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The Practice of "Approximate Original Contour" in the Central Appalachians. II. Economic and Environmental Consequences of an Alternative

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ABSTRACT

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Coal surface mining has had profound effects on the steeply sloping central Appalachian (U.S.A.) landscape since the early 1950s. The "shoot-and-shove" mining practices of past years resulted in a number of environmental problems. A federal law, The Surface Mining Control and Reclamation Act of 1977 (SMCRA), was passed to rectify these problems. A major provision of SMCRA is its requirement that mined lands be returned to "approximate original contour" (AOC). SMCRA has brought vast improvements in reclamation practice to central Appalachia. However, the return of surface mined lands to AOC remains highly controversial, as many criticize the environmental, economic, and land-use effects of AOC.

An alternative to conventional contour surface mining (AOC) was investigated at an experimental mining site in Wise County, Virginia. The terrain at this site is the steeply sloping "points and hollows" topography commonly found throughout the central Appalachian coalfields, and the equipment utilized was typical of haul-back mining operations throughout the region. This experimental alternative allowed all highwalls to be covered and all SMCRA performance standards (except AOC) to be met. A detailed investigation of the cost of mining and reclamation indicates that the experimental reclamation method was less costly than conventional AOC reclamation at this site. Additional favorable consequences result from implementation of the alternative method, including an improvement of the post-mining land-use potential and less-injurious environmental effects. Although AOC represents a vast improvement over the reclamation methods which preceded SMCRA, additional improvements are possible; opportunities to improve the economic and environmental consequences of coal surface mining in central Appalachia are not being realized under the prevailing AOC reclamation regime.

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INTRODUCTION

The rapid evolution of laws and regulations dealing with coal surface mining during the 1970s caused profound changes in mining and reclamation practice. In 1970, only six states had programs to regulate coal surface mines. By 1975, the number of states with regulatory programs had grown to 38 (Imhoff et al., 1976). However, the largest change occurred in 1977, when passage of The Surface Mining Control and Reclamation Act (SMCRA) initiated a complex, national regulatory system.

Perhaps nowhere has the change in mining practice been so drastic as the steeply sloping mining regions of central Appalachia, where the former "shoot-and-shove" mining techniques have been replaced, primarily by haulback mining (Bell et al., 1989). Where exposed highwalls, flat benches, and sometimes unstable outslopes had been the post-mining norm, today's mining generally returns affected areas to "approximate original contour" (AOC), eliminating all highwalls and replacing the majority of mining spoil upon stable benches (NRC, 1984).

The purpose of this paper is to examine the economic and environmental implications of the AOC provisions of SMCRA, based upon analyses performed at an experimental mining site in Wise County, Virginia.

BACKGROUND

SMCRA, with its AOC provisions, was designed to remedy problems produced by "shoot-and-shove" mining (Bell et al., 1989). Early studies (CEQ, 1973; Mathematica, 1974) identified a number of environmental problems resulting from such coal surface mining in central Appalachia. These included:

(1) Landslides, mud flows, and rock slides resulting from unstable spoil outslopes. The results of a 1964 aerial survey indicated that an estimated 12% of the total surface mined area in eastern Kentucky was in slides. By 1972, in spite of considerable tightening of Kentucky's regulatory standards, the annual eastern Kentucky slide area had increased to 400 ha.

(2) Sedimentation from mined areas, outslopes, and slide areas resulting in damage to water supplies, blockage of streams, water pollution, and other damages. Sedimentation resulted from absence or poor quality of vegetation on mined lands, primarily on the outslopes. A primary cause of poor vegetation was the tendency of pre-law mining to turn mining spoils "bottom side up", since the rock strata lying just above the coal seam were the final materials handled during the mining sequence. These strata, which generally have poor qualities for supporting vegetation, were often left exposed at the surface while natural soils were buried.

(3) Aesthetic disturbances, including flattened mountaintops, exposed highwalls ("scars in the mountainsides"), and poorly revegetated outslopes.

In many respects, SMCRA (including the AOC requirement) was a logical response. In steep-slope areas, the only way to return contour mined land to AOC is to replace the majority of the mining spoil on the solid bench left by coal removal. However, due to spoil "swell" (rock volume expansion caused by blasting and fracturing) there will generally be additional spoils that must be placed elsewhere; these are placed in excess spoil fills. Because of the landslide problems associated with pre-law mining, placement of spoil in such fills is closely regulated. The law also requires that topsoil be salvaged for surface placement, or that suitable overburden strata be placed on the surface during reclamation. Plant-toxic strata must be buried away from the surface and away from subsurface water flows. When AOC mining is properly executed in steep slope terrain, the result is usually a landscape with greater inherent stability (relative to both surface and deep-seated movements) than the "bench-outslope" terrains commonly produced in central Appalachia previous to SMCRA, with all highwalls and other "aesthetic disturbances" associated with pre-law mining eliminated.

AOC problems

However, subsequent experience has shown that problems remain. AOC reclamation can result in environmental problems when implemented in steep-slope terrain (Bell et al., 1989). These include potential instability, when AOC fills are excessively steep or when water infiltrates the fills, and excessive erosion. Although rare, slope failures have occurred. The danger is that an abnormal rainfall event, the "100 year storm", will cause additional failures of the region's prolific AOC backfills, which are steeply sloping masses of soil and rock perched in various locations on the landscape.

A complementary issue is land use. The natural landscape of the central Appalachians is far from ideal, from a human habitation standpoint. Steep slopes limit development to a small proportion of the region's total area (primarily the flat, floodplain lands adjacent to rivers and streams) and the steeply sloping landscape sheds water rapidly. Thus, many of the most heavily developed areas are subject to periodic flooding. The thin soils covering these slopes sharply limit the land's capacity to produce agricultural and timber products, and the land base is not conducive to location of industries other than mining. Hence, unemployment and poverty rates are high (Kraybill et al., 1987). Many contend that there is little sense in reconstructing the pre-mining landscape simply because it is "natural", that steep-slope surface mining operations present an opportunity to produce contours that are more desireable from both economic and environmental standpoints (Simpson, 1985). Although such activities are allowed to occur legally under the "AOC variance" provisions of SMCRA (Section 515(e)), these opportunities are seldom realized (Zipper, 1988; Zipper and Daniels, 1988).

A third issue is the cost of mining under SMCRA. A 1977 study estimated that the cost of contour surface mining in Virginia would be increased on the order of $2.93–4.40 per ton by proposed legislation, the forerunner of SMCRA which included the AOC requirements (ICF, 1977). In Virginia, annual surface mine production has declined from 14 million tons in 1977 to 7 million tons in 1987; surface mining has declined from 36 to 16% of Virginia's total coal production over this period. While this decline cannot be attributed solely to cost increases associated with SMCRA, industry representatives allege that the high cost of AOC has played a part.

Land reclamation opportunities

One unique aspect of Appalachian mining is the opportunity to construct altered landforms as a by-product of mineral extraction activities. There is an opportunity to use the extraction of a non-renewable resource (coal) to produce a renewable resource, lands with improved biological productivity and use potentials relative to the natural landscape and the landscape being produced by AOC mining, and with reduced environmental effects relative to AOC. Such activities can only be justified by a profit-making industry if they can be accomplished at reasonable cost. Since reclaimed lands are produced as a by-product of coal, the cost of land production must be assessed as an influence on the overall cost of mining.

THE CASE STUDY MINING SITE

Our study was conducted at a surface mining operation located in Wise County, Virginia (Fig. 1). The pre-mining topography con-

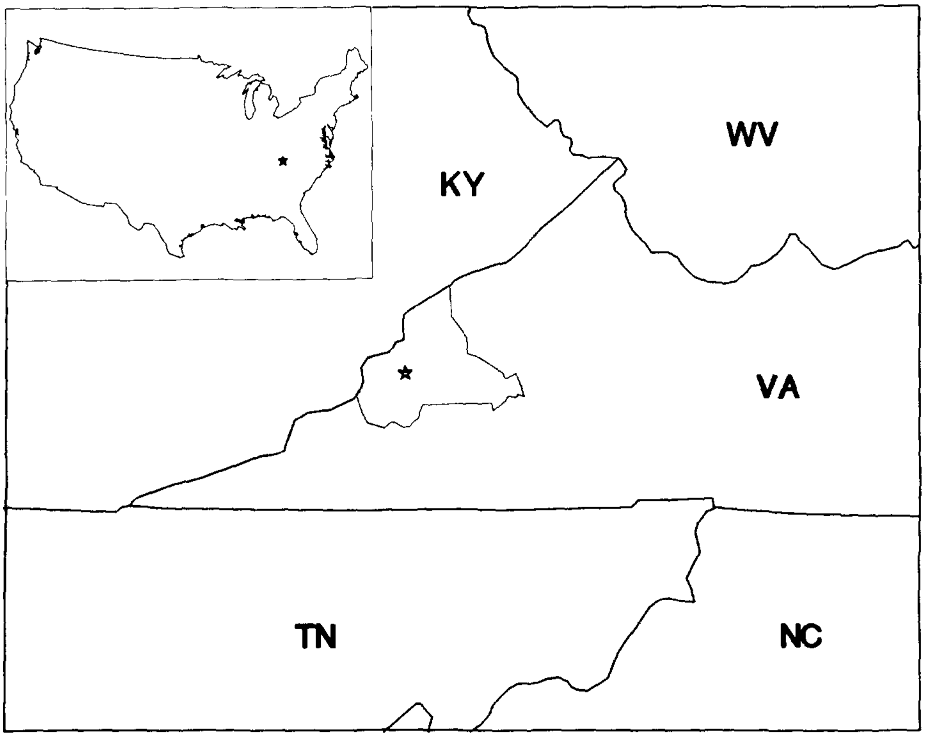

Fig. 1. The location of the case study site, in Wise County, Virginia.

sisted of a series of finger ridges protruding from a central "spine", Amos Ridge (Fig. 2). Excepting the tops of the fingers, nearly all the land being mined had slopes in excess of 20°. This type of topography is common throughout the central Appalachian mining region of south-western Virginia, eastern Kentucky, southern West Virginia, and north-eastern Tennessee.

The site at Amos Ridge was mined by the Amos Ridge Coal Company under an experimental variance from the provisions of SMCRA, obtained with cooperation of the U.S. Office Surface Mining and the Virginia Division of Mined Land Reclamation. Three excess spoil fills ("hollow fills") were constructed so that their upper surfaces are contiguous with flat areas on the tops of the finger ridges, which were not returned to their original heights (Fig. 3). The first hollow fill (HF1) was constructed using conventional durable rock hollow fill techniques (U.S. Code of Federal Regulations; 30 CFR 816.73) while HF2 and HF3 were permitted for construction using experimental techniques (Zipper, 1988). The objective of producing usable land while maintaining stability was pursued by constructing all three hollow fills with outslopes at 3:1 grades, rather than the conventional 2:1, and by constructing the final landform to include a broad, near-level bench area extending over the stripped finger points and filled hollows (Fig. 4). The site was prepared for agricultural post-mining land use (grazing and experimental plots) by using approximately 1 m of uncompacted, selected soil and spoil materials to construct plant growth media on the stable bench and hollow fill outslope surfaces (Daniels and Amos, 1984). The mining permit called for all hollow fills to be monitored for water quality, stability, compliance to construction specifications, and cost. This mining method has been termed "landform alteration" (LA) mining.

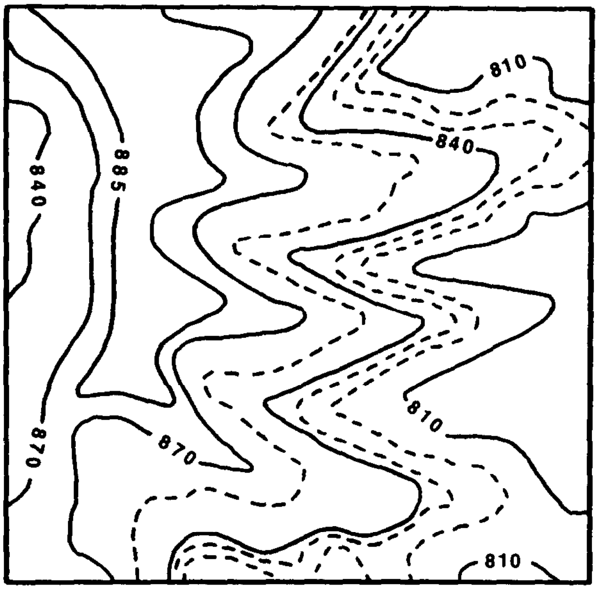

Fig. 2. Premining contours at the case study site. The area represented is 610 m^2; dashed lines represent the mined coal seam outcrops. A series of finger ridges protrude to the east from the central "spine", Amos Ridge, at the map's western edge. The hollow whose center is approximately 150 m north of the southern map border is the location of the first hollow fill (HF1).

Three seams of flat bedded coal were contour mined in sequence, from top down, and the final cuts were augered. The mining method used was typical of haul-back mining operations throughout Appalachia (Bell et al., 1989). Three primary means of spoil movement were utilized: pushing with a bulldozer, carrying with a wheel loader, and using the loader to place the materials in 50 tonne capacity haulers to be trucked to more-distant disposal areas. Reclamation activities consisted of the placement of topsoil or topsoil substitute materials at the surface, grading those materials with a dozer and seeding to establish vegetation. Due to a deep mine in the thickest of the three seams adjacent to the stripping operation, the final landform is not likely to be disturbed by re-mining in future years.

OBJECTIVES

The primary purpose of our study was to compare the cost of mining using the experimental land reclamation strategy under study, as implemented at the case study site, to the cost that would have resulted from a conventional AOC mining plan. In order to accomplish this purpose, we established the following objectives.

(1) To study active mining operations so as to determine the costs of spoil handling and reclamation on haul-back mining operations in steep-slope terrain.

(2) To develop computerized methods capable of estimating spoil handling and reclamation costs in steeply sloping topography.

(3) To use the active mining site cost data and computerized cost-estimating methods to perform the cost comparison of interest: AOC vs. LA.

In order to assess the overall impact of the alternative mining strategy, we also discuss additional economic, environmental and land-use consequences of the experimental mining plan.

METHODS

The study was initiated with visits to a number of mining sites in south-western Virginia during the summer of 1982 to gain familiarity with surface mining operations. During the summer of 1983 a system was established to record daily operations data at the Amos Ridge site (Zipper and Daniels, 1986). Data recorded over a 19-month period beginning on 1 January 1984 form the basis of this study of mining cost.

The daily operations data were supplemented by machinery performance data recorded during 1984 and 1985 at Amos Ridge and at two other contour mining sites in Wise County where conventional haul-back methods were being utilized to reconstruct AOC. The purpose for recording these data was to verify attempts to develop materials move-

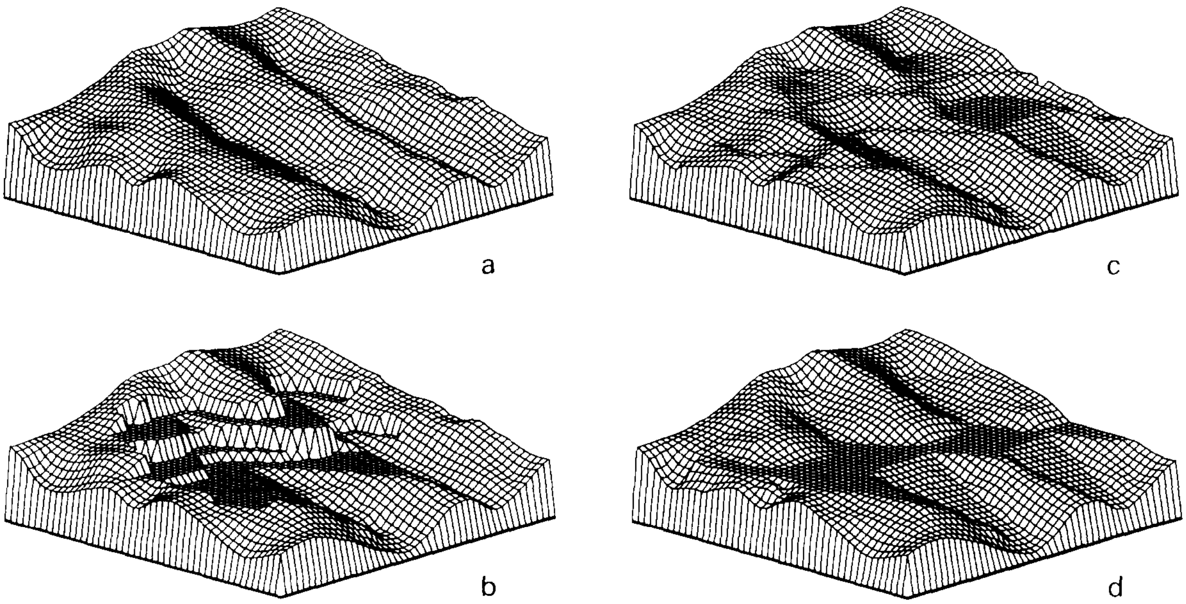

Fig. 3. Isometric representations of various topographies at Amos Ridge. The area represented is 427 m^2, located near the south-east corner of the area represented in Fig. 2, with viewpoints from the south-east. (a) The premining topography. (b) A representation of the mining disturbance during the 19-month study period. The site never actually took this appearance, since spoil removed during mining is generally replaced as close as practicable to its point of origin. (c) A likely post-mining landform had the site been mined using conventional methods, the approximate original contour (AOC) case. An access road is located approximately 11 m above the outcrop of the Lower Marker coal. Excess spoil is disposed in the first hollow above the mining bench and in the fill constructed in the second hollow. (d) The post-mining landform produce through experimental reclamation, the landform alteration (LA) case. The outslopes of HF1 and HF2 are represented by the triangular-shaped surfaces between the finger ridges. The flattened finger ridge between HF1 and the southern map border is the "near-level point area". The area mined in 1983 and reclaimed to AOC in 1984 is located south of the area represented.

ment simulation procedures. In haul-back mining operations the dominant spoil movement mode is via haul truck, so substantial efforts were devoted to monitoring haul truck performance. Timed observations of 487 haul truck cycles over 18 routes form the basis for hauler simulation procedures.

Computerized data analysis and mining simulation techniques were developed to process daily operations data and to estimate the probable cost of operations under a conventional AOC mining plan. COSTSUM is a set of seven programs designed to analyze data from active surface mining sites to determine spoil handling and reclamation costs (Zipper and Daniels, 1986). OPSIM is a surface mining simulator designed to estimate differences in spoil handling costs among reclamation and post-mining landform alternatives (Zipper et al., 1985a). An extensively modified version of OPSIM (called TOPSIM) prepared specifically for use during this study was used to estimate mining costs (Table 1). These programs were supplemented with use of CPS/PC, a software system for gridding, mapping, and analyzing three-dimensional data (Radian Corp., 1986). CPS/PC was used to estimate the spoil movement volumes required to produce specific post-mining landforms.

The actual cost of mining at Amos Ridge was estimated by analyzing daily operations data using COSTSUM (Zipper et al., 1985b). All costs were determined relative to specific mining "blocks" (individual mining area units). Simulation procedures were initiated through application of the TOPSIM model to the recorded data. Spoil movement modeling assumptions appropriate to the Amos Ridge op-

Fig. 4. An aerial view of the Amos Ridge mining site during October, 1986. The mining site is the non-forested area at the center of the photograph. The reclaimed level bench area is closest to the viewer, while highwalls exposed by active mining are visible at the center-right of the photograph. The surrounding forested mountainsides show the effect of pre-1977 mining as exposed highwalls.

eration were developed by duplicating the results of the observed LA mining strategy. Finally, these assumptions were applied to the simulation of an AOC mining plan, assuming an identical area would be mined.

Insofar as possible identical spoil movement modeling assumptions were used in both the LA and the AOC cases (Zipper, 1986). All mathematical factors defining spoil movement were kept constant between the two cases, consistent with the COSTSUM data, except in situations where such assumptions were clearly inappropriate due to the physical differences between the two mining plans. The modeled components of the mining operation primarily included spoil movement. Although spoil movement costs are the dominant components of overall mining cost, differences between the two mining methods included factors other than spoil movement. Modeling results were adjusted accordingly.

RESULTS

Observed costs

During the period of study, approximately 12 ha were disturbed by mining (Fig. 3). HF1 was completed during this period, while approximately 50% of the spoil volume required to complete HF2 was placed. The flat bench over the point south of HF1 was constructed and reclaimed, as were the highwall backfills west of HF1. In addition, reclamation of AOC highwall backfills located directly south of the experimental practice site (areas which were

TABLE 1

Surface mining operations modeled by the mining simulator TOPSIM in order of execution

Order	Machine(s)	Operation
1	Dozer	Prepare for drilling[1]
2	Drill	Drill blastholes
3	Dozer	Push overburden
4	Loader (and dozer)	Carry overburden (with or without dozer assist)[2]
5	Loader and hauler(s) (and dozer)	Load and haul overburden (with or without dozer assist)[2]
6	Coal	Prepare coal for loading[1]
7	Loader	Load coal into contract haulers

[1]Time requirement input directly by user.
[2]Dozer time input as fraction of loader time.

TABLE 2

Components of cost of handling the "average" bank m³ of overburden at Amos Ridge[1]

Component		$ per bank m³
Clear and bench		0.02
Drill and blast		0.53
Carry and push		0.26
Load and haul		
Dozer feed	0.09	
Loading	0.45	
Hauling	0.49	
Dumpsite	0.12	
Total		1.15
Reclamation		0.10
Overhead		0.40
Total		2.46

[1]Note: a bank m³ is a measure of overburden volume before blasting and associated swell.

mined and partially backfilled during 1983) was completed.

The results of the study of mining costs at Amos Ridge were previously reported in detail (Zipper et al., 1985b). In summary, the average cost of spoil handling at Amos Ridge between 1 January 1984 and 1 August 1985 was estimated at $2.46 per bank m³ (Table 2). However, spoil handling costs varied widely between mining blocks. The major factors influencing spoil handling cost were ease of overburden handling, as related to landscape position, the proportion of total spoil moved by hauler, and the distance to hauler disposal areas. On average, it cost more to move spoil by hauler than by pushing with a dozer or carrying with a loader. The data were consistent with expectations based upon on-site observations and discussions with experienced mining operators.

Reclamation costs varied between reclamation areas (Zipper, 1986). The first hollow fill (HF1) was the most expensive area to reclaim, due to the costs of preparing an unmined area for spoil placement and the detailed surface grading required to control surface waters ($0.25 per bank m³ of spoil disposal volume). Of the three backfilled reclamation areas, the flat bench south of HF1 was the least expensive to reclaim ($0.05 per bank m³), while the two highwall backfill areas incurred greater reclamation costs ($0.07 per bank m³ west of HF1, and $0.11 per bank m³ south of the experimental practice area). Costs included in the reclamation cost category included vegetation and topsoil removal from the hollow fill, working dumped materials to appropriate configurations, surface drain construction, finish grading, and revegetation.

Simulation verification

Efforts to simulate mining procedures used to construct the LA landform showed that TOPSIM was able to simulate the drilling, dozer push, and loader carry operations so as to produce costs nearly identical to the observed costs, as calculated by COSTSUM (Table 3). The total simulated mining cost was 89% of the recorded cost, a level of agreement considered as excellent by industry personnel.

The TOPSIM-estimated LA hauling cost was 84% of the recorded hauling cost. Analysis of simulated hauler performance over observed routes showed that wet, foggy weather and muddy road conditions had a strong, negative

TABLE 3

Comparison of estimates of soil handling costs and spoil volumes at Amos Ridge: actual (COSTSUM–LA) vs. simulated (TOPSIM), by post-mining landform (LA vs. AOC)

	COSTSUM–LA	TOPSIM–LA	TOPSIM–AOC
Total cost ($)			
Drill	149 026	150 041	149 998
Push and carry	141 659	140 648	108 531
Dozer push		48 378	38 757
Loader carry		92 270	69 774
Load and haul	574 184	483 070	563 370
Total[1]	864 869	773 759	821 899
Volume (bank m^3)			
Drilled	552 910	553 043	553 036
Moved via			
Dozer push	78 510	78 520	66 205
Loader carry	89 921	89 891	72 047
Load and haul	387 232	387 360	417 523
Total moved[1]	555 663	555 772	555 775
Cost ($ per bank m^3)			
Drill	0.27	0.27	0.27
Push and carry	0.84	0.84	0.79
Dozer push		0.62	0.59
Loader carry		1.03	0.97
Load and haul	1.48	1.25	1.35
Total[1]	1.56	1.39	1.48

[1]Note: columns may not add up to totals due to rounding.

effect upon hauler performance (Caterpillar Tractor Co., 1984, 1985; Zipper, 1986). The hauler "efficiency" over a given route was defined as the ratio of a simulated "optimum" hauler cycle time over a given route (assuming maximum driver and machine performance) to the observed cycle time. Whereas the overall average efficiency was 62%, the average efficiency during the 7% of total observations representing poor weather and muddy road conditions was 34%.

Because of our tendency to avoid the mining site on bad weather days, our data sample was biased towards favorable weather and road conditions. We believe that this unintended bias is responsible for the lack of greater accuracy of hauler simulation. This observation was confirmed by comparing actual hauling rates over individual routes (loads per h, as recorded in the daily operations data) with the simulated hauling rates over those same routes. Poor weather conditions were frequently found to coincide with hauling over routes where relatively low rates were recorded.

Simulation results

The simulated cost of mining over the 19-month study period using conventional AOC techniques exceeded the simulated LA mining plan cost by approximately $48 000, or $0.09 per bank m^3 of overburden handled (Table 3). The simulated drilling cost did not change, due to the assumption that identical areas would be mined in each case. The total cost of moving spoil via dozer push and loader carry operations was estimated to decline with implementation of the AOC mining plan since

TABLE 4

Adjustment of TOPSIM-estimated cost difference between landform alternatives due to non-modeled factors, liberal and conservative assumptions

Factor	Liberal assumption ($)	Conservative assumption ($)
Spoil handling cost difference (AOC>LA)	48 140	40 140
HF1 costs		
Design (3 engineer work days plus one draftsman work day)	−1000	−1000
Bonding	−200[1]	−2000[2]
Construction and reclamation	−31 000	−32 000
Reclamation of mined area covered by HF1 (approx. 0.5 ha, \$6500 ha^{-1})	+3250	+3250
Additional grading costs, AOC slopes south HF1 (approx. 1 ha. \$2500 ha^{-1})	+2500	+2500
Work road and dumpsites, AOC slopes south of HF1 (approx. 170 000 bank m^3)	+5500	+400
Weather-related hauling delays	+15 000	
Total	42 190	11 290
Total per tonne	0.64	0.17

[1]Participation in Virginia Surface Mine Reclamation Fund (bonding pool) at \$3700 ha^{-1}, assuming 60% release after 3 years, 80% release after 5 years, full release after 8 years; \$12.50 per \$1000 per annum bonding fee.
[2]Standard performance bond, \$37 000 ha^{-1}, other assumptions as above.

smaller quantities of spoil could be pushed or carried to adjacent areas, primarily due to the loss of HF1 as a nearby spoil disposal area. However, hauling cost increased substantially with the implementation of the AOC mining plan.

There are two primary reasons for the large difference in hauling cost between the mining procedures used to construct the LA and AOC landforms. The first is the difference in quantities of material hauled. Since less material was carried and pushed, more had to be hauled in order to construct the AOC landform. This effect occurred throughout the mining area. The AOC mining plan caused increases in hauled volumes from nine of 23 mining blocks. Second is the difference in cost per m^3 hauled. The major difference between the two mining plans is that spoil which was disposed in HF1 in the LA case had to be used, for the most part, to reconstruct the mined point south of HF1 in the AOC case. Spoil which had been moved laterally and downward to HF1 would have been moved upward had the AOC mining plan been implemented. Per-cubic-meter cost differences are most distinct for blocks where large quantities of material had to be hauled to the highwall backfill and rebuilt point areas. Again, this difference was fairly well distributed throughout the mining area, as per m^3 hauling cost increases were estimated for 13 of 23 mining blocks.

Adjustment of simulated cost differences

The primary quantifiable costs not included in the simulation procedures were reclamation costs and permitting costs associated with HF1 (Table 4). The major cost adjustment is the result of HF1 not being required for excess spoil disposal in the AOC case. Thus, all costs required to design, permit, and construct HF1, aside from the cost to remove spoil from the coal pits into the fill, were subtracted from the simulated cost difference. However, this cost adjustment itself requires modification, due to the greater area of steep slopes and associated reclamation expenses on the AOC landform. The costs of maintaining haul roads and dumpsites while rebuilding the AOC area south of HF1 were not included in simulation analyses. An estimate of a reasonable range of road and dumpsite maintenance costs was developed from the recorded costs of performing these operations.

The final adjustment is for weather-related hauling delays. This adjustment comes from the observation that hauler efficiencies tend to drop drastically in damp, foggy weather, particularly on the steeper hauling routes. The effects of poor weather were not adequately represented in simulation procedures. The $15 000 "liberal" estimate is calculated by assuming that the adequate representation of poor weather in hauler simulation procedures would increase the simulated LA hauling cost by 19% to $574 000 while also increasing the AOC hauling cost by an identical 19% factor. This may actually be an underestimate of the effect of poor weather on AOC hauling cost, due to the increased incidence of steep, uphill hauling in the AOC mining plan.

The results of this analysis indicate that the Amos Ridge mining operation would have required greater expense had the land been reclaimed to an AOC landform. Thus, a logical conclusion is that, if the mining operation had been conducted in more conventional fashion, the economics of spoil handling would have restricted the mining to the more favorable cuts; coal that was mined in order to produce the LA landform likely would have been left in the ground had a conventional AOC reclamation program been implemented.

DISCUSSION

During the course of on-site investigations at Amos Ridge and other locales, we came to recognize a number of differences in the consequences of constructing AOC, versus the LA landform alternative, effects which could not be quantified through simulation procedures or estimated from the operations data recorded at the site.

Mining cost

The major non-quantifiable cost effects of using LA mining techniques, rather than AOC techniques, result from a reduction in the requirements to operate heavy equipment on steeply sloping surfaces during mining and reclamation operations. A major effect is a reduction in the wear and tear on equipment. The reduction in steep-slope operations required by the LA mining plan is expected to decrease fuel consumption and equipment maintenance and repair costs, and to extend the useful life of machinery. The data indicate that the cost of owning and operating equipment, exclusive of operator wages, is by far the largest expense of the operation. Over the 1984 fiscal year, these costs made up 49% of the total expenses of the Amos Ridge Coal Co. Operator comments and observations at a number of conventional haulback mining sites indicated that breakdowns are more frequent during steep-slope operations.

The implementation of the LA mining plan also increases operational flexibility. The fact that extensive, near-level surfaces are being constructed, rather than steeply sloping AOC backfills, allows equipment storage and maintenance facilities and supplies to be located in a large, contiguous area adjacent to mining operations. Extensive, flat areas are not typically available on AOC contour mining sites.

The availability of extensive flat areas during implementation of an LA mining and reclamation plan also influences operations. Spoil disposal problems are reduced and spoil handling flexibility is increased. The spoil disposal capacity of a stable AOC backfill is rigidly defined. Thus, miscalculations of spoil volume and swell, backfill capacities, or the capacities of excess spoil disposal facilities (non-backfilled spoil disposal areas, such as the hollow fills used at Amos Ridge), can have costly consequences in an AOC mining regime. On occasion, this lack of spoil-handling flexibility can result in a "spoil-bound" condition, where the overburden swell causes the highwall backfill to closely approach the active mining pits and restrict spoil movement options. Such would have been the case at the Amos Ridge site, had the simulated AOC mining plan been implemented.

In contrast, volumetric adjustments are much more easily made in the LA mining plan through adjustment of the elevation of the near-level bench surface. Similarly, the operator's ability to selectively place overburden materials during spoil disposal operations is increased, due to the availability of multiple spoil disposal areas (Zipper, 1986). In addition, the reduced incidence of steep up-hill hauling enhances operator's ability to operate efficiently by confining such activities to times when they are not hindered by weather conditions.

Land use

The LA mining practice enhances the post-mining land-use potential of the reclaimed area in two ways: by producing landforms with near-level areas, and by enabling the operator to isolate favorable materials for surface placement at minimal expense. Thus, the post-mining productivity of the site is enhanced by the reclamation operations.

Beneficial uses of appropriately reclaimed mine sites can include non-flood-prone housing, industrial, and commercial sites; the availability of lands suitable for such uses is limited throughout the central Appalachian coalfields.

Reclaimed mine sites will support livestock and softwood timber production enterprises (Zipper, 1987). The construction of LA landforms will enhance the economics of these post-mining land uses in a number of ways. Of course, favorable surfaces and productive soils will assist profitable establishment. Not so obvious, however, is the problem of maintaining access to steeply sloping reclaimed areas in extensive use. Access roads cutting across such slopes will tend to concentrate downslope runoff, resulting in maintenance difficulties and expenses. A road surface constructed so as to be slightly elevated above a level surface can be maintained more easily over the long term.

Environmental effects

The environmental effects of properly constructed altered landforms would be less injurious than those of steep slopes reclaimed to AOC (Bell et al., 1989). The chances of slope failure are reduced by LA mining strategies, since the areas of reconstructed steep slopes are themselves reduced. The increased spoil-handling flexibility reduces the economic incentives to produce unstable convex AOC slopes. If an unstable highwall backfill were to be produced during LA mining procedures, the existence of the broad bench at the base of the backfills will limit off-site effects.

Erosion of surface soil from the reclaimed landscape would also be reduced by implementation of the LA mining strategy, relative to the results of AOC. Erosion is favored by long, uninterrupted steep slopes and by high surface silt contents (Bell et al., 1989). The incidence of steep slopes as a proportion of total area is reduced by the LA mining strategy. The majority of the steep slopes that are produced are interrupted by the bench constructed at the slope base (Fig. 3). The increased spoil-handling flexibility afforded the operator by the LA mining plan increases his ability to limit the silt content of materials placed on the backfill surfaces.

An associated hydrologic consequence of the LA mining strategy will be a reduction in rainfall runoff, relative to AOC. Infiltration of incident rainfall will be favored by non-sloping, porous (i.e. uncompacted) land surfaces. In addition, a portion of the surface water moving downslope from the highwall backfills will be dispersed to infiltrate the bench surface, while the construction of deep, loose soils upon that surface will also enhance the landscape's water retention capacity. The net effect of a conscientiously performed LA reclamation strategy will be to decrease stream peak flows and increase base flows, a definite benefit in flood-prone watersheds. This situation occurs in contrast to the AOC landform, where the only interruption of long backfilled slopes is often an abandoned haul road, which tends to concentrate runoff.

Advantages of AOC

There is one environmental advantage to the AOC reclamation strategy, relative to the LA strategy. That is: due to less incidence of hollow fills, less area is disturbed by the AOC mining strategy – only if unstable backfills do not adversely affect downslope unmined areas. At the Amos Ridge site, the LA mining plan disturbs approximately 10% more land than the AOC alternative.

CONCLUSIONS

Although the advent of AOC reclamation in steeply sloping mining regions has resulted in a general improvement of reclamation practice, relative to pre-law "shoot-and-shove" methods, additional improvements are possible. Problems with AOC reclamation include potential negative environmental effects, high costs, and the failure of the AOC reclamation to ease the region's land-use restrictions.

An alternative reclamation strategy is available for application in steeply sloping Appalachian contour mining situations. When conscientiously implemented in appropriate terrain, LA mining practices are capable of producing reclaimed lands with reduced environmental impacts and increased land-use potentials, relative to AOC.

Research results reported here indicate that, at a case study site in Wise County, Virginia, implementation of this procedure resulted in a cost savings to the mining operator. The case study site is similar, in many respects, to contour surface mining locations and operations throughout central Appalachia.

If the current legal and regulatory framework were to allow mining firms a choice of alternative reclamation strategies (AOC vs. LA as demonstrated at Amos Ridge), it is highly likely that there would be situations where LA procedures would be chosen. Results would include an improved central Appalachian landscape, in terms of the requirements of human habitation, and reduced environmental impacts of mining.

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REFERENCES

Bell, J.C., Daniels, W.L. and Zipper, C.E., 1989. The practice of "approximate original contour" in the central Appalachians. 1. Slope stability and erosion potential. Landscape Urban Plann., 18: 127–138.

Caterpillar Tractor Co., 1984. VEHSIM Hauling Unit Simulation. Peoria, IL.

Caterpillar Tractor Co., 1985. Caterpillar Performance Handbook, 16th edn., Peoria, IL.

Council on Environmental Quality (CEQ), 1973. Coal Surface Mining and Reclamation –An Environmental and Economic Assessment of Alternatives. Prepared for US Senate Committee on Insular Affairs, Serial No. 93-8 (92-43). U.S. Government Printing Office, Washington, DC, 143 pp.

Daniels, W.L. and Amos, D.F., 1984. Generating productive topsoil substitutes from hard rock overburden in the southern Appalachian. Environ. Geochem. Health, 7: 8–15.

ICF. Inc., 1977. Energy and Economic Impacts of H.R. 13950 (Surface Mining Control and Reclamation Act of 1986).

ICF, Inc., Washington, DC (National Technical Information Service PB-274 632).
Imhoff, E.A., Friz, T.O. and LaFevers, J.R., 1976. A Guide to State Programs for the Reclamation of Surface Mined Areas. Circular 731, U.S. Geological Survey, Arlington, VA, 29 pp.
Kraybill, D.S., Johnson, T.G. and Deaton, B.J., 1987. Income Uncertainty and Quality of Life – A Socioeconomic Study of Virginia's Coal Counties. Bulletin 87-4, Virginia Agricultural Experiment Station, Blacksburg, VA, 87 pp.
Mathematica, Inc., 1974. Design of Surface Mining Systems in Eastern Kentucky, Vol. 1, Prepared for Appalachian Regional Commission and Kentucky Department of Natural Resources (National Technical Information Service *PB 242 651) 82 pp.*
National Research Council (NRC), 1984. Highwall Elimination and Return to Approximate Original Contour as Required in the Surface Mining Control and Reclamation Act of 1977. Committee on Highwalls and Approximate Original Contour, Board on Minerals and Energy Resources, Commission on Natural Resources. National Academy Press, Washington, DC.
Radian Corporation, 1986. CPS/PC – Advanced Software System for Gridding, Contouring, Mapping, and Analysis. Austin, TX.
Simpson, J.W., 1985. The emotional landscape and Public Law 95-87. Landscape Archit., May–June, 75(3): 60–63.
Zipper, C.E., 1986. Opportunities for Improved Surface Mine Reclamation in the Central Appalachian Coal Region. Ph.D. Dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA, 128 pp.
Zipper, C.E., 1987. An Economic Analysis of Beef Cow–Calf Operations and Eastern White Pine Timber Plantations on Surface Mined Lands in Southwestern Virginia. M.S. Research Paper, Virginia Polytechnic Institute and State University, Blacksburg, VA, 120 pp.
Zipper, C.E., 1988. Amos Ridge Experimental Practice – Final Report. Submitted to U.S. Office of Surface Mining Reclamation and Enforcement, Eastern Field Office, Pittsburgh, PA. Contract EC68-PO8-12867, 76 pp.
Zipper, C.E. and Daniels, W.L., 1988. Institutional Constraints to Production of Reclaimed Mine Lands Suitable for Development in Central Appalachia. In: Mine Drainage and Surface Mine Reclamation, Vol. II. Abandoned Mine Lands and Policy Issues. U.S. Bureau of Mines Circular 1984, pp. 302–307.
Zipper, C.E. and Daniels, W.L., 1986. COSTSUM: A System for Analysis of Operational Cost Data from Coal Surface Mines – A User's Guide. Virginia Agricultural Experiment Station Bulletin 86-1, Virginia Agricultural Experiment Station, Blacksburg, VA.
Zipper, C.E., Chakraborty, A., Topuz, E. and Daniels, W.L., 1985a. A Surface Mining Simulator for Application in Steep Slope Topography. In: Proceedings, 1985 National Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. University of Kentucky, Lexington, KY, pp. 25–28.
Zipper, C.E., Hall, A.T. and Daniels, W.L., 1985b. Costs of Mining and Reclamation of a Contour Surface Mine in Steep Slope Topography. In: Proceedings, 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. University of Kentucky, Lexington, KY, pp. 193–200.