983 to evaluate the consequences of exposing fresh spoil. A small area of fresh spoil exposed by bulldozer activity in constructing a hiking trail enabled the planting of containerized Virginia pine seedlings in the following spoil conditions: 1) disturbed spoil, 2) undisturbed spoil, and 3) undisturbed spoil limed at the rate of 3 tons of agricultural lime per acre. A survival count in late April 1984, revealed that the pine seedlings survived at the rate of only 10% for disturbed spoil condition, 28% for undisturbed spoil and 50% for undisturbed, limed spoil. The finding that in spoils disturbed by grading, 90% of the pines did not survive, made it apparent that grading the spoil banks was not conducive to plant establishment and growth.

Greenhouse studies over the winter of 1983-84 using surface spoil from the problem sites confirmed that pine seeds would germinate and grow on the spoil material. Stratified seed of both loblolly (*Pinus taeda* L.) and Virginia pine actually germinated better on the surface of mine spoil than on a greenhouse rooting mix. Since there was a natural source for Virginia pine seed in the spoils area, it is likely that seeds germinated each spring but did not survive the summer. This was observed to be the case during the spring and summer of 1984, an observation that implicates the high surface temperatures on these black, south-facing spoil banks as the primary reason for their barren condition. In fact, the only surviving growth found on the embankments was located in shade.

The feasibility of planting bare-rooted pine seedlings directly in the spoil was investigated further in the greenhouse studies using spoil from the problem sites. Seedlings of both loblolly and Virginia pine survived well in unlimed surface spoil but survived satisfactorily in the deep spoil only where it was limed. Water movement through pots containing the deeper spoil was excessive, with very little retained to serve as available for water for plants. There was, however, sufficient fine material in surface spoil to slow water movement enough to increase its availability to plant roots. Despite the likelihood of higher erosion during heavy rains on the undisturbed spoil, this was further evidence that any disturbance to these sites would make them more difficult to revegetate.

Based on the greenhouse findings, field plantings of test plots were established in the spring of 1984. Seedlings of both loblolly and Virginia pine were planted on undisturbed spoil treated in the following

Table 1. Spoil pH and conductivity.

Spoil Samples	pH	Conductivity (micromhos/cm)
Surface:		
not limed	2.6	1,000
limed	5.6	1,400
At 10-15 inch depth:		
not limed	2.3	3,800
limed	2.2	3,700

*measurement of resistance to electrical flow

Fribourg, A., C. Jent, S. Mayer, J. Burns, and J.H. Paugh. 1981. Guide to revegetating surface mined areas in Tennessee. USDA and Institute of Agriculture, University of Tennessee, Knoxville.

manner: 1) limed at 5 tons per acre of agricultural lime; 2) limed as above and fertilized at the rate of 150 pounds of nitrogen (N) and 35 pounds of phosphorus (P) per acre; 3) mulched with pine straw to a depth of 2-4 inches; and 4) untreated (control).

Survival, height growth, and vigor (a composite of foliage color and density) were measured at the end of the first growing season (around September 1). As in the previous tests, evaluation was based largely on seedling survival, since establishing vegetation

was the primary concern, seedling mortality after the first growing season is generally very low, and growth the first season commonly reflects an "adjustment" period and is not a good indicator of species/site relationships. Results are presented in Table 2.

As in the preliminary study, soil tests confirmed that lime reduced soil acidity at the spoil surface, changing pH from approximately 2.6 to 5.1, but had no influence at the 10-15 inch depth. Liming significantly improved survival rates, especially for the Virginia pine, which

experienced high mortality in the unlimed control plots. This was not expected as Virginia pine is claimed to be one of the more acid-tolerant of the yellow pines (Fribourg et al. 1981). Further, survival was generally highest where lime alone was applied. The addition of fertilizer generally reduced survival rates (significant at the 90 percent probability level); for loblolly pine, survival rates fell below levels yielded by control conditions. Mulching produced variable results, partly due to compaction and scattering by wind. Even so, mulching appears to have a beneficial influence on loblolly pine survival.

Measurements of height growth and vigor generally supported the beneficial influence of lime. The tallest and most vigorous trees were in the limed and fertilized plots even though survival was poorer than in the limed-only plots. This has been a common finding where fertilizers are applied at planting time. Although results have been variable, pellets containing slowly available fertilizer placed in the closing hole at planting time have successfully averted this problem.

Conclusions and Recommendations

It is apparent that liming is critical to the establishment and survival of vegetation on spoil banks. In addition, mulching provides protective shade, without which (as evidence by field observation of the current growth on the spoils) it is unlikely that seedlings can survive. Under no conditions should the mine-spoil embankments be graded, since this disturbance exposes material that is more acidic and less retentive of water; such conditions only exacerbate revegetation problems. With these points in mind, the following recommendations for the Big South area have been developed, based on the results of these investigations and other studies pertinent to revegetating acid sites:

1. Do not disturb the sites.
2. Lime at the rate of 5-7 tons/acre.
3. Mulch to a depth of 5-8 inches (approximately 200 bales of hay at 10,000 pounds/acre), and secure with erosion-control netting.
4. Place a fertilizer pellet containing nitrogen and phosphorus (but no potassium) in the closing hole at planting time.
5. Plant between mid-February and mid-March an even mixture (one-third of each species) of Virginia pine, loblolly pine, and black locust (*Robinia pseudoacacia* L.) seedlings. This should be late enough to avoid frost heaving of seedlings but early enough to allow root establishment before rapid top growth begins. Because black locust fixes atmospheric nitrogen and tolerates highly acid sites, it should improve spoil fertility. Spacing should be no greater than 6' x 6'.
6. In late spring direct-seed a mixture of the native hardwoods that are commonly found as secondary successional species in this area. The mixture should include red maple, sourwood (*Oxydendron arboreum* L.), river birch (*Betula nigra* L.), black birch (*Betula lenta* L.), scarlet oak (*Quercus coccinea* Muenchh.), chestnut oak (*Quercus prinus* L.), sycamore (*Platanus occidentalis* L.), and alder (*Alnus* sp.).

These recommendations were implemented on the study sites in the winter and spring of 1985 through a contract with the Tennessee Valley Authority.

Buckner is a professor of forestry with the University of Tennessee in Knoxville; Rikard is a hydrologist with the Big South Fork NRR; Kunkle is a forest hydrologist with the NPS Water Resources Division, Fort Collins, CO.



Eroding mine spoil embankment dwarfs the human figure in the gorge area of Big South Fork National River and Recreation Area.



An ugly, poisonous edge to the Big South Fork is provided by this sprawling bank of mine spoil.

Table 2. Survival (percent) of seedlings after one growing season in undisturbed mine spoil according to treatments.

Treatments	Loblolly pine			Virginia pine		
	un-mulched	mulched	Average	un-mulched	mulched	Average
Control	37	46	41	16	12	14
Limed	48	71	59	79	54	67
Limed & fert.	29	35	32	52	54	53
Average	38	51	45	49	40	45