HOLLOW FILL CONSTRUCTION AT THE AMOS RIDGE EXPERIMENTAL PRACTICE[1]

Carl E. Zipper and W. Lee Daniels[2]

Abstract: Between January, 1984, and October, 1988, the Amos Ridge Coal Company performed contour surface mining operations in steeply-sloping terrain under an experimental practice variance from the requirements of SMCRA, as implemented by the Virginia Coal Surface Mining Regulations. The objective of the experimental practice was to investigate the feasibility of experimental spoil handling practices. All environmental performance standards of SMCRA were met, with the exception of those regulations dealing with the construction of hollow fills and the restoration of approximate original contour. Three different hollow fill construction methods were used; one conforming to OSMRE and Virginia regulations, and two using experimental techniques. An intensive data collection program documented economic, operational, and environmental consequences of the mining and reclamation procedures utilized. The results indicate that spoil was handled in cost-effective and environmentally sound fashion, in spite of departure from procedures specified by SMCRA. Analysis of costs of constructing hollow fills indicate distinct differences in the per-cubic-yard costs of spoil disposal among the three fill designs utilized. An experimental hollow fill design, using a rock core chimney drain, appeared to be more cost effective than either of the other two fill designs. However, elapsed time since completion of the fills is not sufficient to compare long-term environmental impacts.

Additional Key Words: Surface Mining Control and Reclamation Act, Excess Spoil Disposal, Reclamation Costs, Steep-slope mining.

Introduction

The Amos Ridge Coal Company performed contour surface mining operations in a steeply-sloping section of Wise County, Virginia, over a period extending from the 1960s to the late 1980s. Between January, 1984, and October, 1988, mining operations were conducted under a permit specifying an experimental practice variance from the requirements of the Surface Mining Control and Reclamation Act (SMCRA).

The purpose of the experimental practice was to investigate the feasibility of spoil handling practices other than those required by SMCRA and the Virginia Coal Surface Mining Regulations implementing SMCRA. The practices investigated were alternatives to standard hollow fill construction techniques and the restoration of approximate orginal contour. The post-mining landform includes a large flat bench area, extending over the three hollow fills and the adjacent points which were not restored to their original heights after mining. The upper surface of this bench area was constructed using a thick layer of uncompacted soil and spoil materials, selected and placed to maximize plant growth potential. The resultant landform is suitable for a wider variety of economically-valued land uses than the steeply-sloping premining topography.

The purpose of this report is to summarize the results of observations and analyses at the experimental practice mining site over the 1984 - 1988 period, with special emphasis on those results comparing the costs of hollow fill construction. Personnel from Virginia Polytechnic Institute and State University, representing the Powell River Project, monitored mining and reclamation operations at Amos Ridge throughout the experimental practice period.

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The Experimental Practice

The experimental practice variance was obtained in accordance with the requirements of Section 711 of SMCRA, with the cooperation of the Virginia Division of Mined Land Reclamation and the U.S. Office of Surface Mining Reclamation and Enforcement. The objectives of the experimental practice as stated in the permit application were to:

1. investigate the economic and engineering feasibility of constructing excess spoil fills using alternatives to procedures specified in the then-current Virginia Coal Surface Mining Regulations.
2. determine the long run impacts of this and similar practices on the environment and the southwest Virginia coal industry.
3. produce a carefully constructed surface mined area of higher land use value for use in the ongoing reclamation research program of the Powell River Project.

There were two distinct components to the experimental spoil handling procedures employed in reclaiming the mining site; both were essential to the ultimate result: a stable, environmentally-sound landform with an improved land use potential, relative to the steeply-sloping pre-mining landform (Fig. 1).

Experimental hollow fill construction procedures were employed at the Amos Ridge mining site. A major purpose of the experimental practice was to determine the feasibility of using construction techniques other than those specified in Virginia Coal Surface Mining Regulations V816.71 (which corresponds to federal regulations 30CFR 816.71) for the disposal of excess spoil. In carrying out this experiment, one excess spoil fill was constructed using standard design practices, and two fills were constructed using experimental techniques.

The mining operation also was conducted with a variance from the "approximate original contour" (AOC) provisions of SMCRA. This variance was obtained by meeting the requirements of Section 515(e) of SMCRA. Variance from AOC was an essential component of the experimental mining method investigated at Amos Ridge, where the pre-mining topography consisted of a series of finger ridges protruding from the central "spine" of Amos Ridge. This type of topography is common throughout central Appalachia. Excepting the tops of the fingers, nearly all the land being mined slopes in excess of 20 degrees. Thus, the Amos Ridge mining operation constitutes steep slope mining as defined by SMCRA.

Figure 1. An aerial photograph of the Amos Ridge site in October, 1987. Active mining is shown on the right side of the photo; reclaimed areas are located left of the active mining area. The outslopes of HF1 and HF2 are visible in the reclaimed area; HF3 was under construction at this time. Exposed highwalls above and below the mining site are the result of pre-1977 mining. Experimental plots are visible on the level bench area to the immediate left of HF1.

Contour mining was conducted across four finger ridges and three intervening hollows while removing three seams of coal (the Low Splint seam, and its Upper and Lower Markers) running through the upper fraction of these ridges. Rather than completely rebuild the finger ridges to their approximate original contours, the firm used spoil generated from the finger ridges to construct three hollow fills. The result is a relatively large near-level "bench" (approximately 12 of the 72 acres under permit), a terrace-like landform extending over the stripped fingers and filled hollows. The objective of producing a usable, stable landform was pursued by constructing the hollow fill outslopes at

3:1 grades (rather than the maximum-allowable 2:1 [30CFR 816.71]) and by building plant growth media with selected, uncompacted soil and spoil materials. All highwalls were backfilled. With the exception of the AOC and hollow fill construction provisions, all SMCRA performance standards and Virginia regulatory standards were met.

Economic, environmental, and regulatory implications of the AOC variance have been summarized elsewhere (Daniels et al., 1989; Zipper et al., 1985, 1988, 1989a, 1989b). The primary purpose of this manuscript is to review results of monitoring hollow fill construction.

Data Collection

Over the January 1, 1984 - April 15, 1988 period, the mining site was visited at least one day per month. Four additional site visits were made, for data collection purposes, in May, July, and August, 1988, and in October, 1988, when reclamation had been totally completed. During these visits to the site, a variety of data were collected.

Photographs (35mm slides) were taken each month. These photos were numbered, described, and submitted to OSMRE with monthly reports. Many of the photos were taken from pre-defined "photo points", locations on the landscape providing an excellent view of one or more areas of mining operations. The month-by-month sequences of photos taken from these points provide a visual record of mining operations.

Daily records of machinery operation and mining progress were maintained by the operator on forms provided specifically for this purpose. During each site visit, a package of completed forms was picked up and a fresh package delivered. All operations lasting 20 minutes or longer were recorded on the forms. The data forms were supplemented with a site map on which the mining operator used symbols to depict mining operations. Data were kept continuously in this fashion over the entire 1984-1988 period. Locations were specified with reference to mining blocks, which were defined and numbered as appropriate at the site.

Hauler load counts were maintained by the hauler drivers between August, 1984 and April, 1988. Each hauler was outfitted with pencils, a clipboard, a calendar, and a hand-operated counter. The drivers were asked to count and record the number of loads hauled each day. Marked calendars were retrieved and replaced during monthly visits.

Selected site measurements were taken during the most intensive period of observation, between January, 1984, and August, 1985. The objective of these measurements was to accurately estimate overburden volumes.

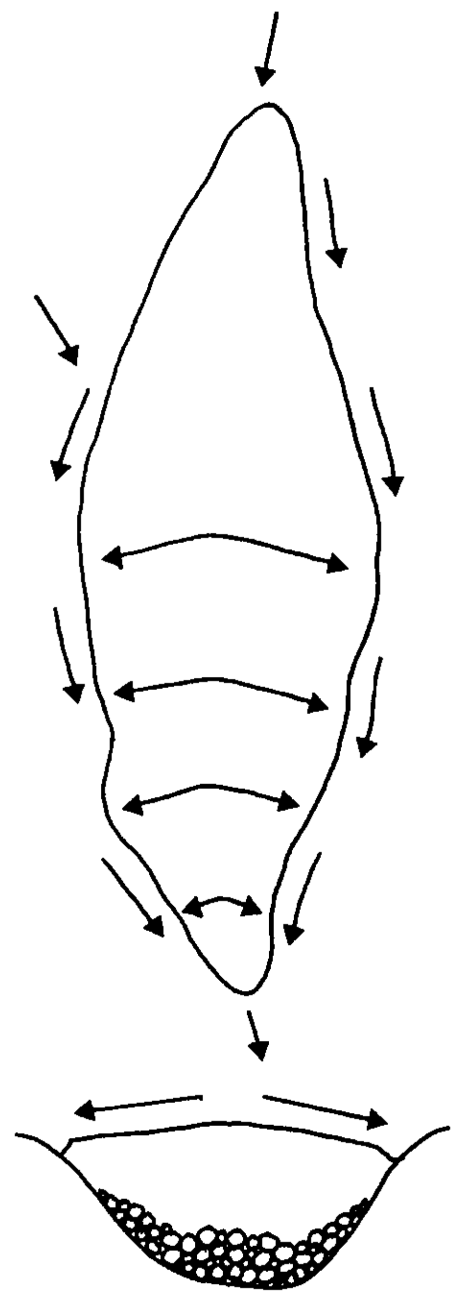

Figure 2. Plan and cross-section drawings of Hollow Fill 1. Drawings are not to scale. Arrows indicate directions of surface drainage flow.

Data on unit operations were also recorded, as appropriate. Operations timed and measured included blasthole drilling rates, and overburden movement by dozers, loaders, and haulers. Again, these data were recorded during the 1984-1985 period.

Observations on mining progress were recorded. Mining progress was discussed with the operator. These observations were summarized and recorded in the inspection reports submitted to OSMRE.

Pneumatic piezometers were installed in the base of the hollow fills, to determine subsurface pore pressures.

Water quality data were collected by Amos Ridge Mining Co. as required by the Virginia Coal Surface Mining Reclamation Regulations. Four sampling points were defined, including the outflows of the three hollow fills.

The Hollow Fills

Construction Procedures

Hollow Fill 1 (HF1) was constructed as a conventional durable rock fill (Fig. 2), as described in Virginia Coal Surface Mining Reclamation Regulation V816.73. These regulations correspond to federal regulations 30CFR 816.73. The total fill contains greater than 80% durable rock. Segregation of spoil at the mining pit was practiced throughout the fill construction period in order to acheive this 80% durable rock standard. The fill was end dumped in lifts approximately 50 to 75 feet in thickness. A blanket drain was constructed by segregating large, durable rocks and by placing these rocks into the fill using end dumping procedures during construction of the bottom lift. The outslope was constructed at a 3:1 grade, with terraces at 50 foot vertical intervals. The outslope was crowned, to lead water to the surface drains at either edge. Surface runoff from the landscape above was directed to the diversion adjacent to the fill's north face.

Hollow Fill 2 (HF2) and Hollow Fill 3 (HF3) were both permitted for construction using experimental procedures. Both were permitted for less than 80% durable rock, with the minimum durable rock content specified at 50% to 55% respectively. Both fills were permitted as variances to the V816.73 durable rock fill construction standards.

Hollow fill 2 was constructed using a rock core chimney drain (Fig. 3) This drain was constructed according the standards of V816.72(b), which defines procedures for rock-core chimney drains in fills with volumes less than 250,000 cubic yards, although the fill's design volume was in excess this maximum capacity. Also, surface drainage water from the fill itself, and from the watershed above, is diverted through the chimney drain, rather than around the fill as is normally required by V816.73(f). Thus, the chimney drain system is dual purpose, serving as an internal drainage system and to carry surface drainage. The outslope was constructed at a 3:1 grade, with terraces at 50 foot vertical intervals. The outslope was not crowned; rather, terraces drain to the outcrop of the chimney drain, at the east-west center line of the fill.

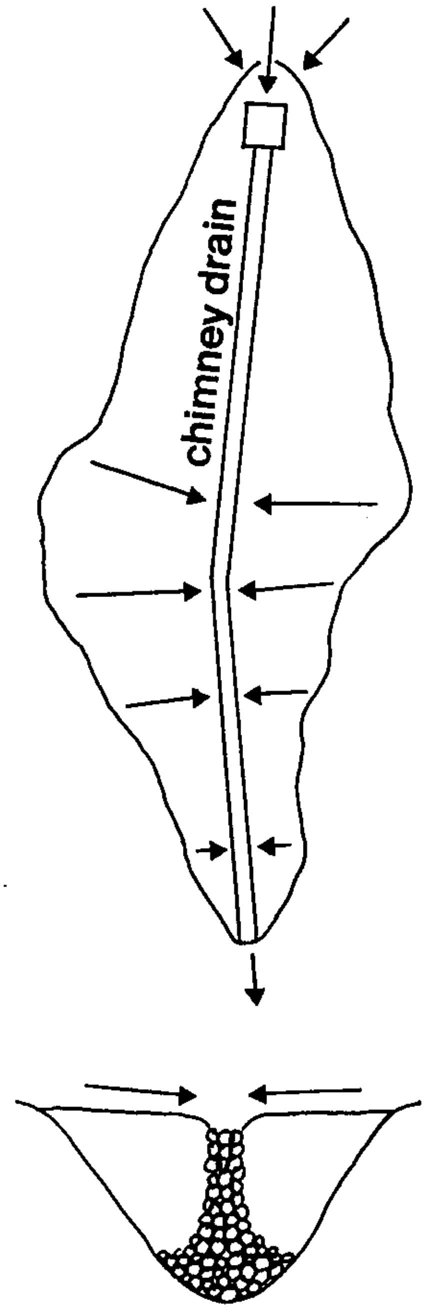

Figure 3. Plan and cross-section drawings of Hollow Fill 2.

In order to achieve this result, the fill was constructed in three lifts, each 50 to 75 feet in thickness. Spoil was placed in the fill by dumping from the fill sides towards the center. As the spoil disposal began to approach the fill center, during construction of each of the three lifts, durable rock was segregated at the mining pit and placed via standard side-dumping procedures. The result was a substantial drainage system, with dimensions far exceeding the 16 foot minimum thickness requirement of V816.72(b), constructed with a minimum of special handling.

Hollow fill 3 was constructed using a filtered underdrain system as defined in V816.71(f) and V816.72(a) (Fig. 4). This drain was constructed as a bed of durable rock boulders, covered by filter fabric and a layer of sandstone fines (Fig. 5). The fill body was constructed using end dumping techniques, in lifts 50 to 75 feet in thickness. The outslope was constructed at a 3:1 grade, with a slight crown to divert surface waters from the face to the diversions constructed at either edge of the face. Surface waters from the landscape above are diverted around the fill, into the rock-lined drainage channel constructed on the fill's north side.

Virginia regulations defining hollow fill construction procedures have been modified during the course of the experimental practice. In the above narrative, we have referred to regulatory statutes using the current numbering system, rather than the outdated system found in the original permit. A consequence of regulatory change is that HF3 is no longer experimental. Recent changes in the Virginia system allow non-durable rock hollow fills to be constructed in lifts greater than four feet in thickness, if a minimum factor of safety is met. Due to the favorable characteristics of the site and the 3:1 hollow fill outslope gradient, these standards are achieved by the third hollow fill. Therefore, HF3 meets current regulatory standards in spite of being initiated as an experimental fill.

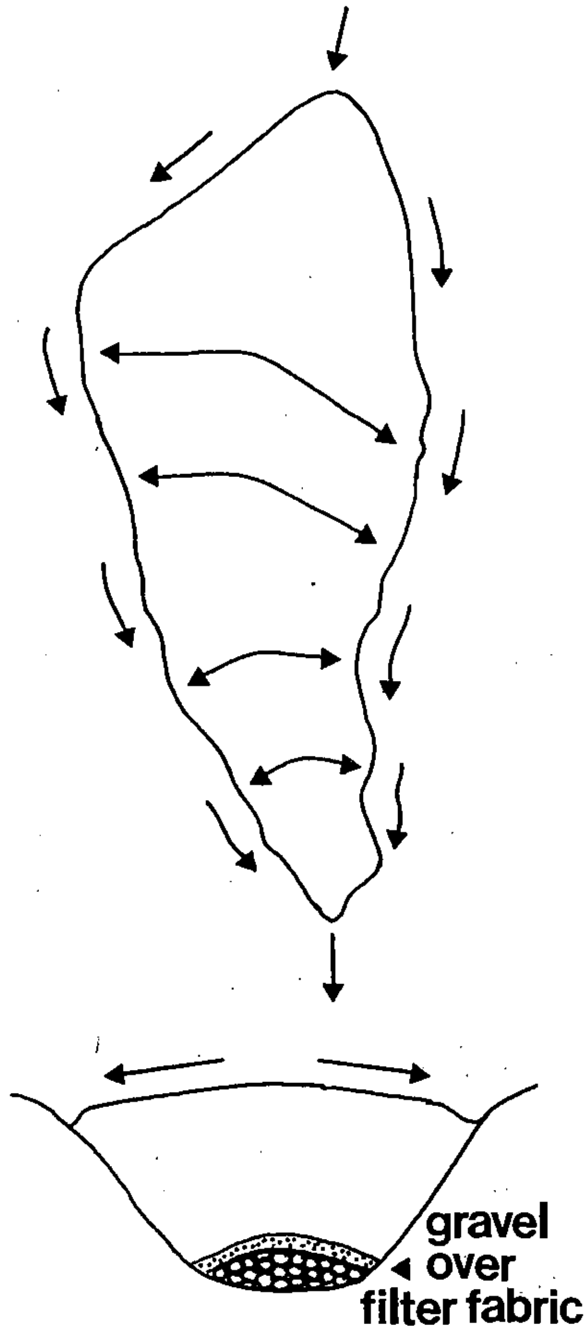

Figure 4. Plan and cross-section drawings of Hollow Fill 3.

Differences Among the Fills

Aside from the essential differences among fill designs, there were other differences among the procedures used to complete the three hollow fills which influenced costs (Table 1).

Topsoil was removed from the first hollow prior to fill construction. Since this proved to be a costly and time-consuming operation, a variance from the topsoil removal requirement was sought and obtained for the second and third hollows. Due to hollow configurations, fill stability does not seem to be a problem with topsoil in place. The widespread availability, and permit approval for use of, topsoil substitute materials eliminates the necessity to remove topsoil for revegetation purposes. Nonetheless, large quantitities of topsoil were removed from easily-accessible areas of the second and third hollows, in order to aid revegetation of reclaimed areas.

Substantial reworking of materials dumped into all three fills was required in order to achieve the 3:1 outslope gradient, since 3:1 is less steep

Figure 5. Underdrain of HF3 during construction in December, 1986.

than the angle of repose of the sandstones and siltstones spoils used for fill construction. This procedure proved to be most difficult and costly in HF1, since this fill was constructed of greater than 80% durable rock. The operator had far more latitude in selecting materials for the second and third hollow fills. Thus, he was able to place softer, more easily worked, spoil materials in the outslope zone of these two hollow fills.

Due to unanticipated coal marketing problems, HF3 construction was halted prematurely. However, the design standards defined in the permit application were followed during reclamation and drainage channel construction. Inability to complete the fill as planned was the cause of the decision to rehandle spoil to complete HF3 (Table 2). This procedure was employed in order to blend the configuration of HF3 in with that of the surrounding landscape. Had mining been able to proceed as originally planned, this rehandling of spoil would not have occurred.

Estimating Costs and Volumes

Expenses required to complete the hollow fills are calculated on the basis of the number of man hours and machine hours expended to perform hollow fill related operations, as recorded in the Daily Record of Machine Operations. Machinery hours spent moving material from the mining blocks to the hollow fills were not considered as a cost of hollow fill construction. Rather, these were considered as direct costs of mining coal from the blocks indicated. Similarly, the cost of moving topsoil to hollow fills for reclamation purposes is not included in the operation and cost summaries. The costs of the hollow fills include all machine and man hours spent preparing the hollows for material placement, working material after placement as per design and reclamation requirements, and preparing the surface materials for revegetation. The method used to develop hourly cost estimates for machinery operation is detailed by Zipper et al. (1985).

The estimate of the volume of materials placed in HF1 is based upon counts of the number of hauler loads placed in the fill, the number of hours spent carrying and pushing from each source area into the fills, and the volume estimates of the source blocks which were developed from on-site measurements. Based upon the estimated block volume and the total number of hauler loads and machinery hours required to completely remove all spoil from each source block, the quantity of materials removed from each block to each disposal area (including HF1) was estimated. After August of 1985, no measurements of source blocks were performed, and no estimates of source block volumes were developed. Subsequent volume estimates (HF2 and HF3) are based upon per-hour and per-hauler-load movement rate estimates which were developed during the source block measurement period over 1984 and 1985 (Zipper 1988).

Table 1. Comparison of hollow fill characteristics.

Characteristic	HF1	HF2	HF3
Topsoil removal required	yes	no	no
Durable rock content	> 80%	50%-80%	50%-80%
Drainage:			
Internal	blanket	chimney	underdrain
Fill surface	side	center	side
Watershed above	around	through	around
Outslope gradient	3:1	3:1	3:1
Filled to design capacity	yes	yes	no
Meets 1984 regulatory standards	yes	no	no
Meets current regulatory standards	yes	no	yes

The loose cubic yard (lcy) figures reported in Table 2 should be considered as approximate, showing greater accuracy in a relative than an absolute sense. Accurate estimates of spoil movement volumes during surface mining operations are extremely difficult to prepare. Difficulties include estimating undisturbed volumes of source blocks, estimating swell factors, apportioning a spoil movement among disposal areas on days when material segregation is practiced, and apportioning disposed spoil among adjacent disposal areas when the disposal point is close to the disposal area boundary.

Comparing Fill Construction Costs

Table 2 summarizes hollow fill costs and volumes. There was a remarkable consistency among the total costs to complete each of the three fills, given the diversity of terrain and construction

Table 2. Comparison of hollow fill costs and volumes.

Volumes and Costs	HF1	HF2	HF3
Volumes (lcy):			
Design	280,000	350,000	240,000
Estimated	197,255	227,029	160,971
Operational Costs:			
Prepare hollow	$9,379	$12,333	$9,469
Construct fill	$9,649	$9,343	$11,415
Reclamation	$9,749	$8,078	$7,461
Rehandle spoil			$3,490
Total costs	$28,777	$29,754	$31,835
Total costs per lcy disposed:			
Design volume:	$.103	$.085	$.133
Estimated volume:	$.146	$.131	$.198
Costs exclusive of rehandle spoil:			
Total	$28,777	$29,754	$28,345
Per lcy: design volume	$.103	$.085	$.118
Per lcy: estimated volume	$.146	$.131	$.176
Costs, fill construction and reclamation only:			
Total	$19398	$17421	$18876
Per lcy: design volume	$.069	$.050	$.079
Per lcy: estimated volume	$.098	$.077	$.117

methods, especially if the cost of rehandling spoil to complete HF3 is eliminated from the comparison. However, a more detailed look at cost figures shows distinct differences among the costs of the various operations required to completely build and reclaim the three fills.

Three major cost categories were used to calculate hollow fill spoil disposal costs. The cost of hollow preparation includes operations required to gain initial access to the fill, clearing trees and vegetation from the hollow sides, and removal of topsoil as required for fill stability and to provide a solid base for drainage structures. HF2 was substantially more expensive to prepare than HF1 or HF3, due to the steepness of the hollow sides. A large amount of hand work was required to remove vegetation from the hollow, including manual removal of trees and stumps with a dozer and chain. In the other two hollows, these operations were accompished more efficiently.

The construction cost category includes internal and surface drainage construction and reconfiguration of the fill body to achieve a 3:1 outslope gradient. Two major factors help to explain construction cost differences among the fills. As discussed above, reconfiguration of HF1 materials to achieve the 3:1 outslope gradient was a costly procedure. However, this cost was balanced, in large part, by the ease of internal drain construction which occurred as an integral component of the spoil disposal process. The construction cost of HF3 was the largest of the three fills, primarily due to the high cost of the rock underdrain. This drain design required far more special handling of materials than either of the other two drainage systems even though the total amount of rock involved was less. The cost of operations required to construct the HF3 drain is estimated at $8400. The cost of grading fill materials to a 3:1 gradient was actually the lowest for HF3, due to its reduced volume and the placement of external drainage channels along the fill sides, rather than in the center as in HF2.

The reclamation cost category includes surface grading and seeding. The reclamation cost for HF1 was greater than the corresponding cost for HF2 or HF3. The higher reclamation cost of HF1 was primarily a result of increased grading requirements, due to the establishment a pronounced crown on the fill face and to the detailed grading required to establish surface drainage at the head of the fill.

On a per loose cubic yard of spoil disposed (per lcy) basis, HF2 was the least costly of the three fills, while HF3 was most clostly. This per-lcy cost difference is amplified if preparation of the hollows is eliminated from the comparison, since cost differences within this category result primarily from hollow configuration rather than fill design.

Because the total costs of all three fills are so similar, it is difficult to draw a firm conclusion that the HF2 design is clearly superior to the other two designs, from a cost standpoint. A major cost of HF1 -- reconfiguration of spoil to a 3:1 gradient -- was an outgrowth of the experimental practice procedure. Had a more conventional (i.e. steeper) outslope gradient been employed, HF1 would not have suffered this particular cost disadvantage relative to the other two designs. Differences in hollow configurations, and in various aspects of mining operations among the periods when the the three fills were being constructed, make it difficult to conclude that the HF2 design is clearly more cost effective. Similarly, had the the other two hollows been filled to the volume of HF2, the cost of hollow fill operations may not have increased in direct proportion to volume which would have reduced per-lcy cost differences among the three fill designs.

Nonetheless, from an operational standpoint, there are clear differences among the fills which are not reflected in the cost figures and which cause HF2 to be considered as superior to the other two designs.

HF3 was the most costly of the three fills, due primarily to the direct cost of establishing the underdrain. There is also a major disadvantage to HF3 from an operational standpoint: the entire drain must be constructed before filling of the hollow can be initiated. The drain runs down the center of the hollow, the precise location where operations are most likely to be disrupted in the event of wet weather. This requirement to install the drain before initiating spoil disposal can act as a major constraint on mining operations. In both HF1 and HF2, drains were constructed as integral components of spoil disposal processes (Fig. 6).

In comparison with HF1, the obvious advantage of the HF2 design is the reduced quantity of durable rock that is required. Although durable rock segregation was not calculated as a cost of hollow fill construction in this analysis, it can be a very real cost of operations where durable rock is limited in quantity. Not so obvious is the difference in costs of handling surface drainage. The HF1 design requires that surface drainage channels be constructed down either side of the fill outslope, and that the surface drainage from the watershed above be diverted around the fill. Surface drainage is handled in more cost-effective fashion in HF2 where only one channel is required (up and down the center face of the fill). Watershed drainage is allowed to enter a basin at the head of the fill, and to

Figure 6. Upper surface of HF2 during the final stage of fill construction, prior to reclamation.

pass through the chimney drain to emerge at the fill's toe.

Non-cost Fill Comparisons

Land Use: One difference that does not show up in Table 2 is the effect of surface drainage structures on land use. From a land use standpoint, the "double" surface drain requirements of HF1 and HF3 limit the operator's ability to tie the topside of the hollow fill surface into the adjacent stripped points to create a more continuous landform. The final, upper surface is dissected on both sides of HF1 and HF3, as these designs require surface drainage structures to be constructed on both the north and south edges of each fill. In contrast, HF2 only has one surface drainage system, which runs through and over the the center line of the fill and the hollow. This situation more closely resembles the natural terrain, allows the upper surface of HF2 to be tied more directly to the stripped points, and requires that less surface area be occupied by surface drainage structures.

Internal drainage: In spite of the differences in fill designs, field operations caused the basal portions of HF1 and HF2 to be quite similar. In both fills, the first stage of fill construction was to dump a lower lift of durable rock. In both cases, large, durable rocks tended to roll from the dumpsite to segregate at the base of the filled materials, covering the terrain underlying the fills. Also in both cases, the thickness of this durable rock base tended to be greatest at the hollow center. The cross-sectional areas of the drainage structures at the base of HF1 and HF2 appeared to exceed that of HF3, and far exceed the minimum underdrain cross sectional area defined by V816.72 and the corresponding federal regulation. A logical conclusion would seem to be that these drains, with larger cross-sectional areas, would be less vulnerable to clogging or other disruptions of function.

Environmental: Piezometer readings taken thus far indicate no drainage problem with any of the fills (Zipper 1988). Although elapsed time has been insufficient to draw any conclusions regarding long-term fill stability, all fills are currently draining freely. In fact, based upon the piezometer readings, it is difficult to discriminate summer from winter. Large, hard sandstone boulders were used to construct the drains in all three fills. All three drains were oversized, relative to permit specifications.

Similarly, there has been no problem with the drainage from any of the fills, in terms of water quality. No treatment of drainage has been required to meet water quality standards.

Conclusions

Research conducted at the Amos Ridge Experimental Practice over the 1984-88 period indicates that the spoil handling procedures utilized provide substantial benefits relative to standard AOC practices at this site. The advantages of the method utilized at Amos Ridge, in comparison to AOC, include a more stable landform, enhanced land use potential, increased coal recovery, and decreased spoil handling costs (Bell et al. 1989; Zipper et al. 1985, 1988, 1989a, 1989b). The experience gained at Amos Ridge indicates that spoil can be handled in cost effective and environmentally sound fashion, in spite of departing from standard AOC practices.

The ability to construct cost effective, environmentally sound hollow fills is essential to the ability of mining firms to produce reclaimed lands with enhanced use potentials: flat lands that will serve as assets to the communities of central Appalachia. The results reported here indicate that the most cost effective fill design utilized at Amos Ridge is the design which does not conform to current regulatory requirements. To this date, this experimental fill has shown no signs of being any less environmentally sound than either of the other two fills. However, insufficient time has passed to judge the long term environmental impact of this currently experimental hollow fill design.

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