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ASSESSMENT OF ACREAGES IN ROAD AND CULTURAL FEATURE BUFFERS IN SIX MAJOR LONGWALL MINING COUNTIES

by

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INTRODUCTION

The U.S. Geological Survey in cooperation with the Office of Surface Mining Reclamation and Enforcement (OSM) performed an economic analysis to provide information for rulemaking on the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Details of the rulemaking and the economic analysis can be found in Watson and others, 1995. According to section 522(e)(4) and (5) of SMCRA, subject to valid existing rights, surface mining within 100 feet of the right-of-way line of any public road or within 300 feet of any occupied dwelling is allowed only by waiver, and surface mining within 100 feet of a cemetary or within 300 feet of other SMCRA 522(e)(5) cultural features is prohibited. These distances define buffers around surface features. The nonwaiverable cultural features include cemetaries, public buildings, schools, churches, community buildings, institutional buildings, and public parks.

The prohibitions of section 522(e) of SMCRA currently apply to surface mining operations. However, there has been concern over subsidence effects of underground mining. For rulemaking on SMCRA, several alternatives for application of section 522(e) prohibitions to underground mining were considered by OSM. Under the strictest alternative, prohibitions-apply, underground mining beneath buffers around roads and occupied dwellings would be allowed only by waiver, and underground mining beneath buffers around other SMCRA 522(e)(5) cultural features (nonwaiverables) would be prohibited. Under two other alternatives, prohibitions-apply-if-subsidence and prohibitions-apply-if-material-damage, coal mining would be partially prohibited under these areas. With any of the three prohibitions-apply alternatives, waiver refusal by homeowners potentially can affect the availability of reserve blocks large enough to make longwall mining economically feasible.

The buffers for roads, dwellings, and other cultural features (nonwaiverables) can overlap one another. To prevent double counting when calculating privately owned coal acreages within buffers on roads and dwellings, overlap correction factors were derived. Waivers on roads are more likely to be obtained than are waivers on dwellings which are dependent on homeowner discretion. The other SMCRA 522 (e)(5) features are nonwaiverable. Thus, in deriving overlap correction factors, other cultural features received higher priority than dwellings which, in turn, received higher priority than roads.

To examine the effect of homeowner holdout on longwall mining and to derive overlap correction factors for buffers on SMCRA 522(e)(4) and (5) cultural features, data on coal extent, mines, and cultural features were obtained for certain counties which have active longwall mines. The data were analyzed with Geographic Information Systems (GIS). Maps of cultural feature buffers over remaining, unpermitted coal were generated. Miles of roads, numbers of dwellings, numbers of other cultural features, and acreages of buffers were calculated with the GIS.

To derive overlap correction factors for both surface and underground mining, two different buffers were applied on each type of cultural feature. The first buffer for derivation of overlap correction factors for surface mining was the buffer specified in SMCRA 522(e)(4) and (5). This buffer was defined as 100 feet for roads and cemetaries and 300 feet for all other cultural features including dwellings. During underground mining, subsidence forces can spread upward and outward toward the land surface from the outside edge of the coal removal zone at an angle referred to as the angle of draw. This angle is stipulated as 30 degrees in recent proposed regulations submitted by OSM to implement the Energy Policy Act of 1992. To prevent subsidence from impacting a protected area, coal mining must be halted at a distance outside of the protected zone. A second buffer was the width of that distance which is calculated as the product of the tangent of the angle of draw (stipulated as 30 degrees) and the depth to the top of the coal bed. This second buffer was used to derive overlap correction factors for underground mining.

Two geographic information systems were employed. Digitizing of maps with coal extent and mine locations, creation of coverages of remaining coal, populated areas, and road buffers, and creation of plot files of remaining coal and buffered areas were performed with ARC/INFO (ESRI, 1994). Extraction of cultural features from U.S. Census Bureau's 1992 TIGER/Line files, rasterization, and determination of buffer acreages were conducted with Geographical Resources Analysis Support System (GRASS) (USACERL, 1993). The final maps were produced using ARC/INFO.

DATA SOURCES, GIS PROCEDURES, AND DERIVATION OF OVERLAP CORRECTION FACTORS

Six counties in three states were selected for study on the basis of longwall production (EIA, 1994 and Coal Magazine, 1994) and availability of coal-extent and mine data from state agencies. The major coal bed being longwall mined in each county and its average depth and thickness beneath each county were determined from the Longwall Census (Coal Magazine, 1994). The states, counties, coal beds studied, and the average depth and thickness of the coal bed beneath each county are listed in Table 1. The average bed depths vary from less than 500 hundred to more than 800 feet. In the economic analysis, the subsidence impacts were forecast over a 20-year period. In calculating overlap correction factors to apply generally, an 800-foot depth was used as a generalized estimate of the average bed depth for longwall-mined beds in the next 20 years. The use of an 800-foot depth tends to produce estimates of affected areas which are "worse case" in the sense that subsidence impacts are estimated to occur in a large area and economic impacts are high if mining is prohibited.

An ARC/INFO coverage of the extent of remaining, unpermitted coal of the Pittsburgh Coal bed in Greene County, Pennsylvania was created by digitizing, appending, and editing coal outcrop lines and mined-out areas (scale 1:62,500) (Dodge and Glover, 1984) and maps of permitted mines (various larger scales) provided by Jim Welsh of the McMurray District Office of the Pennsylvania Department of Environmental Resources. Jim Welsh also provided maps of outcrop lines and mined-out areas (scale 1:63,360) and maps of permitted mines (various larger scales) in the Pittsburgh coal bed in Washington County, Pennsylvania. An ARC/INFO coverage of the remaining, unpermitted Pittsburgh Coal in Washington County, Pennsylvania was created by digitizing, appending, and editing the outcrop line and mined-out maps.

Table 1
Counties and Coal Beds Studied with GIS

State	County	Coal Bed	Average Bed Depth (feet)	Averge Bed Thickness (inches)
Pennsylvania	Greene	Pittsburgh	821	72
Pennsylvania	Washington	Pittsburgh	471	66
West Virginia	Marshall	Pittsburgh	667	68
West Virginia	Monongalia	Pittsburgh	871	84
Illinois	Franklin	Herrin No. 6	638	96
Illinois	Saline	Springfield No. 5	500	84

For the Pittsburgh Coal bed in Marshall and Monongalia counties in West Virginia, the Fairmont regional office of the West Virginia Miners Health, Safety, and Training provided maps of active and abandoned underground mines to the West Virginia Geological and Economic Survey. Personnel of the West Virginia Geological and Economic Survey transferred the mine boundaries onto mylar overlays on U.S. Geological Survey (USGS) 1:24,000 scale topographic maps and provided these as well as Pittsburgh coal bed outcrop lines on USGS 1:24,000 scale topographic maps. With ARC/INFO, USGS staff digitized, appended, and edited the Pittsburgh Coal bed outcrop lines and mine boundaries to create ARC/INFO coverages showing the remaining, unpermitted Pittsburgh coal in Marshall and Monongalia counties.

With ARC/INFO, the extent of Herrin No. 6 coal bed in Franklin county, Illinois was digitized from the map, Coal Resources of Illinois: Herrin (No. 6) coal (Treworgy and others, 1984a), and the extent of Springfield No. 5 coal bed in Saline county, Illinois was digitized from the map, Coal Resources of Illinois: Springfield (No. 5) coal (Treworgy and others, 1984b). ARC/INFO export files of mines in the Herrin No. 6 and Springfield No. 5 coal beds were obtained from Colin Treworgy of the Illinois State Geological Survey. For each county, the coal extent and the mines were plotted, and the remaining, unpermitted coal was delineated and digitized with ARC/INFO and intersected with a county boundary coverage to create a coverage of remaining, unpermitted coal.

The county boundary, roads, and other cultural features were extracted from the U.S. Bureau of Census 1992 TIGER/Line files using GRASS. The county boundary and roads vector files were ported to ARC/INFO where coverages of road buffers were created assuming a right-of-way road width of 150 feet. A map of the county boundary and roads was plotted. Populated areas were delineated from areas of high road density and were digitized with ARC/INFO. Dwellings overlying the remaining coal area, but outside populated areas, were digitized from USGS 1:24,000 topographic maps. The remaining coal and populated areas ARC/INFO coverages were ported to GRASS using the ungenerate command of ARC/INFO and the v.in.arc command of GRASS. A coverage of remaining, unpermitted coal outside of populated areas was created in GRASS and used as a mask to obtain coverages of cultural features which occurred only over the area of remaining, unpermitted coal but outside of populated areas. This coverage was ported to ARC/INFO and used to clip the roads coverage. The miles of roads over the area of remaining, unpermitted coal but outside of populated areas was then determined.

The dwellings coverage was ported from ARC/INFO to GRASS using the ungenerate command of ARC/INFO to create an ASCII file and then a SAS program (SAS Institute, Inc., 1988) to convert the ASCII file into a GRASS site-file format. The dwellings sites files were converted to vector and then to raster files. The dwelling sites were buffered in GRASS where the total buffer acreage for dwellings was determined.

The other cultural features over the remaining, unpermitted coal areas but outside populated areas were converted to raster files and buffered in GRASS where their total buffer acreage was determined. The ARC/INFO road buffer coverages were ported to GRASS where a raster coverage of road buffers that overly areas of remaining coal but are outside of populated areas was created. Total buffer acreage of roads overlying remaining coal areas but outside populated areas was determined. The acreages of the union of dwellings and other cultural features and the union of dwellings, other cultural features, and roads were determined. The buffer coverages of dwellings and of other cultural features were ported to ARC/INFO where plot files were generated.

A square representing the average size of a longwall mine was also placed on the maps in ARC/INFO. The size of the square was calculated in the following manner:

$$l = ((y)(a) / [(r)(d)(t)(c)])^{1/2}$$

where:

l = length of the side of the square in meters
y = 20 years
a = average annual longwall production in tons/year from the coal bed in the county
r = recovery ratio, assumed to be 0.75
d = coal density, 1800 tons/(acre-foot)
t = average thickness in feet of the coal bed beneath the county
c = conversion factor, 1 acre / 4048 m^2

As discussed previously, the buffers for roads, dwellings, and other cultural features may overlap one another. Waivers on roads are more likely to be obtained than are waivers on dwellings. The other cultural features of SMCRA522(e)(5) are nonwaiverable. Thus, in deriving overlap correction factors for the buffered acreages, the priority from highest to lowest was other cultural features, dwellings, and roads.

In general, the buffer acreage of other cultural features over remaining coal was small, and overlap between buffers on other cultural features was small. Thus, no overlap correction factors were calculated for buffer overlap between other cultural features.

Separate surface and underground overlap correction factors were calculated for the overlap of road buffers with dwelling and other cultural feature buffers, road buffers with road buffers, dwelling buffers with other cultural feature buffers, and dwelling buffers with dwelling buffers. Two different regional overlap correction factors were developed for the overlap of road buffers with dwelling and other cultural feature buffers, road buffers with road buffers, and dwelling buffers with dwelling buffers. The regional overlap correction factors applied in the Appalachian regions were calculated as the average of the four overlap correction factors for the two Pennsylvania counties and the two West Virginia counties. The regional overlap correction factors applied in the Interior and Western regions were calculated as the average of the overlap correction factors calculated for the two Illinois counties.

The formulas used to calculate the overlap correction factors are below:

Overlap of Roads with Dwellings and Other Cultural Features

$$ocf = \frac{a - b}{c}$$

where:

ocf = overlap correction factor

a = acreage of union of buffers on roads, dwellings, and other cultural features

b = acreage of union of buffers on dwellings and other cultural features

c = acreage of road buffers

Overlap of Roads with Roads

$$ocf = \frac{d}{(e)(f)(g)(h)}$$

where:

ocf = overlap correction factor

d = acreage of road buffers

e = miles of roads over remaining coal

f = conversion factor, 640 acres / square mile

g = total road buffer width in feet:

350 feet for surface ocf, assuming:

right-of-way to right-of-way road width = 150 feet and

SMCRA buffer on either side of road = 100 feet
1270 feet for underground ocf, assuming:
right-of-way to right-of-way road width = 150 feet and
buffer on either side of road =
SMCRA buffer + (tan of angle of draw)(average coal depth)
where:
SMCRA buffer on either side of road = 100 feet
angle of draw = 30 degrees
average coal depth = 800 feet
Therefore, total road buffer = 150 + 2 (100 + 460) = 1270 feet
h = conversion factor, 1 mile / 5280 feet

Overlap of Dwellings with Other Cultural Features

$$ocf = \frac{i - j}{k}$$

where:
ocf = overlap correction factor
i = acreage of union of buffers on dwellings and other cultural features
j = acreage of buffers on other cultural features
k = acreage of buffers on dwellings

Overlap of Dwellings with Dwellings

$$ocf = \frac{n}{\Pi(r^2)(l)(m)}$$

where:
ocf = overlap correction factors
n = acreage of buffers on dwellings
$\Pi = 3.1416$
r = radius of buffer circle in feet:
300 feet for surface (SMCRA)
760 feet for underground, assuming:
Buffer for underground = SMCRA buffer + angle-of-draw buffer
= SMCRA buffer + (tan of angle of draw)(average coal depth)
where:
SMCRA buffer = 300 feet
angle of draw = 30 degrees
average depth of coal = 800 feet
Therefore, total dwelling buffer = 300 + (0.577)(800 feet) = 760 feet
l = conversion factor, 1 acre / 43560 feet^2

m = number of dwellings over remaining coal

RESULTS AND DISCUSSION

The miles of roads, number of dwellings, and number of other cultural features over the extent of the remaining, unpermitted coal but outside of populated areas are shown in Table 2. The acreages of the buffers as calculated with GIS are shown in Table 3. Table 4 summarizes the overlap correction factors by overlap, surface versus underground mining, and West and Interior versus Appalachian regions.

Plate 1 is a map displaying the county boundaries, road network, extent of the remaining, unpermitted Pittsburgh coal bed, populated areas, total buffers on roads, and the lateral extent of an average longwall mine for the four counties in southwestern Pennsylvania and northwestern West Virginia. Comparison of the green square representing the average extent of a longwall mine with the total buffers on the roads leads to the conclusion that waivers on roads would be needed in order for new mines to be permitted in this region.

Plate 2 is a similar map displaying the total buffers on dwellings and on nonwaiverable cultural features. Comparison of the green square with the dwelling density leads to several conclusions. There are no areas large enough for an average longwall mine that are also devoid of dwellings. Assuming a homogeneous distribution of homeowner holdout on waivers, even a small proportion of holdout would effectively prohibit longwall mining in the county.

Table 2
Roads, Dwellings, and Other Cultural Features Over Remaining, Unpermitted Coal Areas

State	County	Miles of Roads	Number of Dwellings	Number of Other Cultural Features
Pennsylvania	Greene	790	4,985	57
Pennsylvania	Washington	969	6,747	39
West Virginia	Marshall	722	4,189	21
West Virginia	Monongalia	154	1,232	62
Illinois	Franklin	490	1,458	30
Illinois	Saline	195	664	12

Table 3
Buffer Acreages Over Remaining, Permitted Coal Areas

State	County	Roads	Dwellings	Other Cultural Features	Other Cultural Features and Dwellings	Other Cultural Features, Dwellings and Roads
Surface						
Pennsylvania	Greene	30,476	18,357	1,740	19,827	40,424
Pennsylvania	Washington	31,902	23,224	270	23,387	45,525
West Virginia	Marshall	21,234	14,616	104	14,671	28,426
West Virginia	Monongalia	5,367	4,164	194	4,268	7,430
Illinois	Franklin	16,591	6,772	162	6,810	19,892
Illinois	Saline	7,173	3,172	114	3,240	8,953
Underground						
Pennsylvania	Greene	97,566	76,533	4,099	78,043	111,813
Pennsylvania	Washington	75,006	57,226	900	57,560	94,313
West Virginia	Marshall	61,010	47,234	601	47,419	71,844
West Virginia	Monongalia	18,256	16,441	1,919	16,962	21,761
Illinois	Franklin	46,803	25,035	831	25,187	51,951
Illinois	Saline	18,066	9,396	293	9,478	20,821

Table 4
Overlap Correction Factors

	Surface		Underground	
Overlap	Interior and West	Appalachian	Interior and West	Appalachian
Roads with Dwellings and Other Cultural Features	0.79	0.65	0.60	0.37
Roads with Roads	0.84	0.80	0.61	0.66
Dwellings with Other Cultural Features	0.99	0.99	0.98	0.98
Dwellings with Dwellings	0.72	0.55	0.39	0.27

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