CHAPTER 2.

PROBLEMS OF SURFACE MINING

Table 6 gives a list of the main environmental problems in surface mining. The operator can use this Table to anticipate the problems which may result from the proposed mine operation, and to learn how these problems can be solved, largely by careful planning of the operations in advance. In the Appendix, which follows Chapter 5, there are three Tables which describe the Remedial Measures in more detail and the relevant Sections of the Regulations.

The amount of water which either runs off or infiltrates during a rain storm depends on several factors, including the slope, the cover or vegetation, the soil and the degree of compaction. Removal of vegetation and compaction by equipment will increase the proportion of runoff, as will haul roads which are heavily compacted and sometimes paved. However, the actual process of mining may result in cast spoil, full of voids and with much greater permeability than previously and also capable of holding much greater volumes of water if it is confined by impermeable strata. This is the case for cast spoil but overburden moved by either scraper or truck will tend to be consolidated and may have a runoff coefficient as great or greater than the undisturbed site. The ratio of runoff to infiltration in natural conditions may be 1:3 in the Eastern and Interior provinces on gently sloping sites. The desirability of increasing the infiltration depends on the existing groundwater and the hydrologic balance, and also whether or not an increase of infiltration will cause instability of the spoil mass.

Increasing the groundwater storage capacity can be very valuable in Appalachia where most of the surface mining activity is in areas where the groundwater component is small. Curtis suggests that cast spoil may store 50" (127 cm) of water as compared to the unmined soil horizon that could have a total retention of 19.7" (50 cm) only (9). In fact, the increase in capacity is likely to be greater but will clearly depend on the method of working and also the type of spoil. Curtis suggests that "recharge zones can be created by selecting those portions of the overburden that have the best infiltration rates and placing them so that surface water can be diverted into them" (9).

Increased infiltration usually means a greater baseflow to streams when the water reappears in springs or seeps. This may be very desirable, increasing stream flow during dry weather and prolonging flow in streams which normally flow only intermittently. Studies in some small watersheds in the New River basin of the Cumberland Mountains in Tennessee indicated a probable increase in dry weather stream flow due to surface mining. This was implied through continued stream flow in small disturbed watersheds while all three streams draining undisturbed watersheds were dry during the summer (5).

The ratio, runoff:infiltration, will also be an important factor in flooding. Old pits on unreclaimed mine sites impound water. This detention and the increase in storage capacity of the overburden tend to reduce flood peaks. This theory is supported by studies in Breathitt County, Kentucky, and Raleigh County, West Virginia, where "stream flow from surface mine watersheds peaked (16%) lower than from adjacent or nearby unmined watersheds." The study showed that more than 1" of rain went into retention storage in the two mined watersheds while very little went into storage in the unmined watersheds (7). Studies at the Northeast Forest Experimental Station at Berea, Kentucky showed that surface mining resulted in increases in peak flows 4-5 times higher during and immediately after mining, but that peak flows were significantly lower after reclamation was complete (9). This appears to conflict with the previous hypothesis but was found to be due to the intentional dewatering of pits during heavy rain.

Grading during reclamation will have a major effect on the ratio runoff:infiltration. Small surface impoundments due to rough grades will be eliminated during the smoothing operation associated with grading. Slopes will tend to be longer and continuous, giving runoff a chance to buildup on these slopes. Larger impoundments and pits will also be eliminated and during the process the spoil may become heavily compacted by the passage of scrapers and other earth-moving equipment. The increase in runoff due to reclamation activities may be reduced by various surface modifications, such as terracing and also by various surface treatments, such as ripping and gouging. (Scarification of regraded spoil is required in the performance standards [816.24(a)] but terraces are only permitted with the approval of the RA [816.102(b)].) It was found, for instance, by Curtis that total surface runoff averaged 42% less on terraced plots of mining spoil shale than on unterraced plots (9).

The amount of runoff and the velocity of runoff will also be a major factor in the amount of erosion and hence the amount of sedimentation. This brings us directly to water quality.

PROBLEMS - WATER QUALITY

The impact of surface mining on water quality is fairly well documented, but the emphasis in the past has been on the impact of abandoned surface mines on water quality. The emphasis has also tended to be on water quality of surface water rather than on the quality of groundwater.

Experiments in small watersheds in Tennessee have shown that surface mining has a very serious impact on stream health. Streams draining affected areas were found to be virtually sterile relative to fish. Diatoms in water samples were extremely deficient due to heavy sediment loads, and the insect population showed a reduction in both population size and number of species. Populations crashed after mining and then returned slowly to the original size over a period of more than 20 years (this example pertains to abandoned surface mines). Although the number of insects recovered, the composition remained changed (10). A study in the Beaver Creek basin (KY) indicated that strip mining caused changes in the chemical quality of both surfacewaters and groundwaters in the area. Water draining from surface mines often has a low pH, a solids content in excess of 400 ppm and large amounts of aluminum, iron, manganese, magnesium and sulphate (11). (The performance standards set maximum limits on iron, manganese and suspended solids in discharge waters and a pH range [816.42(a)(7)].) Work is in progress to assess the mobilization of heavy metals and other contaminants from strip mine spoils as part of the Appalachian Resources Project. The purpose of this is, in part, to enable measures to be devised which are more specific and cost-effective (12). In a study in the New River basin in the Cumberland Mountains in Tennessee, streams unaffected by surface mining were found to be notably similar in nearly all respects and uniform in water quality characteristics. On the other hand, streams and basins affected by surface mining exhibited distinct differences one from another and periodic large variations in concentrations of constituents in the water. The concentration of suspended solids rapidly increased following disturbance in the watershed but in some streams the high levels (frequently in excess of 100 mg/l) continued for prolonged periods. Disturbance also produced high levels of calcium, magnesium, sulphate and manganese. The requirement for contemporaneous reclamation [816.100] will undoubtedly reduce the problem of continued pollution of both surfacewater and groundwater following surface mining (5).

The major problems associated with water quality and surface mining are acid mine drainage (AMD) and sedimentation.

ACID MINE DRAINAGE

Sheet 6:9 deals in detail with the problem of acid mine drainage (AMD). This problem is caused by the oxidation of pyritic materials followed by leaching causing sulphuric acid to pass into solution. It is estimated that in Appalachia about 25% of the total acid drainage is caused by strip-mining activities. The problem of acid drainage is considerably worse in the northern one-third section of the Appalachian coal field than in the southern two-thirds. It is reported that Pennsylvania and West Virginia contain over two-thirds of the stream mileage which is adversely affected by coal mine acid drainage in Appalachia. This is probably due to a larger amount of sulphuritic material exposed per ton of coal mined in the north than in the south (18). If oxidation can be prevented by burying pyritic materials at levels above the water table, AMD will be minimal. "It is unlikely that material buried several feet or more below the surface can undergo significant oxidation because of the restriction of oxygen diffusion to these depths" (15). It is on this premise that requirements for burying acid-forming or toxic-forming material in the Regulations are based [816.48]. In studies in Beathitt County, Kentucky, it was found that before mining, the concentration of sulphate in the surface water was generally less than 15 ppm but after mining the concentration was usually more than 100 ppm. Undoubtedly, the requirement for contemporaneous reclamation [816.100] will reduce the concentration of salts after mining has ceased. But to minimize concentration during the mining process, careful handling of spoil [816.41(d)(2)(vii)-(viii)] and attention to site drainage [816.43] are necessary (17). Extensive neutralization of acid drainage occurs within the coal regions. Biesecker and George report that "the mixture of outlying streams with mine drainage waters eventually neutralizes all acid streams in Appalachia." Thus, acid drainage is most serious in head-water streams near active or abandoned surface mines (18).

SEDIMENTATION

Many experiments have quantified the increase in sediment caused by erosion on both active and abandoned surface mines. For instance, in studies of mined and unmined watersheds in Kentucky (Leatherwood Creek and Bear Branch), the impact of surface mining on both the suspended sediments and the bed loads sediments in the streams was investigated. These studies were pre-SMCRA and quantified the continued sediment generation in areas affected by surface mining after abandonment (1). A study in Beaver Creek Basin in Kentucky found that the annual sediment production from land affected by surface mining was 42 tons/acre, 1,000 times higher than the yield of sediment from an unmined watershed (13). Table 3 below shows representative rates of erosion from various land uses.

TABLE 3

SEDIMENT GENERATION BY VARIOUS LAND USES

Land Use	Tons/Mi²/Year	Relative to Forest
Forest	24	1
Grassland	240	10
Abandoned surface mines	2400	100
Cropland	4800	200
Harvested forest	12,000	500
Active surface mines	48,000	2,000
Construction	48,000	2,000

Source: US EPA, October 1973, "Method for Identifying and Evaluating the Nature and Extend of Non-point Sources of Pollutants," EPA 4030/9-73-014, Washington, DC

TABLE 4

COMPARATIVE RATES OF EROSION FROM SURFACE MINING ACTIVITIES

Area	Yield (Tons/Mi²)	Factor
Unmined Watershed	28	1
Mined Watershed	1930	69
Spoil Bank	27,000	968
Haul Road	57,600	2065

Source: EPA, October 1976, "Erosion and Sediment Control Surface Mining in the Eastern US - Planning," Technology Transfer Seminar Publication.

SOME CLIMATIC FACTORS AFFECTING SURFACE MINING

The performance standards of the Regulations contain different requirements in a number of cases for areas where the annual rainfall is above 26" (66 cm) or below 26" (66 cm). For instance the extended responsibility lasts for 5 years in areas where annual precipitation is more than 26" (66 cm) but for 10 years when it is less [816.116(b)]. The whole of the area covered by this Handbook, i.e. the Eastern Coal Province and Interior Province east of the 100th Meridian W longitude, has an annual precipitation of more than 26" (66 cm). (Figure 1)

Figure 1. Mean Annual Precipitation (cm) and Major Coal Reserve Areas. Eastern and Interior Provinces.

Source: Gardner, H.R., Woolhiser, D.A., 1978, Hydrologic and Climatic Factors," Proc. Reclamation of Drastically Disturbed Lands Symp., Schaller, F.W., Sutton, P. (Eds), ASA, CSA, SSSA.

The higher rainfall found in the more humid areas of the Eastern and Interior Coal Provinces is not necessarily indicative of a high erosion potential as erosion is affected by rainfall *intensity.* The humid climate however does favor the rapid and effective establishment of vegetation. Consequently, meeting the requirements for revegetating Eastern and Interior surface mine sites is much easier than in drier regions in the west.

The proportion of rainfall which runs off to that which infiltrates into the ground and that which is evaporated or used by plants varies a great deal, and may be altered considerably by surface mining. The proportion which infiltrates and then reemerges in springs and seeps is important in maintaining the base flow of streams in dry weather. That which infiltrates to deeper groundwater may be important in maintaining water supplies which rely on groundwater sources. Hence the impact of surface mining on this balance is very important.

The amount of water which can potentially be used by the vegetation is called the potential evapotranspiration (PEVT). In the Appalachians the rainfall is greater than the PEVT but in the west the PEVT exceeds rainfall by 2 or 3 times, making water a crucially important factor in revegetation.

The slope, both its steepness and the direction it faces, will have an impact on the microclimate and also the establishment of vegetation. South-facing slopes are hotter and drier than north-facing slopes.

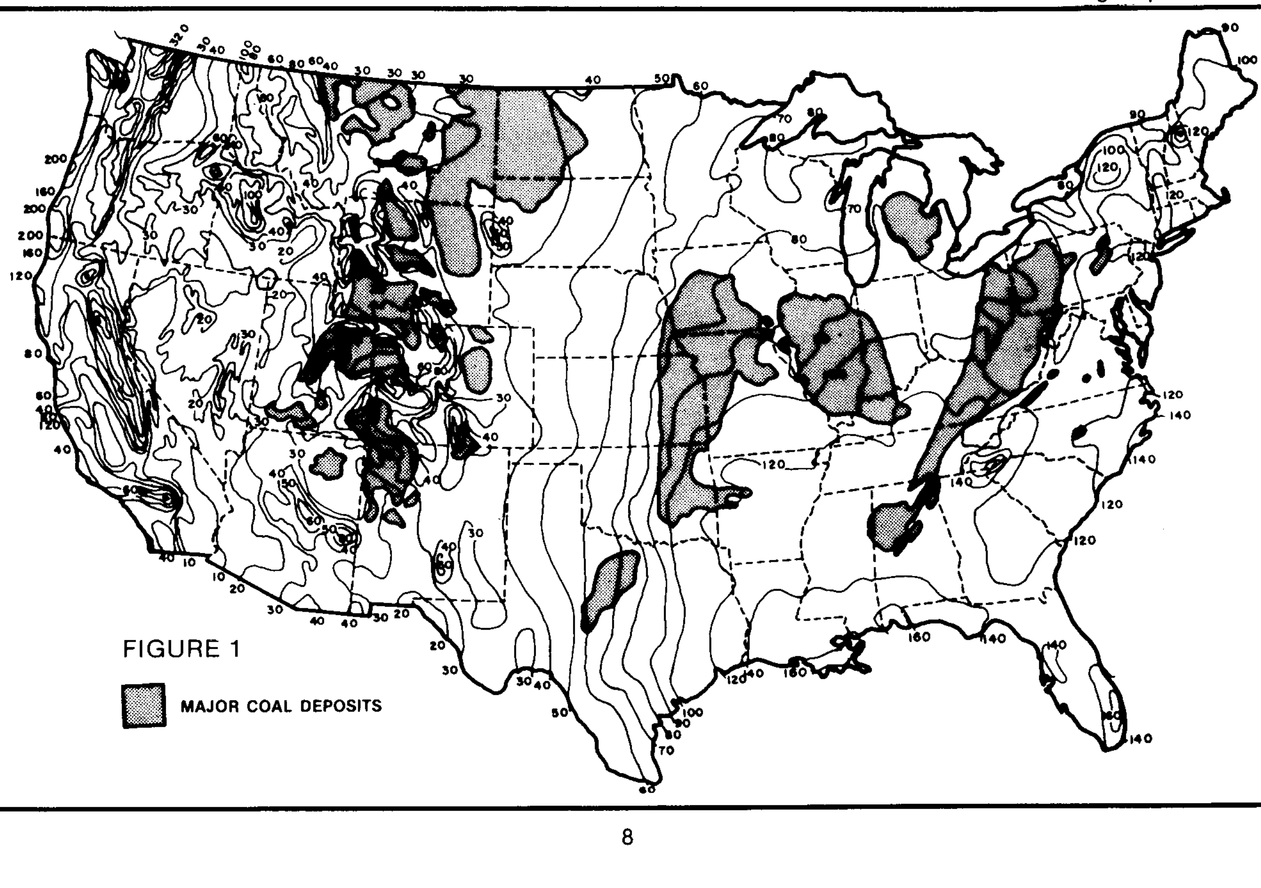

FIGURE 1

TABLE 5

MAJOR WATER RELATED IMPACTS OF SURFACE MINING

1. WATER QUALITY	Description of Impact	Major Operation Causing Impact	Remedial Measures [Regulations]*
1:1 Alteration of flow patterns of streams.	Disturbing the surface during mining may cause increased infiltration of water. But often, consolidation causes increased runoff and reduced infiltration which can cause flooding and erosion problems, and may reduce recharge of aquifers and base flow of streams. Local increases in runoff also may originate from haul roads, etc. Runoff will increase due to excessive compaction during reclamation and the elimination of surface storage by creating smooth slopes.	Removal of vegetation, and all operations involving shifting and regrading and consolidation of overburden. All operations which increase the impermeability of the land surface.	Disturb smallest practicable area at any one time [816.45(b)(1)]. Reclaim as contemporaneously as practicable [816.100]. Design haul roads so as to minimize any increase in runoff [816.153].
1:2 Lowering of groundwater.	Dewatering the pit may cause a lowering of the groundwater. Deep exploratory boreholes may also break through an impermeable stratum which confines an aquifer causing the aquifer to leak to lower strata.	Pit dewatering. Exploration boreholes. Mining through a stratum which previously confined an aquifer.	Casing and sealing of drilled holes [816.13-816.15]. Plan mine excavation so as to prevent adverse impact [816.50(b)].
1:3 Change in storage capacity and transmissibility of overburden.	Decrease in groundwater recharge may result from reduced permeability caused by the removal of vegetation. The removal and replacement of overburden will change both its storage capacity and transmissibility (often increasing both which can be a significant improvement). Vertical leakage to underlying aquifers can increase transmissibility.	Clearance of vegetation. Shifting, regrading and consolidation of overburden. Exploration boreholes. Blasting which causes fracturing and disturbance of basement rock.	Use straw dikes, riprap, check dams, etc. to reduce runoff volume [816.45(b)(b)]. Minimize disturbance to prevailing hydrologic balance [816.51(b)].
2. WATER QUALITY			
2:1 Acidity.	Highly acidic runoff from mined sites results from the exposure of pyritic materials to air and water. Low pH tends to make some compounds toxic to plants, particularly Al and Mn. May cause local groundwater supply to become less than potable.	Exposure of pyritic material, often lying in close proximity to coal, to oxygen and water. The cause may be material exposed in exploration boreholes, material in the pit bottom, material backfilled too close to the surface, or material used in road construction. Also, careless hauling of previously identified acid-producing materials causes this problem.	Conduct coal exploration in a manner which minimizes disturbance of hydrologic environment [Part 815]. Prevent or remove water from contact with acid-forming materials during mining operations [816.43]. Bury acid-forming spoil [816.48]. Correct pH before discharge of water from site [816.42(c)]. Acid-forming materials may not be used in construction of haul roads [816.152(d)(13) and 816.154(b)].
2:2 Sedimentation; Suspended solids.	Erosion of overburden materials may result in very high levels of sediment in runoff from mine sites, which causes a deterioration of stream health, silting of streambeds, etc. Loss of topsoil. Lessens the potential for post-mining use.	All mining operations involving earthmoving. Also haul roads may be serious sources of sediment.	Minimize erosion to the greatest extent possible [816.45(a)]. Reclaim as contemporaneously as practicable [816.101(a) and 816.113]. Manage haul roads so as to cause no additional contribution of suspended solids to runoff flow [816.150(b)]. Provide sedimentation ponds [816.46].
2:3 Hardness; Deposit of iron hydroxide.	Hardness is rarely a serious problem. However, acidic drainage which is neutralized by treating with lime or limestone will increase in hardness. Neutralization will cause the deposit of iron hydroxide (Yellow Boy) and other compounds which may cause problems.	Operations involving the treatment of acid-forming materials.	Monitor surface water and groundwater [816.52]. Treat acid water only as needed [816.42(c)].
2:4 Groundwater pollution.	Groundwater pollution can result from acid water leaching into the groundwater. This may be a problem when acid-producing material is placed so as not to prevent oxidation and leaching. Consolidation and in some cases sealing the acid-producing material should prevent this problem.	Results from placement of acid-forming materials during regrading where oxidation and leaching can take place.	Place backfill material to prevent groundwater pollution [816.101(b)(2)].
3. OTHER WATER RELATED PROBLEMS			
3:1 Instability.	Infiltration of water into the spoil may cause instability and slumping. Most reclamation measures seek to reduce runoff and increase infiltration but in cases where spoil has low shear strength the policy should be to prevent excessive seepage. A slide may have an adverse effect on public property, health, safety or the environment.	This problem occurs mostly on steep sites, particularly for large fills, Head of Hollow and Valley Fills. Providing bench or barrier on outslope. Backfilling and grading.	Provide barrier so as to assure stability [816.99(a)]. Backfill and grade so as to insure stability [816.101(b)(1)]. Construct a subdrainage system [816.71(e)].
3:2 Erosion.	Besides giving rise to sedimentation problems, gully erosion may be so serious to make it necessary to regrade the site. Careful attention to surface configuration and rapid protection with vegetation will avoid this problem.	Regrading operations. Revegetation operations.	Reclaim as contemporaneously as practicable [816.101(a) and 816.113]. Perform regrading operations along contour [816.102(e)]. Regrade or stabilize rills or gullies [816.106].

*For a detailed listing of Remedial Measures, see Tables in Appendix following Chapter 5.

REFERENCES:

(1) Curtis, W.R., 1971, "Strip Mining Erosion and Sedimentation," Transactions of the ASAE, Annual Meeting, Minneapolis, MN.

(2) Ramani, R.V. and Clar, M.L., 1978, "Users' Manual for Premining Planning of Eastern Surface Coal Mining - Executive Summary," Intragency Energy/Environmental Research and Development Program Report, EPA 600/7-78-180.

(3) Leibenguth, C., December 1974, "Strip Mining Covering the Scars," Science Digest.

(4) Skelley and Loy, March 1978, "Environmental Assessment of Surface Mining Methods - Head of Hollow Fill and Mountain Top Removal - Interim Report," USEPA, Cincinnati, OH.

(5) Minnear, R.A., Tschantz, B.A., November 1976, "The Effect of Coal Surface Mining on the Water Quality of Mountain Drainage Basin Streams" Journal WPCF.

(6) Collier, C.R., Pickering, R.J., and Musser, J.J., 1970, "Influences of Strip Mining on the Hydrologic Environment of Parts of Beaver Creek Basin, KY, 1055-66," USGS Prof. Paper 427-C.

(7) Curtis, W.R., 1977, "Surface Mining and the Flood of April 1977," Northeast Forest Experiment Station, USDA Forest Service Research Note, NE-248, Berea, KY.

(8) Curtis, W.R., June 6-7, 1978, "Effects of Surface Mining on Hydrology, Erosion, and Sedimentation in Eastern Kentucky," Fourth Kentucky Coal Refuse Disposal and Utilization Seminar, Lexington, KY.

(9) Curtis, W.R., June 1978, "Planning Surface Mining Activities for Water Control," Proc. Fifth North American Forest Soils Conference.

(10) Vaughan, G.L., May 1977, "Biological Impact of Contour-Strip Mining on Small Watersheds," Appalachian Resources Project Progress Report, Univ. of Tenn. Environmental Center, Knoxville, TN

(11) Hanna, G.P., March 1964, "The Relation of Water to Strip Mine Operation," Ohio Journal of Science.

(12) Minnear, R.A., Overton, D.E., May 1977, "Mobilization of Heavy Metals and Other Contaminants from Strip Mine Spoil," Appalachian Resources Project Progress Report, Univ. of Tenn. Environmental Center, Knoxville, TN.

(13) Collier, C.R., Pickering, R.J., and Musser, J.J., 1964, "Influence of Strip Mining on the Hydrologic Environment of Beaver Creek Basin, Kentucky 1955-1959," USGS Paper 427-B.

(14) Preate, E.D., February-March 1972, "A New Law for an Old Problem" Appalachia.

(15) Shumate, K.S., Brant, R.A., 1971, "Acid Mine Drainage Formation and Abatement," Water Pollution Control Research Series, US EPA.

(16) Ahmad, M.U., Sept. 1973, "Coal Mining and Its Effect on Water Quality." Proc. of the First World Congress on Water Resources, IWRA, Chicago, IL.

(17) Dyer, K.L., and Curtis, W.R., 1977, "Effect of Strip Mining on Water Quality in Small Streams in Eastern Kentucky 1967-1975," USDA Forest Service Research Paper NE-372, Upper Darby, PA.

(18) Biesecker, J.E., George, J.R., 1966, "Stream Quality in Appalachia as Related to Coal Mine Drainage, 1965," USGS Circ. 526, Washington, D.C.