*Environmental Health Perspectives*
*Vol. 33, pp. 159-176, 1979*

# Basis for a National Reclamation Plan

## by Special Committee to Study Health and Environmental Effects of Increased Coal Production*

**The goal of the President's National Energy Plan to produce 1.25 billion tons of coal by 1985 may be achieved, but new legislation constraints and start-up delays may result in a production loss of 200-300 million tons. Well directed research to define the environmental consequence of increased coal production is underway, but it tends to be fragmented and ill coordinated. A national reclamation plan based on an achievable NEP must be developed that schedules, prioritizes, and coordinates research activities. Unless the results of these research activities can be transferred to industry and state and federal agencies, they are useless.**

**The NEP emphasizes increased coal production in the East where historic water resource impacts of coal production have been substantial. Acid drainage during and after mining at both surface and underground mines has been a major surface water quality problem in the eastern and midwestern U.S., but while recent legislation and reclamation techniques have been instituted to mitigate the problem, their effectiveness has not yet been established. Groundwater passing through pyritic spoil materials and underground mines after completion of mining in the East and Midwest is known to cause serious localized impacts to groundwater quality. The effectiveness of reclamation techniques in controlling groundwater quality in mined areas is very doubtful and deserves considerable investigation.**

**A major portion of the near-term increase in production will be in the western coal regions. Increased salinity of surface water as a result of pumping and runoff from surface mines will be a potentially important impact in some western watersheds. Groundwater in reclaimed spoils in the West will have higher total dissolved solids (salinity) than ambient groundwater quality. The potential of local or regional impacts to surface and groundwater resources needs additional investigation. Impacts of aquifer disturbance on agriculture and natural riparian and floodplain vegetation in western alluvial valleys is a topic of considerable concern. Much research is needed to determine the true extent of the problem and the reclamation potential of these areas.**

**Mining in all coal regions will alter surface-subsurface hydrologic systems to some extent. The problems, such as aquifer disruption, excess surface water runoff, and watershed flooding potential are related to site-specific topographic, geologic, and hydrogeologic conditions, and reclamation techniques. Erosion and sedimentation are potential problems at all mine sites. The extent of the problem will depend upon reclamation success.**

**Surface mining will continue to play an important role in the East, Midwest, and West under the NEP. This increase in surface mining may include prime agriculture lands in the Midwest. Overburden analysis and selective spoil placement of unsuitable spoil materials is considered a necessity to successfully return lands to a level of production equal to or better than premining levels. The provision in P.L. 95-87 to regrade to approximate original contour regulation presents problems for land restoration in both the East and the West. Topsoil segregation and replacement has been identified by numerous states as an important part of the reclamation plan to achieve postmining productive land use. Until recently, soil has been treated as a mineral, not an ecosystem. High salinity and clay in conjunction with low precipitation create moisture stress impeding vegetation establishment in the West. Final land use plans, designed to optimize diversity, are not being implemented within the various coal mining regions.**

**Research is needed on erosion control, premine planning, postmining land use planning, proper handling of topsoil, nutrient cycling on disturbed lands, disposal of waste, management of reclaimed lands, and reclamation on arid lands.**

**Atmospheric effluents from coal mine reclamation activities will fall primarily into two categories: (1) dust resulting from earthmoving activities or wind blowing across unstabilized areas, and (2) gaseous effluents ($SO_x$, $NO_x$, CO, and hydrocarbons) from internal combustion engines of reclamation equipment. The adverse health and environmental impacts of these effluents, if they occur, are likely to be very small and within acceptable limits.**

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## Background

### Introduction

The President's National Energy Plan (NEP) invokes three basic strategies — conservation, increased coal utilization, and research and development — to attain the objectives and goals put forth (*1*). This section will identify and discuss the impacts associated with the reclamation phase of increased coal utilization. The NEP would increase the use of coal by 1985 by 565 million tons (total 1.25 billion tons). To stimulate the increased demand for coal, the plan proposes a coal conversion program consisting of tax and regulatory measures. To accomplish this goal, NEP objectives expected that coal production must expand in many regions with an emphasis on the East. It is agreed that current production has a small amount of excess capacity and in many instances, mines are only operating one shift instead of two or three. Coal development and utilization are most economical when near major markets, therefore, it will be necessary to stimulate coal development and production in the highly populated Eastern and Midwestern regions. Because coal from these two regions has a considerably higher sulfur content (3-6%) than western coal, the best available flue gas desulfurization technology must be deployed. Additionally, the National Energy Plan's commitment to the attainment and maintenance of the environmental goals set out in recent legislation requires that these goals be achieved without endangering public health or degrading the environment.

While it is necessary to recognize that increasing coal use requires reasonable certainty and stability in government policies, it is important to note that most new mines are based on the development of long-term (20 yr) steam coal supply contracts that permit an equitable return on the initial large ($10-20 million) capital investment. The lead time required to open a new underground mine is four to six years, whereas new surface mines require three to five years (*2*). Lead-time delays mainly result from the mining company having to obtain several state and federal permits and from the filing of environmental impact statements. It is also agreed that the new Office of Surface Mining performance standards may be tied up in litigation for one to two years, which will lengthen lead time for new surface mines. The total time required for purchasing land, conducting planning, obtaining permits, and selling and producing the coal may be considerably longer than three to five years creating a serious lag time in attaining NEP goals. Because surface mining is environmentally disruptive, the NEP will encourage the opening of as many eastern underground mines as possible. Furthermore, our surface coal reserves represent only a small portion (10%) of total reserves (*3*). Hence, it would be important to develop new safe, efficient, and economical underground mining systems as quickly as possible.

Two conflicting views exist concerning the regionalization of coal development to meet 1985 NEP goals. The NEP view is to promote deep coal development in the eastern and midwestern sections of the country, the underlying reasoning being that less environmental disturbance will occur with eastern deep mining methods and coal production will be located nearer consumers. The other view sees coal development proceeding mostly in the West. The reasoning here follows economic lines; the coal can be more economically extracted and less of an overall surface impact will occur because coal seams in the West are typically 40 ft while in the East and Midwest seams average 4 ft. Tables 1 and 2 have been developed to illustrate the production and surface disturbance impacts of these two scenarios. Table 1 gives the regional distribution of production and disturbance for 1976 and 1985. The 1985 estimates were developed by ANL personnel using NEP production goals and regional objectives as the basis for developing the projections. The surface disturbance was determined on the basis of regional coal seam thickness (BOM, IC 8531), regional coal recovery factors (ANL unpublished data), and the regional production estimates. Table 2 gives similar regional data based on the NCA (July 1977) projections for new coal mine openings. The data indicate that 15% more coal (185 million tons) than the NEP goal of 1.25 billion tons will be produced and 12% less surface disturbance (11,000 acres) will occur in 1985 if coal development proceeds as NCA projects it will. These results indicate less of an overall environmental impact and more coal production if development takes place mainly in the West. It should be understood that "acres disturbed" are only a best guess at this time and a more detailed study is necessary. Table 3 provides comparison of major parameters between the NCA and ANL/NEP coal development.

Since most new mines must operate at least 20 years to return the initial investment, it is apparent that mines opened between now and 1985 will be operating after the year 2000. Based on Table 1, surface disturbance in the West could increase two and a half times by 1985 and at least remain at that level if no new surface mines were opened after 1985.

Implementation of the new Surface Mining Act by the Office of Surface Mining could adversely affect short-term production goals. Western surface ex-

Table 1. Regional coal production and surface disturbances projections incorporating NEP goals and regional objectives.

| | | 1976 | | | | 1985 | | | | Increase | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Production | | Disturbance | | Production | | Disturbance | | Production | | Disturbance | |
| Region | Type | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % |
| West | Surface | 100.3 | | 1,637 | | 282 | | 4,543 | | 181.7 | 181 | 2,906 | 178 |
| | Deep | 10.0 | | 16 | | 18 | | 29 | | 8.0 | 80 | 13 | 181 |
| | Total | 110.3 | 17 | 1,653 | 3 | 300 | 24 | 4,572 | 5 | 189.7 | 172 | 2,919 | 177 |
| Midwest | Surface | 103.0 | | 17,820 | | 225 | | 38,927 | | 122.0 | 118 | 21,107 | 118 |
| | Deep | 56.9 | | 984 | | 75 | | 1,298 | | 18.1 | 32 | 314 | 32 |
| | Total | 159.9 | 24 | 18,804 | 36 | 300 | 24 | 40,225 | 42 | 140.1 | 88 | 21,421 | 114 |
| East | Surface | 157.8 | | 27,300 | | 250 | | 43,252 | | 92.2 | 58 | 15,952 | 58 |
| | Deep | 237.0 | | 4,100 | | 400 | | 6,920 | | 163.0 | 69 | 2,820 | 69 |
| | Total | 394.8 | 59 | 31,400 | 61 | 650 | 52 | 50,172 | 53 | 255.2 | 65 | 18,772 | 60 |
| Totals | | 665.0 | | 51,857 | | 1250 | | 94,060 | | 585.0 | 88 | 43,112 | 83 |

traction problems relate to the question of the potential for acceptable rehabilitation because of the destruction of fragile ecosystems. Water availability and quality problems will be critical in some areas. The prime agricultural land issue will constrain surface mining in the Midwest, especially in Illinois, where, by definition, more than 50% of the surface mineable coal is overlain by prime agricultural land. An increase in eastern mining can increase levels of acid mine drainage and resultant pollutant loading factors to the hydrologic systems.

Reclamation costs vary considerably because of climatic, physical and chemical parameters. In the Midwest, topsoil segregation and replacement costs in prime agricultural land vary between $2,000 and $6,000 per acre depending on the amount of material segregated. Overburden removal costs vary from 10¢-25¢/yd$^3$, depending upon site-specific conditions. However, segregation, storage, and replacement costs can run as high as $1-$2/yd$^3$ when pan scrapers and bulldozers are employed. It is evident that research and development is necessary to reduce these costs.

Because reclamation activities require energy as well as dollars, it would be important to calculate and incorporate the net energy gain into the overall environmental and economic analysis. In this way, selection of specific regions as target areas for coal development can be achieved.

## Legislative Review

***Federal Programs.*** The main federal effort to protect our natural resources from the adverse en-

Table 2. Regional coal production and surface disturbance projection based on National Coal Association estimates.

| | | 1976 | | | | 1985 | | | | Increase | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Production | | Disturbance | | Production | | Disturbance | | Production | | Disturbance | |
| Region | Type | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % | Tons $\times 10^6$ | % |
| West | Surface | 100.3 | | 1,637 | | 505.5 | | 10,783 | | 405.2 | 404 | 9,146 | 559 |
| | Deep | 10.0 | | 16 | | 65.3 | | 176 | | 55.3 | 553 | 160 | 1000 |
| | Total | 110.3 | 17 | 1,653 | 3 | 570.8 | 40 | 10,959 | 13 | 460.5 | 418 | 9,306 | 563 |
| Midwest | Surface | 103.0 | | 17,820 | | 176.45 | | 28,688 | | 73.45 | 71 | 10,868 | 61 |
| | Deep | 56.9 | | 984 | | 100.0 | | 1,545 | | 41.1 | 76 | 561 | 57 |
| | Total | 159.9 | 24 | 18,804 | 36 | 276.45 | 19 | 30,233 | 36 | 116.55 | 73 | 11,429 | 61 |
| East | Surface | 157.8 | | 27,300 | | 224.7 | | 36,098 | | 66.9 | 42 | 8,789 | 32 |
| | Deep | 237.0 | | 4,100 | | 362.8 | | 6,665 | | 125.8 | 53 | 2,565 | 63 |
| | Total | 394.8 | 40 | 31,400 | 61 | 587.5 | 41 | 42,763 | 51 | 192,7 | 59 | 11,363 | 36 |
| Totals | | 665.0 | | 51,857 | | 1,434.75 | | 83,955 | | 769.75 | 116 | 32,098 | 62 |

Table 3. Comparison of NEP projections versus NCA projection for 1985.

| Region | NEP Projections | | NCA Projections | |
|---|---|---|---|---|
| | Production, tons × $10^6$ | Disturbance, acres | Production, tons × $10^6$ | Disturbance, acres |
| West | 300 | 4,572 | 570.8 | 10,959 |
| Midwest | 300 | 40,225 | 276.45 | 30,233 |
| East | 650 | 50,172 | 587.5 | 42,763 |
| Total | 1250 | 94,969 | 1434.75 | 83,955 |

vironmental consequences of coal mining is embodied in the recently passed Surface Mining Control and Reclamation Act of 1977, P.L. 95-87.

Unlike other major environmental laws, P.L. 95-87 directly confronts the trade-offs to be made between environmental protection and energy development. It does this by establishing environmental performance standards and a federal regulatory program for controlling the surface effects of coal mining operations and by establishing research, development, demonstration and training programs on problems related to coal energy development. The primary federal agency for implementing the environmental protection provisions of the Surface Mining Law is the Office of Surface Mining in the Department of Interior. The energy development responsibilities are for the most part with the Department of Energy. Development of environmental standards for air and water quality are EPA's function, while identifying our prime farmland areas and implementing the federal effort to reclaim lands previously affected by coal mining is the Department of Agriculture's concern. Thus, federal programs promoting the reclamation of mined lands involves the cooperation and coordination of several federal agencies (*4*).

This new federal effort to control the surface disturbance impacts of coal mining is the latest governmental response to mitigate the adverse environmental, health and safety consequences long associated with coal development. The Environmental Protection Provisions appear adequate. However, the stress placed on the federal program by the NEP coal production goals and the implementation of a major regulatory program may give rise to a set of problems unanticipated during the legislative formation of a national reclamation program.

One such problem inherent in the new federal reclamation program is the number of adequately trained regulatory personnel. The effectiveness of an environmental protection program is determined by the regulatory personnel's actions. P.L. 95-87 will require many persons to approve mining permits, approve reclamation plans and inspect facilities to ensure that environmental performance standards are met. It is questionable whether an adequate number of qualified persons exist to fulfill state and federal personnel requirements. Conceivably, the use of poorly trained personnel could lead to the approval of permits and reclamation plans that are environmentally unsound and unsafe or lead to unsatisfactory inspection of mining and reclamation sites. Thus, consideration should be given to the quality of the regulatory personnel to ensure that enforcement is undertaken by knowledgeable people.

Another problem which may arise because of federal mining regulations concerns underground mining. An objective of the Surface Mining Law is to promote the development of underground mining. Perhaps the reasons for this stance by the Congress were the view that underground mining had less land impacts than surface methods and most of our reserves lie deep in the ground. As coal production increases, a shift to underground methods could create additional health, safety and environmental problems. If deep mining operations are expanded, serious occupational health and safety hazards, such as black lung and cave-ins, would most probably increase. This situation presents a trade-off between the health and safety impacts of deep mining and the environmental impacts of surface mining. As in situ methods are employed, new land reclamation questions may also be expected to arise. Thus, the promotion of underground technologies in P.L. 95-87 to lessen the environmental impacts from surface disturbance may give rise to more devastating health, safety, and environmental problems than surface extraction now presents.

Although the surface mining legislation is not intended to be a land use bill, it does include several provisions, relating reclamation to land use. Land must be reclaimed to a condition capable of supporting the uses which existed prior to the advent of mining, or some higher or better use. The impacts one could anticipate here concern the environmental and sociological consequences of reclamation, which include the creation of boom towns in the western U.S. An environmentally sound approach to reclamation would be to provide a land use which would ensure that the land would remain undisturbed in the future. An associated social impact of reclamation would be the relationship of the post-mining land use to local development plans. Thus, federally monitored surface mining and reclamation programs should strive to assure the coordination of reclamation with local development objectives, otherwise, reclaimed areas may be adversely impacted by future development and adverse societal

reaction to energy development could arise because of dissatisfaction with reclamation plans.

Federal programs will most directly affect reclamation through the issuance of environmental standards for reclaimed areas. The stringency of these standards will determine both the feasibility of reclamation at a proposed mining site and the adequacy of environmental protection for the mined area. Conceivably under the pressure for higher coal production, reclamation standards may be weakened or loosely enforced resulting in greater environmental degradation of mined areas. Two such areas in the law are alluvial valley floors in the West and prime agricultural land in the Midwest. In many instances, sufficient information does not exist to adequately understand the consequences of these mining/reclamation operations, nor is there a universal standardized system of environmental data collection. Until additional data are available, uncertainty and controversy will hamper execution of the legislation.

In summary, the reclamation issues for federal programs result primarily as a consequence of P.L. 95-87. Four problem areas related to the adequacy of coal mine reclamation could arise because of such federal programs. They are improper permitting and site inspections because of poorly trained personnel; the emergence of new reclamation problems and additional health, safety, and environmental problems because of the promotion of underground and eastern vs western extraction; the occurrence of local post-mining land use conflicts; and the issuance of weakened reclamation standards.

***State Programs.*** Although eight of the 50 states still have no reclamation law, of these only Arizona and Alaska have the potential for substantial strip mining in the near term. All other major coal producing states have reclamation laws. Almost all of the 42 existing state strip mine reclamation laws were either enacted or revised during the past five years, indicating that in most cases recent developments in reclamation research and environmental control policies were available for consideration during the drafting of the laws (*5*, *6*).

As minimum standards, most state reclamation laws require the mine operator to backfill and recontour the mined area to varying degrees, often dependent upon the land use to which the site is being reclaimed. In addition, revegetation is required by all reclamation laws, except where variance is allowed for special uses. Most states require burial or neutralization of toxic substances and prevention of off-site environmental damage. Although they are not all coal producers, 23 states also require topsoil segregation and replacement for at least some operations, and many require screening the operation from public view with buffers of vegetation (see Table 4). Eighteen states require that mining companies consider alternative land uses in the development of reclamation plans, and provide a role for local planning participation by requiring the reclamation plan to be consistent with local land use plans, or that local concerned agencies be notified of the companies intent to mine (see Table 5).

In 25 states, the reclamation law is accompanied by a published set of rules and regulations which spell out to the mine operator more or less exacting procedures to be followed to achieve the goals of the law. For example, slope specifications for regraded spoils are often spelled out in the rules and regulations according to the various land uses to be considered. Steeper slopes are usually allowed for forestry than for pasture or range lands, which can be steeper than row crop areas that must regularly be traversed by farm machinery. The rules and regulations may also contain instructions for revegetation, especially in western states.

Five states (North Dakota, New Mexico, Maryland, Kansas, and Louisiana) have reclamation laws covering only coal, with no provisions for reclamation of other mineral sites. Three other states (Ohio, Alabama, and Virginia) have two laws so that coal can be regulated separately from all other minerals. This philosophy of giving special attention to coal mining dates back more than forty years, when reclamation laws were first being drafted in the Midwest and Appalachia. At that time, virtually all reclamation laws were directed solely at the coal industry. It was not until after several workable coal mine reclamation laws had been enacted that states began amending existing acts, or drafting new bills to include minerals other than coal. The existence of P.L. 95-87 is an example of the same sentiments at the federal level. Only after success has been demonstrated at regulating the coal mining industry will attempts be made to expand to other minerals.

***Current Research.*** While much of the current reclamation research is addressing interesting and real site-specific problems, almost all of it has been initiated without a comprehensive national research plan. Disaggregation and poor coordination are common faults. Some duplication does exist but to some degree this is necessary. There is a strong belief that no one in the government is cognizant of the total reclamation research effort, even OMB. At this time, there does not exist a clear statement of the problems in a regional or national context. As an example, currently, it is impossible to obtain a good national estimate regarding the amount of land that is disturbed each year by surface coal mining to help define the problem. In addition, the disruptive extraction practices of uranium, oil shale, and other

**Table 4. Summary of state reclamation laws (coal mining states).[a]**

| Requirement (at least some provision) | | | | |
|---|---|---|---|---|
| Elimination of highwall | Conserve and replace topsoil | Bury or neutralize toxic wastes | Grade to approximate original contour | Revegetate to premine, permanent, or native vegetation |
| Pennsylvania | Alabama | Alabama | Arkansas | Illinois |
| Ohio | Arkansas | Arkansas | Iowa | Montana |
| Montana | Colorado | Illinois | Kentucky | South Dakota |
| Texas | Illinois | Indiana | North Dakota | Tennessee |
| | Iowa | Iowa | Ohio | Texas |
| | Kansas | Kansas | Pennsylvania | |
| | Louisiana | Kentucky | Tennessee | |
| | Montana | Missouri | Texas | |
| | North Dakota | Montana | Washington | |
| | Ohio | New Mexico | Wyoming | |
| | Pennsylvania | Ohio | | |
| | South Dakota | Oklahoma | | |
| | Tennessee | Pennsylvania | | |
| | Texas | South Dakota | | |
| | Utah | Tennessee | | |
| | West Virginia | Texas | | |
| | Wyoming | Utah | | |
| | | Virginia | | |
| | | Washington | | |
| | | West Virginia | | |
| | | Wyoming | | |

[a]*Adopted from Imhoff (5) and Doyle (6).*

mineral mining require closer scrutiny to determine what research efforts can be undertaken to minimize environmental health and socioeconomic impacts.

Much of the past and current research information has not been transferred from the researcher to the user. Therefore, in many instances, programs are being initiated to gather information that has already been developed. Any effort that does not assign the highest priority to the transfer of research data to the user is useless. In addition, there is a real need to organize and standardize the data collection activities between disciplines and agencies. Better definition and agreement on resource regions and time frames is needed.

**Table 5. Briefs of state assertions of the role of local public planning in regulations of mine reclamation.[a]**

| State | Role stipulated |
|---|---|
| California | Act on mining permits and reclamation plans and mining policy in general plans (of state). |
| Colorado | Review for conformity with local land use controls. |
| Florida | Local government may impose stricter standards (silent on local planning). |
| Illinois | County board may recommend land use, and may request hearings. |
| Kentucky | State permits must comply with local zoning laws. |
| Maryland | State, in acting on applications, takes cognizance of county planning, zoning, and grading permits. |
| Minnesota | "Rules . . . shall conform with any State and local land-use planning." |
| New Mexico | Consultation required with soil and water conservation districts. (No word about other types of planning organizations.) |
| Oregon | Department may approve local governmental permitting or reviewing in lieu of State (local planning involved). |
| South Carolina | Local soil and water conservation districts review and comment. |
| South Dakota | *Incompatibility with local land plans can be basis for State rejection of mining permit application.* |
| Texas | Local governments are notified of mining-reclamation and their comments comprise input to the decision-making process. |
| Utah | Local governments are notified and their comments are taken under consideration. |
| Vermont | State action must accord with local plans. |
| Virginia | Local soil and water conservation districts advise. |
| Washington | Applicant must show legality of action with regard to local mining. |
| Wisconsin | Mining, reclamation and comprehensive plan (for site development) shall conform to local zoning. |
| Wyoming | County involved in administration of act. |

[a]Adopted from Imhoff et al. (5).

There is a growing need to develop a coherent national program that can begin to piece together the patchwork efforts currently underway and identify what information is needed to plan and implement a national land reclamation program that can assess the environmental impacts of coal and other energy mineral development and provide environmentally sound economically feasible techniques to utilize our natural resources.

### Review of Literature

Research activities related to extraction/reclamation of coal have been carried out since the early thirties. All of this research was site specific and tended to focus on well defined efforts of one or more disciplines.

During the sixties and seventies, research activities increased and research efforts were reported by universities and several federal agencies. At this time, there exist thousands of documents that chronicle the development of extraction/reclamation technology.

Rather than attempt an in-depth review of these documents, this study has elected to list 65 bibliographies that deal with reclamation problems. Twenty bibliographies and related works have been selected for annotation. The appendix contains citations to or alphabetical listing of all 65 bibliographies. It is quite possible that some important efforts have been inadvertently overlooked.

## Impacts on Water

### East and Midwest

Increased coal production under the National Energy Plan will create additional impacts to water resources in the East and Midwest qualitatively similar to current problems occurring because of past and present coal mining in those regions. Most studies involving water quality and hydrologic alterations resulting from surface mining have dealt with active mines or abandoned unreclaimed mined areas. However, there has been little research conducted to specifically evaluate the effectiveness of various mining and reclamation techniques to minimize water resource problems in mined areas during and after reclamation. The types of hydrologic and water quality problems, the substantiating empirical data, the areas of uncertainty, and needs for future research will be briefly discussed here.

***Erosion and Sediment Transport.*** Runoff rates and erosion on reclaimed mine areas have not been well documented. Erosion and sediment transport from actively-mined areas and unreclaimed areas have been shown to be much higher than on unmined areas. In a study of strip-mined watersheds in eastern Kentucky (*7*) large sediment transport rates were measured during active mining and in a 2-year period after completion of mining; the rate of sediment yield was correlated with the percent of mined area in the watersheds. Davis and Hines (*8*) monitored mined watersheds for sediment yield and measured 0.2 acre-feet per acre of disturbed land for a three-year period, which is equivalent to approximately 120 tons per acre per year. Generally, sediment transport rates from surface-mined lands are highest in steep sloped Appalachian areas. A large diversity of erosion control and sediment retention procedures and techniques are available for active surface mines and reclaimed lands (*9, 10*). The actual success of erosion control for each mined area or coal refuse disposal site, and the subsequent mitigation of aquatic impacts, is highly dependent on the adequacy of state and federal laws and regulations, the degree of enforcement of these laws and regulations, and the cooperation and effort of mining companies to implement reclamation techniques to minimize erosion and sediment transport. An evaluation of the effectiveness of sediment ponds in reducing suspended solids in the runoff water from coal surface mining activities in the East (*11*) showed generally poor performance because the ponds were found not to be constructed in accordance with the approved plans and specifications, were not properly utilized, or were not properly maintained. The ability of different reclamation techniques to minimize long-term erosion and sediment transport to streams has not been specifically investigated.

***Acid Water Runoff.*** Many coal seams and associated overburden rock, particularly in the northern Appalachian states, Alabama, Ohio, and the Interior Coal Basin states contain significant quantities of pyrite. When exposed to air during surface mining, the pyrite undergoes gradual oxidation. The sulfate minerals produced by pyrite oxidation are soluble and react with water to form what is commonly termed acid mine water, having a low pH and high concentrations of acidity, sulfate, and metals. The acid water accelerates weathering and leaching of other minerals, thus contributing variable concentrations of calcium, magnesium, iron, manganese, aluminum, copper, cadmium, zinc, and other metal ions which are toxic or potentially toxic to vegetation and aquatic life. Acid mine water has long been recognized as a major water quality problem in the East and Midwest.

Grading and compaction of acidic spoils and coal refuse, addition of lime, and a cover of soil with

vegetation has commonly been recommended as the best reclamation technique to effectively retard pyrite oxidation and leaching and has proven to be moderately successful in producing short-term improvements in surface water quality (*12-14*). The long-term effectiveness of a soil cover in reducing pyrite oxidation and leaching is still uncertain. At the New Kathleen mine site in Illinois and innumerable other sites in the East and Midwest, erosion often removes the soil cover along gulleys, thus reexposing pyritic materials and allowing oxidation to be renewed. Reclamation success will therefore play a major role in determining the future levels of acid mine drainage resulting from increased coal production.

***Groundwater Pollution.*** The amount of research that has dealt with groundwater contamination as a result of incomplete reclamation of acidic mine spoils is limited. Water flowing through pyritic materials is capable of dissolving and transporting great quantities of acid, sulfate, and dissolved metals in the subsurface flow systems. Extensive pollution of aquifers has been documented in the Clarion River watershed (*15*) and in Clearfield County, Pennsylvania (*16*) as a result of surface and underground mining. This situation probably occurs to some extent in most areas where mining of pyritic coal seams is occurring, but hasn't been adequately investigated. Whether proper reclamation can control subsurface leaching of pyritic materials is another question that has received inadequate consideration.

***Flooding Potential.*** The hydrologic system of an area or an entire watershed can be drastically altered as a result of mining. Hydrologic research in the mountainous areas of eastern Kentucky has shown that peak discharges (flooding potential) are increased by as much as a factor of 5 as a result of surface mining; whereas studies in Indiana (*17*) indicated that surface mining reduced peak flows, increased groundwater recharge in the spoil materials, and increased low flows of streams in the mined area. The changes seen in the Indiana study were the result of mines not being graded to contour or reclaimed, and as a result water retention in "last cut" ponds reduced runoff and increased groundwater recharge.

The alterations of the hydrology and the flooding potential of a mined watershed will likely occur as a result of mining and reclamation, but the exact nature of these changes is highly dependent on the basin topography and geometry, rainfall, mining and reclamation methods employed, and the area of land disturbed.

In summary, not all water resource impacts resulting from current and future increases in coal production in the East and Midwest are fully recognized or evaluated. However, it is anticipated that the majority of problems will be qualitatively similar to those presently existing. The extent and magnitude of future problems will be primarily determined by the effectiveness of existing and proposed legislation in reducing erosion and sedimentation, and acid mine drainage. The impacts of future coal production will to a large extent be watershed and site specific and it is not within the scope of this cursory discussion to quantitatively assess regional water resource degradation.

## West

Concerns relating to water resource impacts during coal mining and reclamation in the West differ in many respects from those in eastern and midwestern mining regions. These regional variations arise from differences in mining methods used, in the sulfur content of coals, as well as differences in factors such as climate, soil types, land use patterns, and water availability.

***Alkaline vs. Acid Drainage.*** Unlike the situation at many eastern and midwestern mines, acid formation and drainage is not a prevalent problem at western coal mines, nor is it expected to become one. This is attributable to the low sulfur content of most western coals (particularly pyritic sulfur forms which lead to sulfuric acid formation upon oxidation), as well as low water availability and the generally alkaline nature of western soils and water. A further consequence of alkaline water is reduced mobilization of potentially toxic or otherwise undesirable metals which readily enter into solution under acid conditions, but precipitate under alkaline conditions. This lack of acid drainage, both during mining and reclamation, removes a major source of concern for water quality present in other coal regions.

***Erosion-Sedimentation.*** A potential aquatic impact common to all coal regions is erosion and subsequent sedimentation in receiving streams. While total yearly rainfall is low in many western regions, the potential for extensive erosion during intense rainfall events exists, and may be intensified by limited or delayed revegetation success in arid regions. Existing effluent limitation guidelines limit point source discharge of suspended solids during active mining, but currently do not specifically control nonpoint-source loading of suspended solids during mining or reclamation. Thus, a significant potential exists for negative aquatic impacts related to erosion-induced sedimentation during reclamation as well as mining phases. Insufficient data exist to permit estimation of the severity of such impacts; however, it is clear that without implementation of en-

vironmentally compatible mining and reclamation technologies, increased sediment loading in western streams is likely to occur with increased surface mining.

***Salinity.*** Another potential water quality impact at western sites is increased salinity caused by pumped discharges during mining and by surface runoff and groundwater seepage during mining and reclamation. Effluents and runoff at western mine sites often contain concentrations of major soluble ions considerably in excess of ambient concentrations in receiving streams. In some cases, the dilution of mine waters in receiving streams is sufficient so that no detectable impact upon ambient stream concentrations is apparent (*18, 19*), although in at least one documented case substantial salinity increases have been noted (*20, 21*).

Small to moderate increases in salinity (e.g., 10-20%) in most western streams would probably not represent a significant environmental hazard to aquatic biota; however, large increases could not only affect some aquatic biota but also water uses such as domestic consumption, agricultural irrigation, stock watering, and industrial consumption. The actual user effects of salinity increases in a given watershed will be determined primarily by use of the resource. For example, a salinity increase in a Northern Great Plains stream used primarily for stock watering and irrigation of relatively salt tolerant crops (e.g., alfalfa) might be acceptable, whereas the same increase in the lower Colorado River Basin where many irrigated crops are salt sensitive could result in significant agricultural impacts. Increased western coal production is likely to result in salinity increases in some streams, which in some stream basins could affect present water use. Salinity control measures incorporated into mining and reclamation plans will be necessary in sensitive river basins.

***Groundwater.*** The limited available data indicate that groundwater in reclaimed mine spoils is often more highly mineralized (saline) than groundwater in undisturbed media, thus indicating possible local impacts upon groundwater quality and use. Insufficient field data exist to determine the regional extent of this potential problem, but present indications are that such problems will be local and site specific.

The mining method presently used at most western coal mines is area strip mining. This method disrupts all geologic units above the coal seam as well as the coal seam itself. Any permeable layers between the land surface and the bottom of the coal seam are thus interrupted, and may cause an alteration in local groundwater availability and flow paths. Depressions of the groundwater table are experienced in the vicinity of operating mines because of seepage into mine pits and localized dewatering of the aquifer(s). Such depressions of the water table are limited to the mine vicinity and are expected to recover after reclamation, but may cause wells in the vicinity of the mine to go dry during the periods of active mining and early reclamation. The extent to which water table levels will recover after reclamation will be site specific and dependent on proper restoration of groundwater systems in reclaimed areas.

***Water Availability.*** Because of limited water availability in most western coal regions, impacts of mining and reclamation upon water availability assume great importance. Without proper premine planning and reclamation, water availability for specific uses may be affected by alterations in water quality and disruption of local hydrologic systems as a result of expanded western coal mining. Because research data are incomplete, it is not possible at this time to quantify the regional impacts of expanded western mining.

***Alluvial Valley Mining.*** Disturbance of local groundwater systems is presently of particular concern in alluvial valleys. Only approximately 3% of the coal mine lease acreage in an eight-state western area investigated (*22*) was located in alluvial valleys, but since overburden is often thinnest in these areas, mining in alluvial valleys is economically attractive. Additionally, mining adjacent to alluvial valleys (where up to 10% of the strippable western coal is found) could disrupt valley hydrologic systems. Alluvial valley floors play an important role in the agricultural economy of many arid and semi-arid western regions, and any significant disturbance of groundwater hydrology could reduce the long-term agricultural productivity of these valleys and represent a long-term impact upon land use. The reclamation potential of disturbed alluvial valleys is presently not clear, although it is believed that restoration of essential hydrologic functions is possible in some areas. Extensive research on reclamation of alluvial valley floors and adjacent uplands is needed before long-term impacts on agricultural and groundwater hydrology and water quality can be evaluated.

## Current Research

While there is a general lack of pertinent research information concerning water resource impacts of western coal mining, a substantial number of major (and a multitude of minor) research projects are currently underway, and results should soon be available. This does not imply that all questions and

problems related to water resource impacts will be answered, but the types and magnitudes of potential problems that can be expected in western coal regions should be identified, and regional or site specific studies (e.g., baseline data acquisition for mining permits) can be tailored to emphasize pertinent local or regional problems and information requirements that have been recognized by previous research efforts. Once ongoing studies are published, it should also be possible to begin generalized analysis of the cumulative impacts of multiple mines or other energy-related developments such as coal conversion or electric power generation within individual river basins. However, detailed assessments and impact quantitation of specific developments will require additional site specific studies since the detailed conclusions necessary for planning such developments are sensitive to unique site characteristics.

All major federal agencies charged with environmental responsibilities are funding water resource studies in the western coal regions, and virtually all aspects of aquatic and hydrologic impacts of the coal fuel cycle are under investigation. But because of intrinsic inter- and intraregional variability, redundancy among the research efforts is essential to distinguish local unique problems from those of general or regional concern to regulatory authorities.

### Research Needs

Questions of major concern, which will no doubt require additional investigation, deal with such areas as incipient effects of salinity and alkaline soluble metals (e.g., selenium and molybdenum) upon specific aquatic biota and agricultural crops, long-term effects of low level increases in suspended solids, the reclamation potential of alluvial valley mining, biotic effects of reduced flow regimes in streams, and various aspects of aquifer disturbance and restoration.

## Impacts on Land

### East

***Present Problems.*** Expanded production in the East as outlined by the NEP will result in increased pollution even though great strides have been made in developing mining and reclamation technologies which minimize the effects of land disturbance. Although major emphasis is placed upon augmenting production from underground mining, surface mining will still play an important role in meeting the goals of the NEP. This is dictated by manpower shortages in the short term for underground mines and the desirable reserves of coal that can only be safely mined by surface methods.

Erosion of unstabilized spoil resulting from the contour mining of steep slopes or from the mountain-top removal method of mining as well as acid generated from pyritic materials in these spoils are major environmental problems. Sediments eroded from surface mines, from coal refuse areas and from disposal areas of acid mine drainage (AMD) treatment sites are a major problem in the Eastern United States. Additional pollution results from the erosion of haulage roads used for both surface and underground mines and from the land disposal of fly ash, bottom ash, and scrubber sludge. With increased coal production and coal utilization, these areas may have major impacts on the health and environment of the area. Erosion and sediment control are prime concerns in southern Appalachia (Tennessee, Alabama, southern West Virginia, Virginia, and eastern Kentucky) (*23*).

Acidity is a major factor in northern Appalachia including the area of Pennsylvania, southeastern Ohio, northern West Virginia and Maryland. In this area, rock strata overlying the coal are low in fertility and high in acid producing materials. These factors dictate that sound reclamation techniques and maintenance programs (*24, 25*) be used on surface-mined areas. Spoil can turn acidic, resulting in difficulty of vegetation establishment or loss of vegetative cover, and thereby increasing the erosion potential. Overburden analysis and the selective placement of materials have become standard practices in West Virginia and some other eastern states.

The lignite area in Alabama, when developed, may have similar problems as evidenced by high sulfur values found during preliminary analysis of overburden materials.

Damage to off-site properties results from the corrosive action of AMD, from erosion of surface materials, and from slides from the outslope areas of contour mines. In 1965, eastern Kentucky had slides on 12% of its contour mines, causing flood hazards by blocking small streams and natural drainage patterns. In addition, sediment basins at the head-of-hollows are flood hazards if improperly designed; however, there is evidence that properly designed surface mine sediment structures have lessened the effects of the 1977 spring floods in southern West Virginia.

Underground mining, which includes drift, slope, and shaft mines, poses different problems. The Buffalo Creek disaster in West Virginia is a good example. Coal mine refuse was used to construct a water impoundment at the head of a hollow. Instability of this material caused the dam to give way

during heavy rains resulting in the loss of 120 lives and millions of dollars of property damage. A 1974 study, only 40% completed, on dams in the east found 30 similar water impoundments which were classified as imminent flood hazards and 176 additional structures which were classified as potential flood hazards (*26*). An increase in underground mining even with additional safeguards can only aggravate the situation because of the increased volume of coal mine refuse.

***Areas of Uncertainty or Controversy.*** The approximate original contour regulation of the new Federal Surface Mining Act presents a problem for restoration of both surface mining and the surface effects of underground mining in Appalachia. Returning a surface mine to original contour creates long uninterrupted slopes which promotes erosion and slope instability unless proper control measures are taken. A back-to-contour demonstration by TVA at Massengale Mountain has an exceedingly high erosion rate of 113 tons/acre/year (*27*). The storage of mine waste from slope mines exhibit similar problems and creates environmental damage, especially when stored downslope from the mining operation. This material erodes and is deposited in the valleys which contaminate soil and water resources.

Land grant universities, various state agencies, USDA Forest Service, USDA Agricultural Research Service and USDI Fish and Wildlife Service have ongoing research on overburden analysis, revegetation, watershed hydrology, minesoil classification, wildlife habitat restoration and reforestation. Reclamation of surface mine spoils using waste materials from municipalities (sewage sludge), coal-fired power plants (fly ash, bottom ash and scrubber sludge), and AMD treatment facilities (alkaline sludge) are also being instituted. This work has resulted in much duplication in effort. A strong interaction between all agencies funding research in the East would lessen the chances of duplication in the future.

***Resource/Research Needs.*** New areas of needed research in mining and reclamation technologies are necessitated by the regulations of the Federal Surface Mining Act. The approximate original contour regulation in the most controversial issue and will not be resolved until additional data are available. Other areas of needed study include design of sediment structures, methods of controlling erosion onsite before it reaches the sediment structure. Research on the pre-planning of mining operations to include viable future land uses must receive detailed consideration. The characterization and potential use, as construction materials or soil amendments, of waste rock, coal refuse, AMD treatment sludge, fly ash and scrubber sludge are areas which need additional research.

## Midwest

***Present Problems.*** Surface mining for coal in the Midwest has encroached on valuable prime agricultural lands. In 1976, for example, permits were issued to surface mine 17,230 acres within the state of Illinois. Of this total acreage, 12,954 acres, or about 75%, are classified as prime agricultural land by the U.S. Soil Conservation Service (*28*). Projected estimates for the Midwest indicate that land disturbance by surface mining will possibly double to meet the NEP 1985 goals. This increase in surface mining activity will undoubtedly advance the disturbance of prime agricultural lands and affect both the economy and environments in Midwest surface mining areas. The major concern of mining prime agricultural lands is whether or not the technology or knowledge exists which will allow for the successful reestablishment of those soil factors which are conducive to successful crop production.

The new Federal Surface Mine Act (P.L. 95-87) specifies that the root zone of plants be reestablished following mining by topsoil and/or subsoil segregation and replacement to achieve both a texturally and chemically suitable root environment. This section of P.L. 95-87 will not have a major beneficial impact in several agriculturally oriented midwestern states that are major producers of surface mined coal. For example, Ohio, Illinois, and North Dakota have had reclamation regulations requiring topsoil segregation and replacement for at least two years (*29*). Illinois limits topsoil segregation and replacement only to lands suitable for agriculture. North Dakota requirements are for all lands and were developed to alleviate chemical and physical problems associated with lower subsoil strata. Therefore, the potential role of topsoil replacement to lessen the time required to return land to a productive state has been recognized and employed for a brief period of time by numerous states that have surface mining.

***Areas of Uncertainty or Controversy.*** One of the problems associated with surface mine reclamation is the reestablishment of a suitable matrix capable of supporting plant growth at a level of maintenance equivalent to premined conditions. This matrix is called "topsoil." Topsoil is a valuable natural resource containing most of soil organic matter and nutrients required by plants for crop and forage production. The problems associated with reestablishment of this below-ground ecosystem are in part due to the lack of understanding of the biological processes associated with this geochemical and geophysical matrix. Until recently, soil has been

treated as a mineral, not as an ecosystem.

Current laws require that topsoil be removed separately and replaced on the backfill area or, if not utilized immediately, stockpiled. If proper planning is undertaken, the only stockpiles evident are normally those associated with the first cut and exist for the life of the mine. Also, topsoils may not be replaced during certain seasonal periods due to climatic conditions. Thus, the length of storage may be great. The consequences of long term storage of topsoils on below-ground processes are not known. Also, the length of time for which soils may be stockpiled with minimum deleterious effects are not known. Just as important is the depth at which these stored topsoils should be kept. Also, what constitutes an adequate depth of topsoil over spoil? Is an intensive management system necessary to get these soils back into row-crop production. If so, for how long?

One factor which undoubtedly will influence the return of lands to a productive state is time. Unfortunately, research data on the time required to reestablish high-quality farm land after surface mining is lacking. However, even with the insufficient data base, estimates of times ranging from 10 to 30 years have been made (*30*). These estimates were made without consideration given to the beneficial impact of topsoil segregation and replacement. Should this time estimate be correct, losing these lands from agricultural productivity could be critical. Perhaps the answer is just a matter of economics. The most expensive steps in surface mine reclamation are topsoil removal, storage and replacement, backfilling and grading, and erosion control. Uniformity is lacking in reporting these costs but with topsoiling, estimates for North Dakota range from $2400 to $6600/acre (*31*). If additional segregation of lower soil horizons is found to be necessary in order to return land to a productivity level equal to or greater than premining levels, it may be just a matter of added cost/ton of coal mined.

Is the potential loss of prime agricultural lands a problem to be concerned about? Based on past history, the answer to this question would be yes. However, with the awareness now at both the state and federal level of the importance of the darkened surface soil component which contains the major portion of the important soil ecosystem, the answer is perhaps no.

We still do not completely understand the biogeochemical processes associated with native soils let alone disturbed systems such as those encountered in the reclamation process. Thus at this point, the consequences of our actions as to expanded coal mine development on prime agricultural land cannot be addressed in a rational manner since the data base necessary for making realistic decisions as to what can be done is not at hand. What is necessary, then, is an increase in research addressing questions so as to gain a better understanding of the microbial processes occurring within the soil. Particular emphasis should be addressed towards a better understanding of the carbon and nitrogen cycle. Also, research should address the role of soil symbionts, particularly mycorrhizae and nitrgoen fixers in undisturbed and reclaimed systems as to the potential benefit of such associations.

Prime agricultural lands are often prime lands for other uses. Residential and industrial developments, road construction as well as surface mining are making large demands on the limited supply of this valuable natural resource. Among the above mentioned uses, only surface mined lands have the potential to be returned to their former use. Additional research is needed in many areas to determine the most rapid and economical means to reclaim these areas of high agricultural production. Of equal importance, other efforts must be oriented to control the destruction of prime agricultural lands by all forms of development.

***Resource/Research Needs.*** Currently, the Department of Agriculture and the universities in cooperation with several mining companies are initiating a research program to better understand the impacts of mining prime agricultural land in the Midwest. Additionally, the Department of Energy-funded Land Reclamation Program at Argonne National Laboratory is conducting a field research program to evaluate alternative topsoil materials and management practices. Several universities, including Iowa State University (Iowa coal project), have preliminary data that will be helpful in determining the most environmentally acceptable and economic way to restore high agricultural production. Unfortunately, most of this research was initiated during the past two years and preliminary data are inconclusive. There exists considerable disagreement regarding time that will be required to answer the questions related to disturbance of prime agricultural land.

## West

***Present Problems.*** The precipitation patterns over much of the western coal regions are highly variable and consistently low. Low precipitation, and hence low available moisture, is the most serious in the southwestern coal fields, particularly in the Four Corners area and the Red Desert area of southern Wyoming. Both areas average 6 to 9 in. precipitation annually; they frequently receive less. Currently, some companies are irrigating reclamation

sites for the first growing season to enable perennial species to become established. Irrigation is not a solution for all mines in semi-arid sites since water rights are usually not available. Mine-mouth power plants are a source of irrigation water for some reclamation, while other mines must rely on mulching and spoil surface manipulation to hold available moisture (*32*). In areas where wind is a problem, mulching is not effective. There are many areas in the western U.S., however, where annual precipitation is 14 to 16 in. or greater and where acceptable revegetation (including establishment of native species) can be accomplished after surface mining.

Alkaline or saline spoils are a problem throughout the West. High salinity and clay in conjunction with low precipitation create moisture stress inhibiting vegetation establishment (*33*). Alkalinity problems can be avoided through selective overburden placement in some cases. The use of tolerant species can also ameliorate the impact of alkaline and saline spoils. In North Dakota, legislation has been passed which requires selective overburden placement to bury toxic overburden.

***Areas of Uncertainty or Controversy.*** Irrigation is a center of controversy. The question of whether initially irrigated plant communities on reclaimed areas can maintain native area densities for an indefinite period of time has not been answered. The controversy centers around the fact that initial establishment rates under sprinkler irrigation are higher than normal, and a drought year may severely impact the reclaimed community (*34*). Many states require the use of "native" species only. There is no allowance made for a blend of "native" and adapted introduced species which is a common condition on many rangelands. The use of early successional species and other invaders in reclamation is also a source of controversy (*35*). Currently, reclamation practice uses only late successional or climax species. Some researchers believe early successional species will aid in the establishment of these more desirable species. Some researchers maintain that regrading for more effective range management, e.g., the creation of stock ponds, may be an advantage (*36*). The question of alluvial valleys and whether they should be mined is also of concern. Some argue that mining would impact subsurface irrigation which is thought to be highly important to agriculture in these areas.

Small mammals can also impact reclamation. Seed-eating mammals will follow drill rows, consuming all seeds in a furrow. Rabbits consume large quantities of young vegetation, particularly grasses. In some cases, grass establishment is impossible without rodent control.

***Resource/Research Needs.*** All of the areas discussed above require research. Land management decisions and the knowledge to make them are among the most critical. It is possible that some areas which are regraded as marginal, e.g., southwestern Wyoming, can be improved through recontouring for better land use. Spoils reshaped to create stock watering ponds, for example, could greatly improve land use efficiency by spreading grazing activity. Spoils reshaping and other land management tools could improve reclamation effectiveness in other ecosystems as well.

Increased mining in the West will make the demand for adapted species greater. If "native" species are a requirement, a premium will be placed on their development. Several western companies are concerned about potential future shortages of adapted seeds to accomplish reclamation if legislation requires revegetation with native species.

Irrigation will continue to be a tool until alternative methods are developed; the lack of water will be a major problem at mines where water for irrigation is not available.

## Health and Ecological Effects of Atmospheric Effluents from Coal Mine Reclamation Activities

Atmospheric effluents generated as a result of coal mine reclamation activities will fall primarily in two categories: (1) dust generated and entrained in the air as a result of earthmoving activities or by wind blowing across unvegetated or unstabilized piles or areas of spoil, refuse or topsoil, and (2) gaseous effluents from diesel or gasoline powered internal combustion engines of reclamation equipment. It should be emphasized at the outset that the off-site adverse health and ecological impacts of these atmospheric effluents, if they occur, are likely to be small and within acceptable limits. This conclusion is based on the fact that the concentrations of those effluents that are of even marginal concern are extremely localized ($< 1$ mi$^2$) and of short duration ($<$ 1 yr) for any given location. Thus, in most cases, potential impacts will be limited to the operator's site or lease area. Potential impacts to onsite workers and biota will be addressed by the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87), when it is fully implemented, and by the Federal Coal Mine Health and Safety Act of 1969.

### Dust

Dust may be entrained in the air by the following coal mine (primarily surface) reclamation activities:

use of haul roads by heavy equipment; topsoil removal; backfilling; grading; topsoil respreading; preparation of soil for planting; application of lime, fertilizer, mulch or other amendments; seeding; and unvegetated or unstabilized piles or areas of spoil, refuse, or topsoil.

Dust consists of chemically active and/or inert particulates in the size range of $< 1\ \mu m$ to $> 150\ \mu m$ in diameter. These particles are not a stable component of the atmosphere because they eventually fall back to the earth's surface (*37*). Concentrations of dust vary from city to rural areas and can range from 30 $\mu g/m^3$ in rural areas to over 200 $\mu g/m^3$ in urban regions. In areas of high earthmoving activity, values can exceed 1000 $\mu g/m^3$ (*38*).

Entrained or deposited dust in the vicinity of reclamation activities may pose potential health and environmental effects due to reduced visibility, increased inhalation of particulates including trace elements or other toxic materials brought to the surface by soil and subsoil relocation, aggravation of pre-existing respiratory problems by particulates, shading and/or suffocation of vegetation due to dust deposited on aerial plant parts, reduction of palatability of vegetation to livestock and wildlife due to dust deposited on plant surfaces, or deposition of dust in water bodies adding to the sediment and/or salt loads of these waters.

The magnitude of effects due to dust caused by reclamation activities can vary considerably depending on mitigative measures employed by the operator. Measures that will reduce the amount of entrained and deposited dust include: good engineering practices used during earthmoving, sprinkling of haul roads with water or dust-suppressant solution, and rapid revegetation or stabilization of temporary storage piles and other unstable areas.

Entrained and deposited dust may be more of a problem in the arid West where there is less precipitation and where vegetative cover to stabilize surface materials is more difficult to establish. Also, in many coal mining areas of the West average wind velocity and persistence are greater than mining areas in the Midwest or East.

## Gaseous Effluents

Relatively small amounts of $SO_x$, $NO_x$, CO, and hydrocarbons are emitted by the internal combustion engines (diesel and gasoline) of reclamation equipment. However, realistic estimates of ground level or low level concentrations of these effluents (*39*) for a typical reclamation operation are several orders of magnitude below the concentrations that have threshold acute effects on biota, including humans. Therefore, the effects of gaseous effluents will not be addressed further here since the probability of adverse impacts is extremely low.

## Conclusions

As discussed above, the probability of offsite adverse health and environmental impacts due to atmospheric effluents from coal mine reclamation activities is very low. Onsite workers and biota will be covered by federal and/or state regulations. Thus, if an operator conducts reclamation within these regulations, the impacts should be within acceptable limits.

# APPENDIX
# Review of Reclamation Research Bibliographies

To date more than 50 bibliographies have been developed that list and describe publications related to coal extraction and mined land reclamation. Discussed below are a number of selected, larger bibliographies; an additional 49 bibliographic documents are given as references (*40-88*). The bibliographies summarized below are classified according to the region of the U.S. they cover and the organization that sponsored their development. The volume of literature pertaining to Western mining operations is relatively small in comparison to that for the East and Midwest; this reflects the historical dominance of Eastern and Midwestern mining.

## Eastern and Midwestern U.S. Bibliographies

***National Coal Assn./Bituminous Coal Research, Inc.*** A major source of environmental damage resulting from mining operations in the East is acid mine drainage. More than 2300 documents have been listed in the MINE DRAINAGE ABSTRACTS: A BIBLIOGRAPHY produced by the National Coal Association and Bituminous Coal Research, Inc. Published as a series of annual abstracts, this bibliography identifies the major works on the formation, abatement, and effects of water pollution related to underground and surface coal mining. Documents are

arranged according to year of publication and are indexed by author, subject, geographic features, and organization.

Another Bituminous Coal Research, Inc., bibliography, RECLAMATION OF COAL-MINED LAND: A BIBLIOGRAPHY WITH ABSTRACTS, indexes and abstracts more than 700 technical articles and reports. The publications included in this reference cover all aspects of reclamation.

***U.S. Department of Agriculture/Forest Service.*** Publications resulting from the U.S. Forest Service's program on forestation of strip mined lands, which began in 1937, are summarized in G.A. Limstrom's FORESTATION OF STRIP MINED LAND, published in 1960 as Agricultural Handbook 166. The 135 documents described in this bibliography identify the characteristics of overburden and their effect on the establishment and growth of plants and trees.

As a follow-up to Limstrom's original bibliography, David Funk published A REVISED BIBLIOGRAPHY OF STRIP MINE RECLAMATION in 1962 which lists nearly 100 publications, plus more than 70 technical citations that appeared in Limstrom's report. Reclamation research publications also are documented in the Forest Service's STRIP MINE RECLAMATION: A DIGEST, published in 1962. This document reviews and summarizes the published reclamation literature through mid-1961.

Miroslaw Czapowskyj's ANNOTATED BIBLIOGRAPHY ON THE ECOLOGY AND RECLAMATION OF DRASTICALLY DISTURBED AREAS, published in 1976, is a general publication which illustrates the accomplishments in improving the condition of mined lands. Produced by the U.S. Forest Service, this bibliography lists nearly 600 technical documents written by university, government, and industrial researchers.

***U.S. Department of Energy.*** The Argonne National Laboratory Land Reclamation Program has published A SELECTIVE BIBLIOGRAPHY OF SURFACE COAL MINING AND RECLAMATION LITERATURE, VOLUME 1: EASTERN COAL PROVINCE; VOLUME 2: INTERIOR COAL PROVINCE. This bibliography has been compiled for use by researchers, students, and other groups who need a reference source of published literature related to surface coal mining and reclamation. Each volume contains more than 1300 references, including government reports, journal articles, symposium proceedings, industrial reports, workshop proceedings, theses, and bibliographies. A simple format was used to categorize citations.

***U.S. Department of the Interior.*** In 1971 DOI produced SURFACE MINED AREAS: CONTROL AND RECLAMATION OF ENVIRONMENTAL DAMAGE, A BIBLIOGRAPHY, which lists 387 references on soil shifts, chemical modifications, and water pollution resulting from surface mining and the restoration of mined areas. This document references literature published in the United States between June 1960 and June 1970.

***U.S. Department of the Interior/Geological Survey.*** A common reclamation problem in the Midwest is land-use conflict in areas where coal is being strip mined from highly fertile row crop land. This conflict has resulted in a strong opposition to the extraction process. A BIBLIOGRAPHY OF INTEGRATED MINED-AREA RECLAMATION AND LAND USE PLANNING was prepared by the USGS Resource and Land Investigations Office and Argonne National Laboratory; it was compiled for use by planners who deal with the problems presented by surface mining and reclamation. There are 424 citations, many relating to reclamation planning in all parts of the United States.

***U.S. Department of the Interior/Bureau of Mines.*** SURFACE MINED LAND IN THE MIDWEST: A REGIONAL PERSPECTIVE FOR RECLAMATION PLANNING is a 691-page report by Argonne National Laboratory which addresses the problems of coal extraction and surface mine reclamation in the 11-state Midwestern coal resource region. This report includes a detailed state-by-state bibliography with 530 entries for Illinois, Indiana, Western Kentucky, Missouri, and Ohio.

***Universities.*** A SELECTED BIBLIOGRAPHY AND DISCUSSION OF THE EFFECTS OF STRIP MINING UPON NAVIGABLE WATERS AND THEIR TRIBUTARIES was compiled by the University of Pittsburgh in 1972. It is a major review of the literature on the sedimentation and acid mine drainage attributable to strip mining for coal.

R. F. Munn, from West Virginia University, compiled 611 references and grouped them into several categories in STRIP MINING — AN ANNOTATED BIBLIOGRAPHY. The categories include history, government regulations, environmental effects and reclamation.

AN ANNOTATED BIBLIOGRAPHY ON SLOPE STABILITY OF STRIP MINE SPOIL BANKS, which lists 366 references, was compiled in 1964 by the Ohio Agricultural Experiment Station.

***Miscellaneous.*** A BIBLIOGRAPHY OF SURFACE COAL MINING IN THE UNITED STATES TO AUGUST, 1971, by F. V. Kieffer, is another major reference source. It lists 730 references dealing with surface coal mining and the ecology of disturbed lands.

## Western U.S. Bibliographies

***Regional Commissions.*** A BIBLIOGRAPHY PERTAINING TO VEGETATIONAL ESTABLISHMENT AND MANAGEMENT ON LANDS DISTURBED BY MINING IN

THE WESTERN STATES was written by the Western Regional Coordinating Commission in 1975, in order to provide an up-to-date list of recent publications.

SURFACE MINING AND MINED LAND RECLAMATION, A SELECTED BIBILOGRAPHY, prepared by the Old West Regional Commission, also emphasizes the literature pertinent to Western surface mining and reclamation. It contains about 1300 references grouped into such sections as Surface Mining and Distribution of Land and Water, Reclamation, Revegetation, and Revegetation of Sand Dunes and Arid Areas.

***Universities.*** A BIBLIOGRAPHY OF LITERATURE PERTINENT TO MINING RECLAMATION IN ARID AND SEMI-ARID ENVIRONMENT is a bibliography prepared by Utah State University which lists 312 references, grouped under 27 headings. Coal-related reclamation topics include: ash spoils, coal spoil banks, and lignite spoil banks.

VEGETATION AND METAL TOXICITY IN RELATION TO MINE AND MILL WASTES, also produced by Utah State, is an annotated bibliography dealing with the various toxic elements found in mine and smelter wastes and their toxic effects on vegetation. It lists 167 publications.

The Office of Arid Land Studies at the University of Arizona has compiled a 278-page bibliography entitled THE IMPACT OF ENERGY DEVELOPMENT ON WATER RESOURCES ON ARID LANDS: LITERATURE REVIEW AND ANNOTATED BIBLIOGRAPHY.

Another important contribution to the literature relating to the Western United States is a bibliography entitled THE ECOLOGICAL EFFECTS OF COAL STRIP-MINING: A BIBLIOGRAPHY WITH ABSTRACTS. Prepared by Colorado State University, it contains nearly 1300 references on the ecological effects of Western coal strip mining with particular emphasis on the Northern Great Plains.

Of particular significance to the literature is SELECTED BIBLIOGRAPHY ON COAL-ENERGY DEVELOPMENT OF PARTICULAR INTEREST TO THE WESTERN STATES, prepared in 1974 by the North Dakota Agricultural Experiment Station. This bibliography includes 486 references grouped under the following topics: general references and bibliographies, coal resources of the Western states, demand for Western coal, surface coal mining, spoil bank reclamation, mineral rights and public regulation of strip mining, economic impact of strip mining and power production, and environmental impact of strip mining and power production.

## REFERENCES


1. The National Energy Plan. Executive Office of the President Energy Policy and Planning, Washington, D.C., April 1977.
2. NCA. New Coal Mine Additions and Expansion Plans. National Coal Association, July 1977.
3. Strippable Reserves of Bituminous Coal and Lignite in the United States. U.S. Department of Interior Bureau of Mines IC 8531, 1971.
4. Agnew, A. F. Coal, Carter, and Constraints. Congressional Research Service, Library of Congress, April 1977.
5. Imhoff, E. A., Friz, T. O., and LaFevers, J. R. A Guide to State Programs for the Reclamation of Surface Mined Areas. U.S. Geological Survey Circ. 731, Washington, D.C., 1976.
6. Doyle, J. C., Jr. State Strip Mining Laws: An Inventory and Analysis of Key Statutory Provisions in 28 Coal-Producing States. Environmental Policy Institute, Washington, D.C., March 1977.
7. Curtis, W. R. Strip-mining increases flood potential of mountain watersheds. In: National Symposium on Watersheds in Transition, AWRA, Fort Collins, Col., (June 19-22, 1972), p. 357.
8. Davis, J. R., and Hines, B. J. Debris basin capacity needs based on measured sediment accumulation from strip-mined areas in eastern Kentucky. Proc. Research and Applied Technology Symposium on Mined-Land Reclamation, Bituminous Coal Research, Inc., Pittsburgh, Pa., 1973.
9. West Virginia Department of Natural Resources. Drainage Handbook for Surface Mining, West Virginia Dept. of Natural Resources, Charleston, 1975.
10. U.S. EPA, Erosion and Sediment Control, Surface Mining in the Eastern U.S. U.S. EPA, Technology Transfer Seminar Publication EPA-625/3-76-006, Vols. 1 and 2, 1976.
11. Kathuria, D. V., Nawrocki, M. A., and Becker, B. C. Effectiveness of Surface Mine Sedimentation Ponds. U.S. EPA, Environ. Protect. Tech. Ser. Rept. EPA-600/2-76-117, U.S. EPA, Cincinnati, 1976.
12. U.S. Bureau of Mines. Methods and Costs of Coal Refuse Disposal and Reclamation. Inf. Circ. 8576. U.S. Dept. of Interior, Washington, D.C. (1973).
13. Kosowski, Z. V. Control of Mine Drainage From Coal Mine Mineral Wastes; Phase II — Pollution Abatement and Monitoring. U.S. EPA, Environ. Protect. Tech. Ser. Rept. EPA-R2-73-230 (1973).
14. Martin, J. F. Quality of effluents from coal refuse piles. In: Proc. 1st Symp. on Mine and Preparation Plant Refuse Disposal, NCA/BCR, Inc., Louisville, Ky. Oct. 22-24, 1974, p. 26.
15. Emrich, G. H., and Merritt, G. L. Effects of mine drainage on ground water. Ground Water, 7: No. 3, 27 (1969).
16. Caruccio, F. T., and Parizek, R. R. An evaluation of factors affecting acid mine drainage production and the ground water interactions in selected areas of western Pennsylvania. In: Proc. 2nd Symp. on Coal Mine Drainage Research, BCR Inc., Monroeville, Pa., 1968.
17. Corbett, D. M. Ground-water hydrology pertaining to surface mining for coal — Southwestern Indiana. In: Proc. 2nd Symp. on Coal Mine Drainage Research, BCR Inc., Monroeville, Pa., 1968.
18. Dettmann, E. H., and Olsen, R. D. Assessment of water quality impacts of a western coal mine. In: Proceedings of the Symposium on the Reclamation of Disturbed Arid Lands, Denver, University of New Mexico Press, Albuquerque, 1977.
19. Van Voast, W. A., and Hedges, R. B. Hydrologic Aspects of existing and proposed strip coal mines near Decker, Southeastern Montana. Mont. Bur. Mines Geol. Bull. 97 (1975).
20. McWhorter, D. B., Skogerboe, R. K., and Skogerboe, G. V. Water Quality Control in Mine Spoils, Upper Colorado River Basin. Rept. EPA-G70/2-75-048, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1975.
21. McWhorter, D. B., and Rowe, J. W. Inorganic water quality in a surface mined watershed. Paper presented at American Geophysical Union Symposium on Methodologies for En-

vironmental Assessments in Energy Development Regions, San Francisco, Calif., Dec. 8, 1976.
. Hardaway, J. E., Kimball, D. B., Lindsay, S. F., Schmidt, J., and Erickson, L. Subirrigated alluvial valley floors — a reconnaissance of their properties and occurrence on coal resource lands in the interior western United States. Draft manuscript, U.S. Environmental Protection Agency, Denver, Col., 1977.
23. West Virginia University. Mine Spoil Potentials for Water Quality and Controlled Erosion. Water Pollution Control Research Series 14010 EJE 12/71, U.S. Environmental Protection Agency, Cincinnati, Ohio (1971).
24. Smith, R. M., Grube, W. E., Jr., Arkle, T., Jr., and Sobek, A. A. Mine Spoil Potentials for Soil and Water Quality. EPA-670/2-74-070, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1974.
25. Smith, R. M., Sobek, A. A., Arkle, T., Jr., Sencindiver, J. C., and Freeman, J. R. Extensive Overburden Potentials for Soil and Water Quality. EPA-600/2-76-184, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1976.
26. U.S. Corps of Engineers, Department of the Army. The National Strip Mine Study, Volume I. Summary Report, Washington, D.C., 1974.
27. Curry, J. A. Surface mining coal on steep slopes: back-to-contour demonstration. In: NCA/BCR Fifth Symposium on Surface Mining and Reclamation, J. R. Boyer, Jr., Ed., NCA/BCR Inc., Louisville, Ky., 1977.
28. Department of Mines and Minerals. 1976 Annual Report — Surface Mined Land Conservation and Reclamation. Springfield, Ill. 1976.
29. U.S. Department of Interior. Laws and Regulations Affecting Coal. Office of Minerals Policy and Research Analysis, Washington, D.C., 1976.
30. Morrison, M., Ed. EPI Cautions About Strip-Mining Illinois Corn Belt. Coal Week, p. 2 (July 26, 1976).
31. LaFevers, J. R., Johnson, D. O., and Dvorak, A. J. Extraction of North Dakota Lignite: Environmental and Reclamation Issues. Argonne National Laboratory Report ANL/AA-7 (1976).
32. Sindelar, B. W., Hodder, R. L., and Majerus, M. E. Surface mined land reclamation research in Montana. Montana Agricultural Experiment Station, Res. Rept. 40, Montana State Univ., Bozeman, 1973.
33. Johnsgard, G. A., Salt affected problem spoils in North Dakota: their properties and management. Extension Bull. No. 2, Coop. Exten. Serv. N.D.S.U., Fargo.
34. Study Committee on the Potential for Rehabilitating Lands Surface Mined for Coal in the Western United States. Rehabilitation Potential of Western Coal Lands. Ballinger, Cambridge, Mass., 1974.
35. Morken, J. Pioneer vegetation on various treatments of coal overburden. Paper presented at the 1975 Meeting of the North Dakota Academy of Science, 1975.
36. Ogden, P. R. In: Range Management and Surface Mining in Reclamation and Use of Disturbed Land in the Southwest, John L. Thames, Ed., Univ. of Arizona Press, Tucson, 1977.
37. Resource and Land Investigations (RALI) Program: An Approach to Environmental Assessment with Application to Western Coal Development. Mitre Corp., Washington, D.C., August 1975, pp. XII-12 and 13.
38. Treshow, M. Environment and Plant Response, McGraw-Hill, New York, 1970.
39. Habegger, L., Wolsko, T., Ecamaioni, J., Kelermeyer, D., and Dauzvardis, P. Dispersion Simulation Techniques for Assessing the Air Pollution Impacts of Ground Transportation Systems. Argonne National Laboratory Report ANL/ES-29, 1974.
40. Averitt, P., et al. Minor Elements in Coal — A Selected Bibliography, U.S. Geol. Surv. Res. Prof. Pap. 800-D, Washington, D.C., 1972, pp. D169-D171.
41. Bergoffen, G. S. Strip-Mine Reclamation: A Digest, U.S. Forest Service, USDA, Washington, D.C., 1962, 49 pp.
42. Bituminous Coal Research, Inc. Reclamation of Coal-Mined Land: A Bibliography with Abstracts, BCR Inc., Monroeville, Pa., Oct. 21, 1975, 188 pages, 739 references.
43. Bituminous Coal Research Inc. Mine Drainage Abstracts: A Bibliography, BCR Inc., Monroeville, Pa. (annual supplements, 1967-1974).
44. Bowden, C. The Impact of Energy Development on Water Resources in Arid Lands: Literature Review and Annotated Bibliography, Arid Lands Resource Information Paper No. 6, Office of Arid Land Studies, University of Arizona, Tucson, Jan. 1975, 278 pp.
45. Bowden, L. L. A Bibliography of Strip Mine Reclamation, Department of Conservation, University of Michigan, Ann Arbor, 1961, 13 pp.
46. Brooks, D. B. Strip mine reclamation and economic analysis — Bibliography. Nat. Resources J. 6: 13-44 (1966).
47. Caldwell, N. B. An Annotated Bibliography of the Surface-Mined Area Restoration Research Project, U.S. Forest Service, Northeastern Forest Experiment Station, Berea, Ky., 1974, 21 pp.
48. Carpenter, L. H., and Williams, G. L. A Literature Review on the Role of Mineral Fertilizers in Big Game Range Improvement, Special Report No. 28, Colorado Division of Game, Fish, and Parks, Denver, 1972.
49. Coaldrake, J. E., McKay, M., and Roe, P. A. Annotated Bibliography on the Ecology and Stabilization of Coastal Sand Dunes, Mining Spoils and Other Disturbed Areas, Commonwealth Scientific and Industrial Research Organization (CSIRO), Division of Plant Industries, Canberra, Australia, 1973, 158 pp.
50. Coalgate, J. L. Literature Survey — Coal Association Wastes (1900-1972), Coal Research Bureau, W. Va. Univ., Morgantown, Report No. 115, 1972.
51. Czapowskyj, M. M. Annotated Bibliography on the Ecology and Reclamation of Drastically Disturbed Areas, USDA, Northeastern Forest Expt. Stn. General Technical Report NE-21, Upper Darby, Pa., 1976.
52. Dalstead, N. L., and Leistritc, F. L. A Selected Bibliography on Coal-Energy Development of Particular Interest to the Western States, Agricultural Economics Misc., Report No. 16, Department of Agricultural Economics, North Dakota Agricultural Experiment Station, North Dakota State University, Fargo, April 1974, 82 pp.
53. Earney, F. C. F. Mining, Planning, and the Urban Environment: An Annotated Bibliography, 1960-1975, Exchange Bibliography 881, Council of Planning Librarians, Monticello, Ill., Sept. 1975, 36 pp.
54. Environmental Protection Agency, A Preliminary Bibliography of Publications Concerning Rehabilitation of Lands Disturbed by Mining and Associated Activities for the Northern Great Plains Research Program, U.S. EPA, Rocky Mountain Prairie Region, Denver 1973, 19 pp.
55. Frawley, M. L. Surface Mined Areas: Control and Reclamation of Environmental Damage, a Bibliography, Bibliography Series No. 27, U.S. Department of the Interior, Office of Library Services, Washington, D.C., Sept. 1971.
56. Funk, D. T. A Revised Bibliography of Strip Mine Reclamation, Misc. Release No. 35, U.S. Forest Service, Central States Forest Experiment Station, Columbus, Ohio, 1962.
57. Gifford, G. F., Dwyer, D. D., and Norton, B. E. A Bibliography of Literature Pertinent to Mining Reclamation in Arid and Semiarid Environments, The Environment and Man Program, Utah State University, Logan, Utah, 1972, 23 pp.
58. Gilmour, E. H. Index Map and Bibliography of Coal Studies

in Montana, Montana Bureau of Mines and Geology, 1966.
59. Greene, J. E. Selected Materials for Planning the Reclamation of Mined Land, Exchange Bibliography No. 795, Council of Planning Librarians, Monticello, Ill., 1975, 8 pp.
60. Hodder, R. L., et al., Coal Mine Spoils Reclamation Research Project, Western Energy Co., Colstrip, Montana, 1971, 56 pp.
61. Hoffman, G. J., Curry, R. B. and Schwab, G. O. Annotated Bibliography on Slope Stability of Strip Mine Spoil Banks, Research Circ. 130, Ohio Agricultural Experiment Station (now Ohio Agricultural Research and Development Center), Wooster, 92 pages (March 1964).
62. Honkala, R. A., Surface Mining and Land Reclamation: A Selected Bibliography, The Old West Regional Commission, Washington, D.C., Oct. 1974, 154 pp.
63. Kentucky, State of, Bibliography of Coal in Kentucky, Kentucky Geological Survey, 1970, 73 pp.
64. Kieffer, F. V., A Bibliography of Surface Coal Mining in the U.S. to August, 1971, Forum Associates, Columbus, Ohio, 1972, 71 pp.
65. Laszkiewicz, O. T. M. Reclamation of Land Used for Mineral Industries, Strip Mines, Quarries, etc., Research Service Biblography Series 4, No. 80, Public Library of South Australia, Adelaide, Dec. 1966, 18 pp.
66. Lehmann, E. J. Strip Mining, A Bibliography with Abstracts, NTIS, Springfield, Virginia, Jan. 1975, 101 pp. with appendices.
67. Limstron, G. A. A Bibliography of Strip-Mine Reclamation, Misc. Release No. 8, U.S. Forest Service, Central States Forest Experiment Station, Columbus, Ohio, 1953, 25 pp.
68. Loomis, T. H. W. Compiled Research Data on Reclamation of Disturbed Lands in the Western United States, 1970, Bureau of Land Management U.S. Department of the Interior, Washington, D.C., 1971, 18 pp.
69. Lorenz, W. C. Progress in Controlling Acid Mine Water: A Literature Review, U.S. Bur. Mines Ser. Information Circ. No. 8080, USDI, Washington, D.C. 1962, 40 pp.
70. Meshenberg, M. J. Environmental Planning: 2. A Selected Annotated Bibliography, Report No. 264, Planning Advisory Service, American Society of Planning Officials, Chicago, Dec. 1970, 79 pp.
71. Munn, R. F., Strip Mining — An Annotated Bibliography, West Virginia University Library, Morgantown, W. Va., 1973, 190 pp.
72. Munn, R. F., The Coal Industry in America: A Bibliography and Guide to Studies, West Virginia University, Morgantown, W. Va., 1965.
73. Parsons, J. D. Literature Pertaining to Formation of Acid Mine Wastes and Their Effects on the Chemistry and Fauna Streams, Trans. III, 1957, 10 pp.
74. Peterson, H. B., and Monk, R. Vegetation and Metal Toxicity in Relation to Mine and Mill Wastes, Circ. 148, Utah Agricultural Experiment Station, Logan, Sept. 1967, 75 pp.
75. Ralston, S., et al., The Ecological Effects of Coal Strip-Mining: A Bibliography with Abstracts, Colorado State University, Fort Collins, Col. March 1977, 416 pp., 1300 references.
76. Research and Development Industrial Environmental Research Lab., Mining Pollution Control Reports, 45268. Resource Extraction and Handling Division, Cincinnati, Ohio, May 1977.
77. Resources and Land Investigations Program (USGS) and Argonne National Laboratory, Integrated Mined-Area Reclamation and Land Use Planning, Vol. 4, A Bibliography of Integrated Mined-Area Reclamation and Land Use Planning, with Annotations, Argonne Report No. ANL/EMR-1, Vol. 4, Dec. 1976.
78. Ringe, A. C. Land Reclamation in Mining Areas: A Bibilography with Abstracts, National Technical Information Service, U.S. Department of Commerce, Springfield, Va., Nov. 1973, 25 pp.
79. Siehl, G. H. Strip Mining: Selected References, 1969-1972, Environmental Policy Division, Congressional Research Service, Library of Congress, Washington, D.C. Aug. 1972, revised Jan. 1973.
80. Siehl, G. H., Strip Mining: Selected References 1970-1973, 74-16 EP, Environmental Policy Division, Congressional Research Service, Library of Congress, Washington, D.C., 1974, 21 pp.
81. Steen, C., and Berg, W. A. Bibliography Pertinent to Disturbance and Rehabilitation of Alpine and Subalpine Lands and the Southern Rockies, Colorado State Univ. Information Ser. No. 14, Environmental Resources Center, Colorado State Univ., Fort Collins, Col. 1975, 104 pp.
82. Tompkins, D. C. Strip Mining for Coal: Public Bibliographies No. 4, Institute for Governmental Studies, University of California, Berkeley, 1973.
83. University of Pittsburgh, A Selected Bibiography and Discussion of the Effects of Strip Mining Upon Navigable Waters and Their Tributaries, Graduate Center for Public Works Admin., Univ. Pittsburgh for U.S. Army Corps of Engineers, Univ. of Pittsburgh, 1972, 94 pp.
84. Van Alphen, J. G., and Abell, L. F. Annotated Bibliography on Reclamation and Improvement of Saline and Sodic Soils, (1966-1970), Bibliography No. 6, International Institute for Land Reclamation and Improvement, The Netherlands, 43 pages (1967).
85. Walker, F. K. Bibliography and Index of U.S. Geological Survey Publications Relating to Coal, January 1971-June 1974, U.S. Geol. Surv. Circ. No. 709, Washington, D.C., 1974, 18 pp.
86. Weiss, N., et al., A Selected Bibliography of Surface Coal Mining and Reclamation Literature, Volume I, Eastern Coal Province, Argonne National Laboratory Report ANL/LRP-1, 1977, 158 pp.
87. West Virginia, University of, Appalachian Bibliography, Morgantown, W. Va., 2 Volumes, 1970.
88. Western Regional Coordinating Committee, Bibliography Pertaining to Vegetational Establishment and Management on Lands Disturbed by Mining in the Western States, In: Massive Displacement of Land from Coal and Oil Shale Development, Western Regional Coordinating Comm. Rep. No. WRCC-21, 1975, 6 pp.