



# Reclamation Guidelines

*for surface mined land*

Powell  
River  
Project

## Establishing Ground Cover for Forested Post-Mining Land Uses

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Publication Number 460-124, Posted June 2008. Updated 2009. (pre-publication draft).

### Introduction

Productive native forests create economic value for landowners while providing landscape benefits such as watershed control, water quality protection, carbon sequestration, and native plant diversity. In the Appalachian region, owners of lands mined for coal are increasingly interested in assuring that productive forests are restored after mining.

Revegetating mined lands with grasses and legumes (“ground cover”) is essential to mine reclamation under the Surface Mining Control and Reclamation Act (SMCRA). This publication describes how mining firms can establish ground cover while reclaiming lands to forested postmining land uses.

### The Forestry Reclamation Approach (FRA)

The Forestry Reclamation Approach (FRA) is a method for reclaiming coal-mined land to forest under SMCRA (see [VCE Publication 460-123](#) and [ARRI Forest Reclamation Advisory No. 2](#)). The FRA differs from the common reclamation practices of past years that utilize agricultural grasses and legumes, such as K-31 tall fescue and red clover. The FRA has five steps:

1. Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone, and/or the best available material.
2. Loosely grade the topsoil or topsoil substitute established in step one to create a noncompacted growth medium.
3. Use ground covers that are compatible with growing trees.
4. Plant two types of trees – early successional species for wildlife and soil stability, and commercially valuable crop trees.
5. Use proper tree planting techniques.

This publication deals with the FRA’s third step; it describes how to establish ground-cover vegetation while controlling erosion without hindering the survival and growth of planted trees.

## Revegetation for the FRA

The revegetation method described here differs from the “grassland reclamation approach” that has been used commonly by coal-mining firms in past years to establish both hayland pasture and unmanaged forest postmining land uses. The grassland reclamation approach uses fast-growing agricultural grasses and legumes to achieve rapid and complete ground cover. In contrast, FRA reclamation establishes “tree compatible” grasses and legumes to minimize competition with tree seedlings. In order to establish a tree-compatible ground cover, mining operators seed in a manner that differs from common grassland reclamation by:

1. using less-competitive grass and legume species,
2. using lower seeding rates,
3. using less nitrogen fertilizer, and
4. accepting a lower herbaceous ground cover in the first few years after seeding.

The result will be a lower-growing, less vigorous, sparse ground cover that allows planted tree seedlings to survive and grow, allows more invasion by plant species from nearby areas, and achieves complete cover over time (see [Figure 1a-c](#)).



**Figure 1a.** Tree-compatible ground cover in mid-summer, about three months after planting. The cover is sparse but planted trees are able to survive and grow, and native plants can seed in and become established.



**Figure 1b.** A grass-dominated ground cover that is typical of conventional grassland reclamation three years after planting. The site is fully covered, but the tree is growing at less than half its potential and is exposed to predation.



**Figure 1c.** A tree-compatible ground cover also three years after planting. The site is also fully covered, but at least half the cover is made up of native plants, including trees that seeded in via wind and wildlife. Trees are growing faster because the cover is less competitive. In and among the native plants, trees are less exposed to predation

Recommended species, seeding rates, and fertilizer rates are shown in [Table 1](#). The grass and legume species are selected to be slow and low growing, to be tolerant of low fertility and pH, and to grow in bunches rather than as a continuous cover. Legume inoculants should also be included in the planting mix so as to assure that the legumes are able to convert (“fix”) atmospheric nitrogen to plant-available forms. Recommended seeding rates are lower than those used for grassland reclamation approaches so that openings are left to allow for invasion by native plants. Lower nitrogen fertilizer rates are used to minimize ground cover height. Instead of the high-nitrogen and low-phosphorus rates used for grassland reclamation, FRA reclamation uses low nitrogen to reduce the vigor of the early-growing grasses and high phosphorus to nourish the trees for the long term. The fertilizer rates in [Table 1](#) are adequate to establish seeded grasses and legumes; as the legumes mature, they convert nitrogen from the atmosphere to plant-available forms.

Using tree-compatible ground cover as an alternative to the faster-growing grasses and legumes that are used in grassland reclamation approaches can help establish forested post-mining land uses in several ways:

- The lower-growing tree-compatible species allow more sunlight to reach the planted tree seedlings.
- The tree-compatible species withdraw water and nutrients from the soil more slowly than faster-growing agricultural grasses and legumes, leaving more of these essential resources for the planted trees.
- The tree-compatible species do not cover the ground as rapidly or completely, allowing more of the seeds that are carried to the site by wind and wildlife to land on the soil surface, germinate, and become established. In Appalachian coal-mining areas, most of these seeds are generally of native forest species.
- The tree-compatible species are less attractive to animals such as deer and rodents that may damage the planted tree seedlings through browsing or other means.

Revegetation using the FRA typically is done in two steps: 1) planting bare-root tree seedlings, and 2) hydroseeding grass and legume seeds, fertilizer, mulch, and lime if needed. Herbaceous ground cover aids in controlling erosion, but it often competes with the trees, reducing their survival and growth. Therefore, whenever possible the trees should be planted first in late winter followed by hydroseeding in the following spring, or even in the following fall if allowed by the regulatory authority. Hydroseeding over planted seedlings in the spring should be done prior to leaf formation by the trees, while any fall over-tree hydroseeding should be delayed until after tree leaves change color so as to avoid the possibility of seedling damage. Planting trees in established ground cover can reduce seedling survival, especially if the young seedlings experience drought or near-drought conditions.

**Table 1.** Recommended seeding and fertilizer application rates for FRA reclamation.

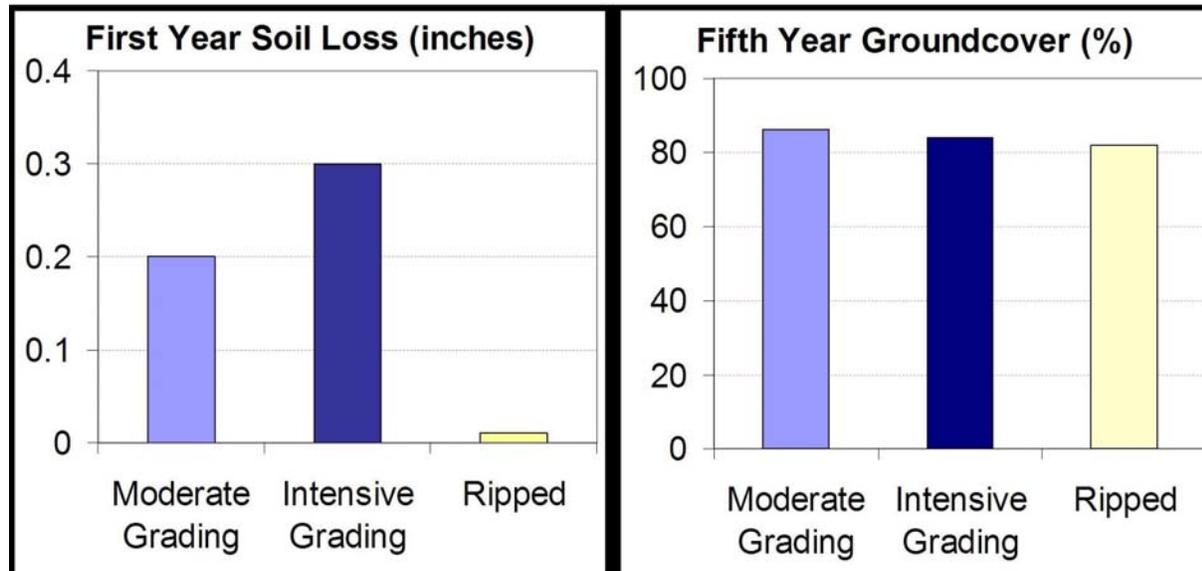
Species/Fertilizer	Rate (lbs/acre)
<b>Annual Grasses:</b>	
foxtail millet (spring seeding only)	5
annual ryegrass (fall seeding only)	10
<b>Perennial Grasses</b>	
timothy	5
perennial ryegrass	10
orchard grass (steep slopes only)	5
<b>Legumes (with inoculant):</b>	
birdsfoot trefoil	5
ladino or white clover	3
<b>Fertilizer*:</b>	
nitrogen	50 to 75
Phosphorus (as P) (as P <sub>2</sub> O <sub>5</sub> )	80 to 100 180 to 230
* Recommended fertilizer rate can be achieved by applying 400 lb./acre di-ammonium phosphate, by blending 200 lbs/acre concentrated superphosphate with 300 lbs/acre 19-19-19 fertilizer, or with other fertilizer blends.	

## FRA Ground Cover with Loose Grading Controls Erosion

The recommended seeding rates will not accelerate erosion when used in association with FRA step 2 (“Loosely grade the topsoil or topsoil substitute ...” -- see [ARRI Forest Reclamation Advisory No. 3](#)). Step 2 leaves the surface soil looser than conventional grading that compacts the soil. Loose soil allows more rapid water infiltration, which means that rainfall causes less surface runoff and more rainwater enters the soil where it can be used by plants. Thus, when the soil is not compacted, erosion can be controlled without establishing dense sod-forming ground-cover vegetation.

[Figure 2](#) shows results from a study on an active coal surface mine in eastern Kentucky (Torbert and Burger 1994). Areas of the site were graded and tracked-in using practices that were conventional at that time; some areas received “moderate grading” (two passes with a D-10 dozer), while others received “intensive grading” (three dozer passes plus tracking). Some of the graded areas were “ripped” (i.e., disturbed to a depth of about four feet by a heavy-steel single-shank ripper pulled by a D-10 dozer). The data show that the moderate grading reduced soil loss compared to intensive grading, while the rough surface created by ripping nearly eliminated soil loss. The amount of ground cover (>80 percent) was essentially the same on all treatments showing that a heavily graded, tracked-in surface is not necessary for establishing ground cover vegetation. Interpretation of these data and subsequent observations to indicate that roughly

graded, noncompacted mined land reduces and slows surface water movement, thus increasing water infiltration for plant use and reducing erosion.



**Figure 2.** (left) Ripping compacted mine soils reduced soil loss on an eastern Kentucky coal-mining site; leaving a mine soil loose and uncompacted can have a similar effect. (Right) Ground cover was adequate on both the graded and the ripped portions of the site (Torbert and Burger 1994).

### FRA Ground Cover Encourages Ecological Succession

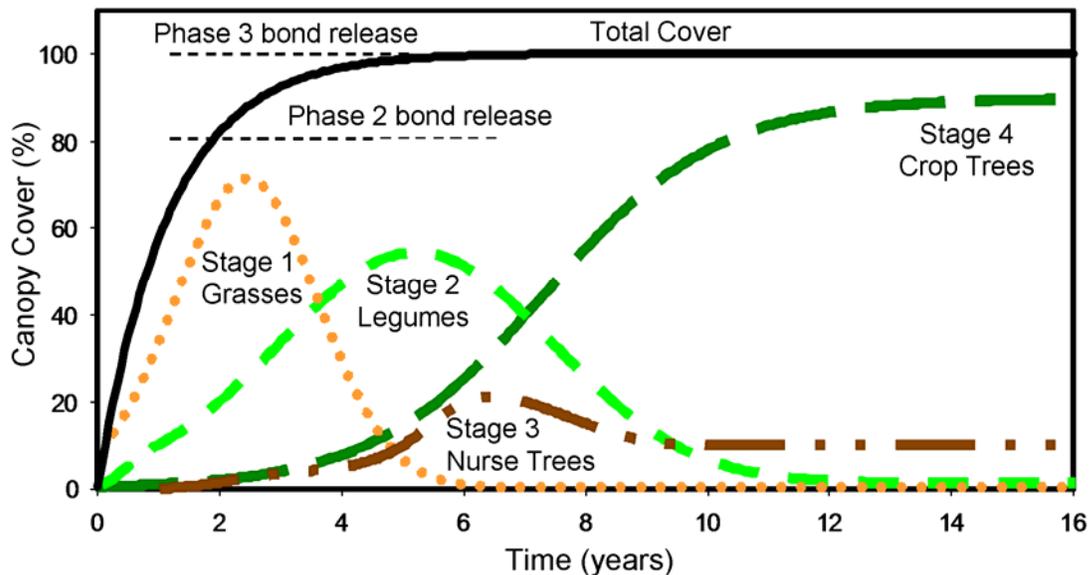
Succession is a term used to describe natural changes in plant community composition over time (see [ARRI Forest Reclamation Advisory No. 5](#)). [Figure 3](#) represents how the vegetation mix established by FRA reclamation changes through time. Four vegetation types are established during reclamation, but they grow at different rates and flourish, or dominate, at different times. Vegetative cover is provided by a combination of grasses, legumes, nurse/wildlife trees, and crop trees. As represented by the top bold line (“total cover”), the revegetation mix is designed to provide vegetative cover of at least 80 percent by the end of the second growing season and to approach 100 percent by the fifth growing season.

Four stages of plant community development occur (see [Figures 3 and 4](#)).

- Stage 1: Grasses dominate and provide most of the cover. The slow-growing, bunch-forming grasses of [Table 1](#) will be sparse at first, especially during the first year, but will produce more ground cover during the second and third years. When fertilizer nitrogen has been fully utilized, the grasses thin, creating openings for plants that are carried onto the site as seed by birds, other wildlife, and wind.
- Stage 2. Legumes dominate and provide most of the cover between years four and six. The legumes add nitrogen to the soil and are less competitive than grasses. The herbaceous legumes persist until they are shaded out by the trees.

- Stage 3: Fast-growing nurse/wildlife trees make up 10 percent to 20 percent of the total trees planted in the FRA (see [ARRI Forest Reclamation Advisory No. 2](#)). Some of these trees fix nitrogen from the atmosphere and all provide habitat for wildlife and canopy cover for erosion control. Those nurse trees that grow edible fruits and seeds attract seed-carrying birds and other wildlife, thus aiding establishment of plant species from nearby unmined areas.
- Stage 4: By the time the trees close canopy (i.e., when the tree tops grow together), the crop trees dominate and provide most of the cover. Fallen leaves and other organic litter accumulate and begin to decompose, providing additional fertility for the trees. Because trees shade much of the ground, the non-tree vegetation closer to the ground (“understory”) remains sparse. Because the hydroseeded ground cover remained sparse during the first few years, native plants including forest trees were able to invade. Thus, the plant community at this stage is comprised of many species in addition to those established intentionally by the mining firm during reclamation. Over time, the plant community has changed to become more similar to the region’s native forest.

The recommendations of [Table 1](#) are intended to establish vegetation that can aid in controlling erosion, allow invasion by native plant species for increased diversity, fix nitrogen from the atmosphere, create wildlife habitat, and develop into a productive and valuable forest dominated by native hardwoods. Experience has shown that invading species often include trees from the surrounding forest, which can help the mining firm to satisfy regulatory stem-count requirements if the mining permit describes those species as components of the post-mining land use.



**Figure 3.** This figure represents how vegetative cover changes through time when FRA reclamation is used. All four vegetation types are sown or planted during reclamation, but each type is dominant at a different stage.



**Figure 4.** Photographic examples of the four vegetative cover stages.

### **FRA Ground Cover: How it Looks and Works**

“Tree compatible” FRA ground cover ([Table 1](#)) is designed to be less competitive than grassland-reclamation ground cover. The FRA ground cover looks short and sparse on a rough-graded surface, especially during its first year. This is by design. Some miners and inspectors who are familiar with grassland reclamation may have trouble, at first, accepting the “look” of the FRA reclamation. What is important, however, is not the look but how it works. The use of tree-compatible ground cover within the FRA allows operators to establish a productive forest while meeting regulatory standards. When reforesting nonmined sites, foresters usually kill competitive grasses and weeds with herbicides as a standard practice before planting trees. Conventional mine reclamation has taken the opposite approach, sowing competitive grasses and legumes and then planting trees. Mine reclamation procedures for establishing forests differ from

those for establishing hayland pasture and other uses that require agricultural grasses. The two reclamation approaches look different because they are intended to achieve different purposes.

In a study at the Powell River Project, Burger and others (2008) demonstrated the effect of ground cover on native hardwood trees over five growing seasons. The mine soils were prepared using FRA procedures, but a “grassland reclamation approach” ground cover was seeded, as was standard practice at that time. A mix of native Appalachian trees was planted into the ground cover, and a glyphosate herbicide was applied on part of the area by spraying a three-foot diameter circle around each tree, reducing average ground cover to approximately 70 percent for the first three years. Tree survival and growth in areas that received no herbicide (full cover) were compared to sprayed areas (reduced cover).

The planting plan called for 700 trees per acre (eight-foot x eight-foot spacing): six timber-producing species (“crop trees”) at 100 per acre, and four wildlife tree species at 25 per acre. The actual numbers of trees planted were 687 and 663 per acre for the full cover and reduced cover treatments, respectively ([Table 2](#)). In Virginia, required stocking rates for “commercial forestry” are 400 crop trees and 40 wildlife trees per acre (400/40). The counts after five years were 335/80 and 394/52 trees per acre, respectively, for the full cover and reduced cover areas. The wildlife trees are a minor component of the overall stocking requirement, but they were adequately stocked in both reduced and full cover. The data suggest that several wildlife species survived better in full cover, but those in reduced cover plots may have suffered herbicide damage because of their small size when planted.

**Table 2.** Timber crop and wildlife tree stocking immediately after planting and after five years (data from Burger and others, 2008).

	<b>CROP TREES</b>						
Treatment	White Ash	Sugar Maple	Yellow Poplar	Chestnut Oak	White Oak	N. Red Oak	Total Stocking
	<b>Prescribed Stocking (trees/acre)</b>						
	100	100	100	100	100	100	600
	<b>Original Stocking after Planting (trees/acre)</b>						
<b>Full Cover</b>	100	99	95	94	84	102	574
<b>Reduced Cover</b>	84	92	94	86	78	108	542
	<b>Stocking after Five Years (trees/acre)</b>						
<b>Full Cover</b>	94	39	39	39	51	73	335
<b>Reduced Cover</b>	73	48	45	53	70	78	367
	<b>NURSE / WILDLIFE TREES</b>					<b>ALL TREES</b>	
	Crab-apple	White Pine	Silky Dogwood	Bristly Locust	Total Stocking	<b>Total Stocking</b>	
	<b>Prescribed Stocking (trees/acre)</b>					<b>Prescribed</b>	
	25	25	25	25	100	700	
	<b>Original Stocking after Planting (trees/acre)</b>					<b>Original</b>	
<b>Full Cover</b>	28	27	32	26	113	687	
<b>Reduced Cover</b>	31	33	28	29	121	663	
	<b>Stocking after Five Years (trees/acre)</b>					<b>After 5 Years</b>	
<b>Full Cover</b>	24	10	32	14	80	415	
<b>Reduced Cover</b>	9	11	26	6	52	419	

More important, the crop-tree survival on the reduced-cover plots was 69 percent of the original planting, nearly adequate to meet the regulatory target of 400 crop trees per acre (Table 3). A 70 percent survival rate is common for hardwoods in reforestation projects on nonmined land. At 69 percent survival, the commercial-forestry performance standard of 400 crop trees per acre would have been met easily if the prescribed 700 trees per acre had been planted. Furthermore, trees of several species that had not been planted, including black cherry and sycamore, became established within the reduced-cover areas. With a survival rate of only 58 percent, the full cover plots did not meet the crop tree performance standard, and would not have met it in any case.

**Table 3.** Crop and wildlife tree survival after five years, expressed as percentages of trees originally planted (data from Burger and others, 2008).

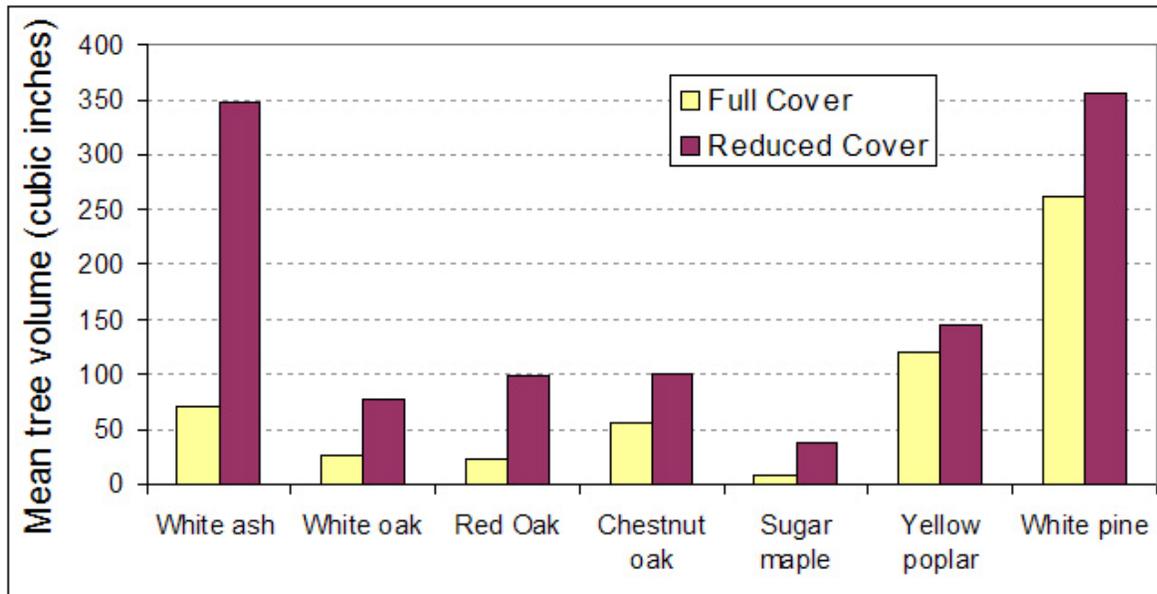
Treatment	CROP TREES Survival						
	White Ash	Sugar Maple	Yellow Poplar	Chestnut Oak	White Oak	N. Red Oak	Overall Survival
<b>Full Cover</b>	92	43	43	43	57	73	58
<b>Reduced Cover</b>	88	52	47	65	85	74	69

Treatment	NURSE / WILDLIFE TREES Survival					ALL TREES
	Crab-apple	White Pine	Silky Dogwood	Bristly Locust	Overall Survival	Overall Survival
<b>Full Cover</b>	84	38	100	61	71	<b>60</b>
<b>Reduced Cover</b>	26	28	92	20	42	<b>65</b>

Crop tree growth was also affected by the competitive ground cover ([Figure 5](#)). White ash, sugar maple, and the oaks grew two to three times larger on sites with reduced ground cover. Because all experimental areas were prepared using similar soils and grading practices, these results indicate that differences in tree growth were caused by differences in ground cover competition.

As demonstrated by these data, ground cover affects the survival and growth of native hardwood trees. Using the seeding rates of [Table 1](#) in association with the full suite of FRA reclamation practices when establishing ground cover for forested postmining land uses, allows planted trees to thrive without the application of herbicides.



**Figure 5.** Effect of reduced ground cover on tree volume after five years.

## Summary

The Forestry Reclamation Approach (FRA) is becoming more popular with mine operators and landowners as a way of reducing reclamation costs while improving the postmining land's value as productive forest (see [VCE Publication 460-123](#) and [ARRI Forest Reclamation Advisory No. 2](#)). A slow-growing, noncompetitive, tree-compatible ground cover is essential to the FRA. Such a ground cover will have a sparse "look" for the first several years, but – when used within the FRA – such ground cover controls erosion while encouraging invasion by native forest species and allowing planted trees to survive and grow.

Over the past 30 years, common reclamation practices have not established diverse, native forests on mined lands. The Forestry Reclamation Approach (FRA) is a new reclamation method that aids timely bond release, reduces costs, improves mine soil quality, improves crop-tree survival and growth, and establishes productive forests on mine sites. The use of the FRA in the eastern U.S. is supported by federal and state regulatory authorities (see [ARRI Forest Reclamation Advisory No. 1](#)).

## References

**Powell River Project / Virginia Cooperative Extension Publications:** Available from Powell River Project (<http://www.cses.vt.edu/PRP/>) and Virginia Cooperative Extension.

How to Restore Forests on Surface-Mined Land. J.A. Burger and C.E. Zipper. VCE Publication 460-123.

Maximizing the value of forests on reclaimed mined land. J.A. Burger and C.E. Zipper. VCE Publication 460-138.

Recovery of native plant communities after mining. Karen D. Holl, C.E. Zipper, J.A. Burger. VCE Publication 460-140.

Mine Permitting to Establish Productive Forests as Post-Mining Land Uses. J.A. Burger, C.E. Zipper. VCE Publication 460-141.

**Appalachian Regional Reforestation Initiative (ARRI) Publications:** Available from <http://arri.osmre.gov/FRA.htm>

Forest Reclamation Advisory No. 1: The Appalachian Regional Reforestation Initiative.

Forest Reclamation Advisory No. 2: The Forestry Reclamation Approach.

Forest Reclamation Advisory No. 3: Low Compaction Grading to Enhance Reforestation Success on Coal Surface Mines.

Forest Reclamation Advisory No. 4: Loosening Compacted Soils on Mined Sites.

Forest Reclamation Advisory No. 5: Mine Reclamation Practices to Enhance Forest Development through Natural Succession

## Research Publications

J. Burger, D. Mitchem, C. Zipper, R. Williams. 2008. Hardwood Reforestation For Phase III Bond Release: Need for Reduced Ground Cover. In: *Proceedings, National Meeting of the American Society of Mining and Reclamation*

J. Torbert, J. Burger. 1994. Influence of grading intensity on ground cover establishment, erosion, and tree establishment on steep slopes. p. 226-231. In: *International Land Reclamation and Mine Drainage Conference Vol. 3. Reclamation and Revegetation. USDOJ Bureau of Mines Special Pub. SP 06C-94*