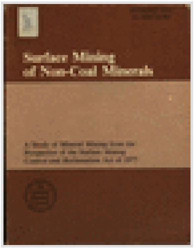

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Surface Mining of Non-Coal Minerals

A Study of Mineral Mining from the Perspective of the Surface Mining Control and Reclamation Act of 1977

A Report Prepared by the
Committee on Surface Mining and Reclamation

Board on Mineral and Energy Resources
Commission on Natural Resources
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1979

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

On August 3, 1977, the 95th Congress passed Public Law 95-87--The Surface Mining Control and Reclamation Act of 1977. The focus of the law was coal; but Section 709 called for a study of surface mining for minerals other than coal to determine whether existing and developing technology for mining minerals other than coal can be used to achieve the requirements of the Act, and to discuss alternative regulatory mechanisms to control mining. The Act directed the Council on Environmental Quality (CEQ) to contract with the National Academy of Sciences, other agencies, or private groups, as appropriate, to conduct the study. In response to a request from the Council, the Board on Mineral and Energy Resources of the Academy's Commission on Natural Resources formed the Committee on Surface Mining and Reclamation (COSMAR). This report presents the results of COSMAR's efforts to match environmental objectives of the Act with current and foreseeable mining practices in light of geologic and climatic conditions and engineering and economic constraints. Since the Act also deals with social and economic effects, COSMAR discusses the principal knowns and unknowns bearing on these problems. The Act controls coal mining in part by regulating particular details of coal mining practice and in part by specifying certain environmental conditions to be achieved during and after mining; COSMAR examines the effectiveness in non-coal mining of a series of control mechanisms and suggests appropriate circumstances under which these might be considered, singly or in combination.

In carrying out its charge, COSMAR called upon the skills, knowledge, and experience of a broad range of experts. Nine panels were organized to study the nature of different ore deposits and the mining techniques used to extract them under different environmental conditions. (See the listing of panel members preceding the Preface.) There are also economic and social costs that must be considered for all mining operations, and they were studied by a separate subcommittee. Another subcommittee concentrated on environmental questions, to assure that in studying the technology, adequate attention is paid to effects of the mining methods and procedures on the immediate locality and on the ground waters and surface waters downstream from the operations.

Finally, COSMAR, in responding to the specific request of PL 95-87, discussed ways in which regulations are developed and carried out, whether alternative methods could be used, and what form they might take if indeed they are needed. A third subcommittee studied the findings of each of the nine panels and considered alternative institutional approaches.

Case studies and working papers from the panels provided the raw material for this final report of COSMAR. The Working Paper of the Panel on Oil Shale and Tar Sands and the Working Paper of the Panel on Sand and Gravel are available under separate cover as appendixes to the Committee report. The papers of the other panels and the subcommittees form part of the archival record of the project. The papers are stored in the archives of the National Academy of Sciences, and they can be consulted there or reproduced for a fee upon arrangements with the archivist of the National Academy of Sciences.

COSMAR's report to the CEQ will provide scientific and technical assistance to the Council as it prepares its recommendations to the President and the Congress for formulating specific legislation for regulating the conduct and effects of surface mining in this country for minerals other than coal.

James Boyd
Chairman, COSMAR
October 1979

SUMMARY AND FINDINGS

In response to the specific charges addressed to the Committee in Section 709 of the Surface Mining Control and Reclamation Act of 1977 (PL 95-87), COSMAR finds:

(1) that the degree to which the requirements of the Act can be met by existing or developing technology ranges from readily achievable to impractical depending on specific requirements and on the location and nature of the mineral deposit and method of mining and processing; when existing or projected data made it possible, compliance costs were ascertained or estimated;

(2) that there are areas where the requirements of the Act cannot be met because of technological or economic limitations;

(3) that in those instances where the requirements of the Act cannot be met, COSMAR identified requirements most comparable to those of the Act that could be met, described the differences between these requirements and those of the Act, and estimated costs when estimates are feasible;

(4) that there are alternative regulatory mechanisms, and institutional approaches not regulatory in character, that could ensure the achievement of the most beneficial postmining land use for areas affected by surface and open-pit mining; these alternatives were identified and their applicability to a range of requirements and situations was discussed.

Highlighted in this summary are COSMAR's findings in response to the charges and related considerations, including the character of non-coal mining, designation of land use, appropriate levels of governmental jurisdiction, along with certain mining practices and effects and environmental, social, and economic questions not addressed in the Act.

INTRODUCTION

COSMAR finds that, in general, the broad purposes of the Surface Mining Control and Reclamation Act (PL 95-87) in protecting society and the environment from the surface effects of mining are being or can be met using existing or developing technology. There are, however, particular provisions of the Act that either cannot be met by existing technology or for which the efforts to adapt technology would be extremely difficult and not necessarily beneficial. COSMAR identifies ways in which the surface effects of coal mining and of non-coal mining are similar and ways in which they differ. In so doing, the Committee analyzes the applicability of the Act's technical provisions to non-coal minerals, drawing on numerous examples identified in the course of the study (Chapter 5).

A principal finding is that most non-coal mineral mines, despite their obvious diversity, can be considered in two major groups: the numerous, mostly small, units mining construction materials in all of the States; and the few gigantic metal mines and other deposits confined to limited regions. With few exceptions neither of the two groups is amenable to the coal mining practices addressed by the Act (Section 5.4). However, minerals such as pebble phosphate in Florida and red-bed copper in Oklahoma that are strip-mined can concurrently be reclaimed by mining in the manner envisaged in the Act.

Most of the construction material that is quarried serves a local need until the deposits are consumed, usually after several decades. In addition, removal of the deposit will have dictated that, when the mines are reclaimed, postmining land use can rarely resemble the premining use. Needs for institutional control for the mostly small construction material mines are discussed in Chapter 6.

The huge mineral deposits require enormous capital investment for development and can take centuries to exploit fully. Economically, these deposits are a mainstay of the nation's way of life, but geographically they are confined. For example, in the case of molybdenum, active mining is limited to two States; in the case of uranium, to a group of contiguous States. These deposits are thus regional in occurrence but of national interest. Activities necessary to produce these minerals bring to local areas irreversible social, economic, and environmental changes, all of which involve trade-offs between benefits and hardships.

When alternative sources of minerals are not available, or when technologies for environmental control are ineffective, economic and environmental goals may be in conflict. After consideration of the full spectrum of relevant social, economic, and environmental factors, a decision can be made about whether or not to develop minerals. Such planning, which is one of the aspects of mineral development discussed in this report (Sections 2.2, 2.4, 2.5, 4.1, 4.6.4, 6.2, 6.7, 6.8), can resolve possible conflicts and satisfy the broad objectives of the Act for non-coal minerals.

Existing institutional procedures for planning often do not consider mining as an aspect of land use, even though mining is an essential use at particular times and places. To the limited extent that such planning exists, its functions are dispersed among local and State governments and the Federal Government, and are poorly coordinated. Coordination of these activities within the Federal agencies is also poor. Furthermore, governmental efforts to impose control over unwanted effects of mining--by implementing zoning, rules, and procedures--are, again, poorly coordinated and variable (Chapter 4). The Act refers to governmental controls as "alternative regulatory mechanisms," but COSMAR prefers the term, "institutional approaches," thus avoiding the implication that desired objectives can be achieved only by regulation. The report presents a range of alternative institutional approaches, together with criteria for choosing among them, singly or in combination, and gives examples of how they might be used to control the mining and reclamation of non-coal minerals (Chapter 6). The objective of these approaches is to provide needed minerals while causing least damage to the environment.

Institutional approaches to control mining and reclamation must be designed with a knowledge of technical practices used in extracting minerals and with an understanding of environmental consequences. Knowledge of the nature and location of the nation's mineral deposits is also necessary, together with an understanding of the economic and social conditions under which non-coal minerals are mined (Chapter 2).

In discussing and analyzing the complexity of the subject, each chapter is, to a considerable degree, self-contained and important points are repeated to preserve continuity and reduce reliance on cross referencing.

MINING AND LAND USE

Mining competes with other land uses in many parts of the country because the natural circumstances under which essential minerals are found determine where they can be exploited (Section 2.3.1). To a considerable degree, natural circumstances also determine mining practices, as well as most aspects of reclamation and the possible choices for postmining land use (Section 2.2). Mining is thus an important use of the land, but one that usually has long-lasting effects on other uses (Section 2.3.1). These effects are major considerations in allocating the nation's land resources among various competing uses (Chapter 4).

Also, because of wide differences in mineral values and land capability, such allocations should be made before competing uses make mining infeasible, as in the premature spread of urban areas over gravel deposits. The location of mines is also influenced by public perceptions of the most beneficial use of the land, now and in the future. Mining uses a relatively small part of the land resource of the Nation as a whole and even in particular mining districts, despite the movement of large masses of rock in some areas. Ample space remains to accommodate mining within a system of national and regional priorities capable of dealing with evolving technological, economic, and social conditions.

DISTRIBUTION OF MINING

In terms of material handled, the mining effort in the United States is unequally divided, mainly because of differences in the nature of the many mineral commodities (Section 2.1). The United States mines nearly 80 non-coal minerals, all of which are beneficial to the nation. Minerals are mined where they have been deposited or concentrated in greater than average abundance. The quantities of rock that are excavated to recover minerals strongly reflect both the variable scarcity of minerals and the demands for them from local consumers, the Nation, and the world. As shown in Table 1, some 50 percent of the material mined (counting both overburden and ore) is excavated by 2 percent of the mines, most of it for recovery of copper, iron, phosphate rock, uranium, and titanium. Another 5 percent is excavated by 5 percent of the mines, recovering asbestos, barite, bauxite, diatomite, feldspar, gold, lead, and several other commodities. Forty-five percent of all material mined is thus left to the remaining 93 percent of mining operations made up largely of quarries for sand and gravel, crushed stone, clay, and related materials used for construction. An important difference between the few regional mines and the many construction mineral mines and quarries is that much of the material handled at regional surface operations becomes solid waste, whereas the material excavated at quarries is mostly consumed.

TABLE 1 Percentage Distribution of Total Number of Mines and Total Materials Mined, by Class

Class	Total Number of Mines, %	Total Material Mined, %
Large and Regional	2	50
Construction Materials	93	45
Other	5	5

Some minerals are currently mined at only a few places. Beryllium ore, for example, is mined only at Spor Mountain, Utah. Similarly, geologic availability accounts for 80 percent of our domestic iron ore coming from mines in Minnesota and Michigan and a similar proportion of phosphate rock is being produced in Florida. Sixty-two percent of domestic copper is mined in Arizona. In contrast, common materials like sand and gravel that are widely used for construction are available and produced in every State.

The wide distribution of construction materials results in their occurrence under innumerable combinations of geological, environmental, and cultural conditions. The individual disturbances caused by extracting the minerals, however, are ordinarily localized and small. The large mining districts in areas of major mineral deposits are also peculiar unto themselves, in part because of the geology of the deposits, but also because of regional differences in economic, social, and environmental conditions.

The diversity of mineral deposits, and the contrasts between places in which they are found--from flat to mountainous terrains, from tabular shapes to large masses, from humid to arid climates, and from urban to wilderness areas--explain the great variety in the ways in which the deposits are mined and in impacts of mining operations on the environment.

MINING AND THE ENVIRONMENT

Mining technology (Section 2.2) is no longer devoted solely to excavating the most mineral at the least cost; instead, within a framework of existing and anticipated environmental controls, mining now usually involves integration with a reclamation plan. Nevertheless, the traditional steps of the mining cycle (discovery, exploration, development, production, and abandonment) still largely determine the character of an operation and its environmental effects. The cost of mining also influences the economic factors of cut-off grade and stripping ratio, which together determine the extent and depth of the mine and, hence, the amount of ore recovered and the degree of environmental disturbance. In addition, the cost of mining is influenced by the expense of environmental control, and this expense accordingly also has its effect on resource recovery if market conditions are assumed to remain the same (Sections 2.2, 2.4).

The environmental effects of non-coal mining (Section 2.3) are substantially more diverse than effects caused by surface mining of coal, in part because of the variety of environments in which non-coal mining is done. More fundamental differences, however, are generated by quarrying and by the quantity of solid waste produced by large open-pit mines. Both cause virtually permanent changes in the land and thereby influence choices for its subsequent use. In addition, some waste from non-coal mining may be weakly radioactive, like the waste from processing of uranium and phosphate rock; or it may contain undesirable leachates, like the waste from oil-shale processing.

WASTE MANAGEMENT AND RECLAMATION

Wastes generated by most kinds of non-coal mining generally involve conventional methods of control; but some operations--notably the mining and processing of uranium, phosphate rock, oil shale, and lead--produce unusual liquid, gaseous, and solid wastes that create difficult problems (Chapter 3). Control of water pollution at mines is largely concerned with limiting the discharge of sediment or with recycling water used in processing, but certain pollutants require chemical treatment or special technology for removal. Fugitive dust is a common problem at nearly all mines, and processing and handling typically require various kinds of dust collectors. The solid waste from mining consists mostly of overburden and waste rock, together with tailings, slurries, and slimes from processing. Their management is primarily a matter of selecting a suitable site for disposal, but finding a site can be a difficult problem when the amounts of waste are large, as in most open-pit operations. Placement of tailings and piles of waste rock could be planned in a manner that enhances postmining land use.

Reclamation efforts (Section 3.5) have the greatest chance for success if they are integrated into the total mining operation and are directed toward a desired postmining land use. Commonly the aim is to return a disturbed area to some natural state, and, in such cases, effective revegetation is accepted as being the best means for controlling erosion and promoting recovery of the hydrologic balance, thereby limiting off-site impacts. A long-term ecological approach to land reclamation that emphasizes self-perpetuating plant and animal communities is favored. The ultimate purpose of reclamation, however, is a beneficial postmining land use, and this may include meeting needs for industrial and residential sites, agricultural and forest lands, recreational areas, or other uses, none of which may necessarily be the use that existed before mining. As long as marginal or incremental benefits of reclamation exceed marginal or incremental costs, the additional investment in reclamation is justified (Section 2.4).

The costs of waste control and reclamation are hard to estimate accurately because relevant information is scarce and accounting methods vary widely. The quantity and nature of particular wastes and the difficulty of revegetation also vary according to the character of mineral deposits, the mining and processing methods, and natural conditions. Nonetheless, installation costs and the expense of operating treatment facilities for particular wastes in given amounts are roughly comparable from place to place. COSMAR summarizes actual and estimated costs determined during its study, realizing that the data are unavoidably incomplete. The report also discusses the effect of such costs on the economics of mining copper, uranium, phosphate rock, and iron, to the extent that further controls on waste and reclamation might be applied (Section 2.4.2).

EXISTING GOVERNMENTAL CONTROLS

Responsibilities for controlling unwanted effects of mining are dispersed among various levels of government but in a variable manner (Section 4.1). The result is a number of significant gaps in control, particular among them being problems of reclaiming disturbed land for anticipated postmining uses, balancing mining against other land uses, and protecting land from abuses under provisions of existing mining laws. Local governments usually have authority to regulate mining and reclamation through zoning ordinances and land use decisions. Even though such local control is intended to satisfy local needs, known mineral deposits are not generally reserved for future mining. Many of the States, but not all, have adopted reclamation laws that depend on systems of permits and performance standards, but the various other substantive requirements do not appear to have a coherent pattern. Some State programs provide no practical power for enforcement, and they mostly lack specific technical requirements for the mining of non-coal minerals. The Federal requirements are embodied in numerous laws dealing with pollution of air and water, waste control, and protection of wildlife, natural areas, cultural resources, and the like. These laws, however, are not yet completely implemented or integrated, and they fail to consider all aspects of mining and the environment. The social consequences of mining have, for example, been largely ignored (Section 2.5).

Decisions to mine and control impacts of mining on Federal lands under the 1872 General Mining Law have never been well integrated with other decisions on use of these lands, nor have the surface impacts of mining been adequately controlled. This is true for all minerals on Federal lands other than those leased under the 1920 Mineral Leasing Law (i.e., oil and gas, oil shale, coal, sodium, phosphate, potash, and sulfur), common varieties of sand, gravel, stone, pumice, and minerals on acquired Federal lands. Land use planning now under way on public lands administered by the Bureau of Land Management and in the national forests administered by the Forest Service provides a framework for guiding decisions on mining and on setting environmental controls. The laws governing mining on public land need to be integrated with laws providing for land use planning.

The existing mixture of governmental controls for mining and reclamation has evolved from three streams of legislation, which are yet to be coordinated and integrated into decisions at the various levels of government: the streams are health and safety, land use planning, and conservation and protection of natural resources and the environment (Section 4.6). Historically, the goals of land use planning have overlapped the other two streams of legislation in that land use planning is aimed at protecting the wider community from action by single owners, promoting efficiency in the layout of major land uses, and enhancing the stability and aesthetics of man-made features. Each of these aims is expressed in the broad purposes of choosing where to mine, how to operate the mine, and how to reclaim the site for postmining use.

In short, State and Federal governments already control some mining land uses under a variety of regulations, while local governments already have land use planning procedures, with provisions for public and professional participation, action, and enforcement. The questions, then, are how to fit State and national priorities into local land use planning, and how to fit Federal and State land use controls into the context of a plan. Thus, it appears that efforts to coordinate the present array of regulations--and new ones yet to be added--inevitably will focus on the land use planning process.

APPLICABILITY OF PL 95-87 TO NON-COAL MINERALS

A major part of the COSMAR report describes non-coal mining and possible institutional approaches to its control in light of the provisions of PL 95-87 (Chapters 5 and 6).

The discussion responds to the directive of Sec. 709 of the Act and strives to provide the Council on Environmental Quality with information essential to preparing its legislative recommendations on non-coal mining. The analysis is also intended to be directly useful to the Congress. The discussion stresses provisions of the Act concerned with environmental protection. The report examines technologies and techniques available for meeting the requirements of the relevant provisions and discusses alternative procedures for achieving the purposes of the Act.

Return to Original Contour

The Act requires that the land be restored to approximately its original contour. This provision is generally not technically feasible for non-coal minerals, or has limited value because it is impractical, inappropriate, or economically unsound (Section 5.2.2). Areas mined for flat-lying deposits that resemble coal in thickness and in amount of overburden could be graded in a manner analogous to the surface mining of coal, but such deposits are unusual among non-coal minerals. More commonly, little overburden accompanies the material that is excavated and consumed from flat-lying deposits. Further, to restore the original contour where massive ore bodies have been mined by the open-pit method would incur costs roughly equal to the original costs of mining. Although technically possible, such backfilling of a large open pit would be of uncertain environmental and social benefit, and it would be economically impractical to mine some deposits under the current cost structure.

Exploration

Although mentioned only briefly in the Act (Sec. 512), exploration is essential to the development of all minerals and cannot be done without access to the land (Section 5.2.2). The effects of exploration on the land, and on ground water if exploratory holes are deep, are more or less widespread even though they are confined to drilling sites, test pits, and access roads. The Act indeed recognizes that areas disturbed by exploration are to be reclaimed in a manner comparable to other disturbed sites, but it does not address the wide differences in geology, hydrology, climate, and surface conditions under which exploration for non-coal minerals is carried out. Requirements for reclaiming areas disturbed by exploration should recognize such diversity.

Effects on Land

The requirements for reclaiming prime farm land are generally not applicable to typical quarry operations, either because the land surface is lowered, perhaps even below the water table, or because the deposits occur in places not used for farming (Section 5.2.2). However, sand and gravel operations on stream terraces could be reclaimed for farming under a suitable reclamation plan.

Open pits involve excavation and dumping of earth and rock in quantities that are not anticipated by the Act (Section 5.2.2). This process completely changes the character of the land surface. The wastes generated can ordinarily be placed in stable configurations, as required by the Act, but spoils from pits dug for phosphate rock in Idaho, for example, are sometimes placed on steep slopes where they are vulnerable to slumping and erosion (Section 5.2.7). Backfilling, provided that depletion of the mineral deposit makes it at all possible, is a costly requirement of the Act. However, even without backfilling, solid wastes can be placed so as to build a new landscape suitable for anticipated postmining land uses, and the practice would be consistent with provisions of the Act.

Subsidence from block caving operations and from some in situ and solution mining involves activities not considered in the Act.

Control of Waste

Wastes from mining and processing of non-coal minerals can be largely controlled by conventional methods to comply with requirements of the Act, but the nature and amounts of some wastes differ greatly from those associated with the mining of coal (Section 3.4). Thus even though waste management is a major and integral part of a mining operation, problems exist for which suitable control techniques are still uncertain. Such problems are mostly peculiar to the mineral being mined, but they are further influenced by conditions of the natural setting.

Processing of phosphate rock in Florida and refining of bauxite by the Bayer process produce slimes for which dewatering techniques are still experimental. Reclamation of these slimes is largely an unsolved problem (Section 5.2.7.2).

The discharge of acid, metals, and sediment from inactive underground mines is also an unsolved problem (Section 5.2.7.1), and leachate from tailings and waste dumps presumably is added to ground water at some places, although the amounts are poorly documented.

Various in situ and solution methods involve problems in control of waste that are not considered in the Act. In situ recovery of oil-shale, for instance, would generate large amounts of carbon dioxide and would involve the risk of contamination of ground water if the underground retorts were flooded. Safe disposal of excess retort water could also be difficult. Solution mining of uranium also involves the possible risk of contaminating ground water, in part by leakage from the leach field that may be hard to control, and in part from traces of the leaching solution that cannot be easily removed when attempting to restore the aquifer to the original condition at the conclusion of leaching (Section 5.2.7.1).

Wastes associated with the processing of uranium ore, and to a lesser extent of phosphate ore, are characterized by small amounts of radioactivity. Current reclamation regulations of the Nuclear Regulatory Commission require that tailings and other solid wastes with residual radioactivity from processing of uranium ores be safely covered or buried. If necessary, radioactive residues from processing of phosphate ore could also be covered or buried.

Revegetation

The Act provides for soil reconstruction and for revegetation of disturbed areas, recognizing that differences exist between humid and arid regions. Because non-coal mining takes place in a great variety of climatic conditions, the potential for revegetation or for use of substitutes for soil is highly site specific and more variable than for regions mined for coal. Areas with little or no soil or little rainfall are difficult to revegetate, whereas the ordinary mining waste and overburden of other areas, if they do not naturally revegetate, can be successfully planted. Despite differences, a vegetative cover can be established in most regions of the country (Section 5.2.7.3). This practice, however, is not necessarily compatible with all aspects of non-coal mining--for example, the stockpiling of lean ore--and the Act does not take into consideration the lengthy timetable customary for these operations.

Removal and storage of topsoil now required for coal mining by PL 95-87 would involve stockpiling for decades at some operations, and ultimate use of the stockpile would remain uncertain until plans for the eventual land use became final. Furthermore, at some quarries, topsoil is considered to be a marketable commodity.

In arid regions, although remarkable results have been achieved in revegetating mining waste, consideration could be given to other methods of inhibiting erosion, such as placement of a cover of rocks. .

Reclamation and Resource Conservation

The Act recognizes the need for conservation of resources by requiring full extraction of the resource before reclamation has begun and by permitting variations in the timeliness of reclamation so as to combine surface mining with underground mining. These concepts apply to some kinds of non-coal mining, but they do not recognize the role that economics plays in the recovery of many non-coal minerals or the effects of local restrictions (Section 5.2.5).

Realizing maximum recovery from quarries is commonly hindered by zoning, although timely knowledge of location of mineral deposits in built-up areas can help to anticipate conflicts between competing land uses.

The degree of resource recovery at open-pit operations is influenced by plans for placement of waste rock and tailings, which may be restricted by patterns of land ownership. Landscape design for management of these wastes may, nonetheless, be technically and economically feasible. However, further processing of waste from earlier mining is not uncommon under changing technology and economic conditions, and recovery of additional mineral matter could be inhibited by backfilling requirements in PL 95-87.

Western Alluvial Valleys

Alluvial valley floors in the west are protected under the Act by special reclamation provisions to preserve their hydrologic functions and by excluding mining that would interrupt farming or damage water supplies. These provisions, if applied to quarries for sand and gravel, might exclude some new operations from western valleys (Section 5.2.3). As far as COSMAR could determine, no clay mine occupies an alluvial valley floor, but the Act's provisions could be significant in the region of western oil shale and tar sands.

Hydrologic Disturbances

The Act provides for an assessment of the cumulative impacts of mining upon the hydrology of the area and for protection of the rights of current water users by requiring plans to provide alternative sources of water. Related provisions deal with data needed to determine disturbances to the hydrologic balance. Non-coal mining, like the mining of coal, does indeed disturb hydrologic systems, but the effects are highly variable. They depend on the region and the nature of the mining activity, and they are not always disruptive to other uses of water (Section 5.2.3).

Quarries do not significantly affect the availability of water in most regions of the country, even though some use water in substantial quantities.

The Act's requirement to provide alternative sources of water could be viewed as discriminating against surface miners in the east, who also have rights to the available water. In the west, where surface water is apportioned and rights to its beneficial use are adjudicated by the State, use of surface water by a mining operation would be limited by such rights, irrespective of provisions of the Act.

Open-pit mines could not generally comply with the provision on maintaining the availability of water, especially in arid and semi-arid regions. Open-pit operations typically consume considerable quantities of water for milling the ore and disposing of tailings. The water is usually pumped from ground water from alluvial basins that are also being pumped for irrigation water. To the extent that these operations may contribute to the problem of ground-water depletion, consideration of water resources as an aspect of mineral policy must recognize the consumptive demands of open-pit mining.

ALTERNATIVE INSTITUTIONAL APPROACHES

The Act asks that COSMAR "discuss alternative regulatory mechanisms designed to ensure the achievement of the most beneficial postmining land use for areas affected by surface and open-pit mining." The term "institutional approaches" is preferred to "regulatory mechanisms" because COSMAR believes that the objective of beneficial postmining land use can be accomplished by various means of which direct regulation is only one. The current system of government controls that affects the impact of mining on the environment is complex, often confusing, and, in many cases, ineffective. Means could be sought to coordinate the components of the existing system, to enhance its rationality, and to integrate it with any new controls to assure that each element of the system, at the several levels of government, is appropriate to its purposes.

COSMAR discusses the following spectrum of governmental control techniques for mining and reclamation, arranged in order of increasing degree of public control: (1) education and technical assistance; (2) economic incentives; (3) regulation aimed at securing certain results after mining; (4) regulation aimed at controlling the practices that produce those results; and (5) public ownership of surface rights.

There appears to be no single set of governmental responsibilities that is appropriate to all situations. COSMAR discusses planning decisions and criteria for selecting among the control techniques listed above, including factors relevant to identifying the level of government best suited to particular tasks in controlling the mining and reclamation of non-coal minerals (Chapter 6). Integration of mining control appears to be best achieved by procedures of land use planning that are specific to the mining district or region; however this planning must involve all land based activities. Plans can be used to indicate objectives to be pursued in specific areas, conditions that may affect the choice of control techniques, and decisions on controlling alternative land uses. It is also appropriate that the costs of future actions to mitigate effects of mining that extend beyond the life of a mine be internalized in the present cost of mining. Planning could include methods for mitigation of these effects once mining has ceased (Sections 4.6, 6.8).

CHAPTER 1

INTRODUCTION

The Congress summarized the range of concerns addressed by the Surface Mining Control and Reclamation Act of 1977, Public Law 95-87, in the statement of findings, Section 101. The purposes of the Act are summarized in Section 102. The main objectives of the Act are to mitigate environmental effects during mining and to bring the mine site to a beneficial postmining land use. The current study is called for in Section 102(j) as follows:

> "provide a means for development of the data and analyses necessary to establish effective and reasonable regulation of surface mining operations for other minerals."

1.1 PURPOSES OF THE STUDY AND CHARGE TO THE COMMITTEE

Section 709, entitled, Study of Reclamation Standards for Surface Mining of Other Minerals (i.e., other than coal), is the vehicle provided by Congress "for development of the data and analyses." Sec. 709(a) supplies the charge to the Committee on Surface Mining and Reclamation by requesting the following action:

> . . . an in-depth study of current and developing technology for surface and open pit mining and reclamation for minerals other than coal designed to assist in the establishment of effective and reasonable regulation of surface and open pit mining and reclamation for minerals other than coal. The study shall--
>
> (1) assess the degree to which the requirements of this Act can be met by such technology and the costs involved;
>
> (2) identify areas where the requirements of this Act cannot be met by current and developing technology;
>
> (3) in those instances describe requirements most comparable to those of this Act which could be met,

the costs involved, and the differences in reclamation results between these requirements and those of this Act; and

(4) discuss alternative regulatory mechanisms designed to insure the achievement of the most beneficial postmining land use for areas affected by surface and open pit mining.

1.2 ORGANIZATION AND SCOPE OF THE STUDY

Pursuant to Congressional wishes expressed to the Executive Branch in Section 709, the Council on Environmental Quality requested the National Academy of Sciences-National Academy of Engineering to conduct the above-described study. The Academies established the Committee on Surface Mining and Reclamation (COSMAR) within the Commission on Natural Resources' (CNR) Board on Mineral and Energy Resources to be responsible for the study.

The Commmittee was made up of 18 members with expertise in engineering and the natural and social sciences. Individuals were chosen for their breadth of experience and skills in environmental and mining matters; the members brought various professional perspectives and orientations to the Committee and did not represent any organization to which they might have belonged.

At the Committee's first meeting--held in Washington, D.C. on June 8-9, 1978--deliberations covered a variety of approaches to the study, which would meet the charge to the Committee within the scale specified in the Act. The scope of the task was obviously enormous: scores of mineral raw materials are mined in all States, within every type of environmental and cultural setting, and with almost every mining method and kind of equipment known. Each of the 15,000 mines in the United States is in some way distinctive. In view of the fact that the preponderance of mining activity occurs in the continental United States, and that another National Research Council committee would be responsible for a study of mining in Alaska as described in Section 708 of the Act, the Committee decided to focus its efforts on the contiguous 48 States. A study plan within the necessary limitations was developed by the Committee and agreed upon at subsequent meetings held in Tucson, Arizona on July 5 and July 8, 1978.

During the Tucson meetings, COSMAR members participated in a workshop on the mining and reclamation programs at six open-pit copper operations south of Tucson and a block-caving operation northeast of Tucson. One-and-a-half days were spent in informal field visits, enabling Committee members to become acquainted with the mining operations and problems and to discuss procedures and results in detail with technical personnel. One day was spent hearing technical presentations on numerous phases of mining and reclamation practices and economics, environmental concerns raised by mining, and some of the conflicts generated between a mining company and a community by an exploration program conducted in Pima County, Arizona. The workshop was a useful step in the development of a common understanding of mining and reclamation problems by COSMAR members.

In support of the study, COSMAR organized nine panels, each chaired by a member, to review and prepare working papers on the various types of environmental and technical conditions dictated by the different geologic occurrences of mineral deposits and by the climatic, geomorphic, and cultural settings surrounding the operations. A total of 47 persons, other than members of the parent Committee, served on the nine panels, thereby providing additional scientific and technical expertise and experience to the COSMAR study.

Each panel held several meetings, some of which were combined with field trips to mining sites to observe current practices and their effects on the environment. During some of these meetings and trips, knowledgeable and interested people from Federal and State governments, industry, academic institutions, and the conservation community were invited to attend and present scientific and technical information related to their special concerns or interests. Limits on time and money did not permit everyone who wished to address the Committee to do so; however, the normal legislative process that is expected to follow this study should provide an opportunity for input by all.

The work of the panels was structured by COSMAR to focus on mining methods and the environmental and economic conditions associated with them and, in addition, the panels were to avoid duplication of treatment of common subject matter. Emphasis onspecific commodities was avoided wherever possible. The working papers prepared by the panels were designed as a whole to serve as a set of reference materials that would support preparation of the COSMAR report by supplementing the experience and knowledge of the Committee. The title and scope of each panel follows.

1. Oil Shale and Tar Sands

Oil shale deposits of Colorado, Utah, and Wyoming were studied, as were tar sands in Utah.

2. Construction Minerals

Sand and gravel, crushed stone, portland cement, lime and limestone, and gypsum were investigated, as well as broken rock and mineral fill material, and riprap. Detailed consideration of conditions in Illinois and California was made for comparison with information from other States.

3. Large Open-Pit Mines in Areas of Low Water Table

This study covered copper mining in Arizona and Utah, molybdenum mining in Colorado, phosphate mining in southeastern Idaho, and gold and mercury operations in Nevada.

4. Large Open-Pit Mines in Humid Environments

Iron mining was studied in the Lake Superior area and, for comparison, at Eagle Mountain, California.

5. Coastal Plain Deposits

Phosphate operations were studied in Florida and North Carolina.

6. Surface Effects of Underground Mining, Solution Mining, and Exploration

General consideration was made of the procedures involved, as well as environmental impacts, and their control or mitigation.

7. Natural Building Stone

Quarries operate in 44 States, but primary consideration was given to deep igneous and metamorphic rock quarries in Vermont and to broad, shallow sedimentary rock quarries in Indiana.

8. Discontinuous Ore Bodies in Sedimentary Formations

This study included uranium deposits, mainly in Wyoming, New Mexico, Texas, Colorado, and Utah; vanadium associated with uranium in Colorado and Utah; vanadium (not sedimentary) in Arkansas; bentonite clay in Wyoming, Montana, and South Dakota; beryllium in Utah; and copper in red-bed deposits in Oklahoma.

9. Clays and Bauxite

Clays and bauxite--including kaolinite, fire clays, and brick clays--were studied, as was barite in residual deposits and diatomite. Special attention was given to the Arkansas bauxite district and the Georgia kaolin district (including residual barite and brick clay).

Information collected in the panel working papers covered the full range of activities encompassed by the term--mining: the exploration required to locate an economically valuable deposit and the subsequent on-site operations that implement a commercial mining venture. The primary emphasis, however, was on activities that affect the environment. For example, the extensive and complicated transportation system within an open pit was not assessed separately from the pit itself because both constitute a single disturbed area. The transportation links between pit and processing mill and between mine site and the local community were considered.

For the most part, the panels studied all stages of mining processes including production of marketable concentrates by physical and chemical processing in a mill located reasonably close to the mine. Refining or fabrication stages at remote locations were not considered. Smelting is somewhat anomalous in this connection: some smelters are far from the mines whose ores they refine, but others, mostly copper smelters, are close to the mine that is the principal source of their concentrate, or they are in a mineral district where they serve a number of mines. The panel studying large open-pit copper mines briefly noted the characteristics and extent of smelter slags.

COSMAR took a broad view of the complex problems presented to it and looked into a number of subjects it deemed important to surface mining and reclamation beyond the needs for analyzing PL 95-87. However, COSMAR did not make an exhaustive study of all mining impacts. For example, placer mining is mentioned, but not pursued, because the Surface Mining Control and Reclamation Act does not address it and few of the Act's provisions could be projected to cover placering. Other questions are also noted as matters for possible consideration in future studies of mining.

Because the Act specifies that sand and gravel, oil shale, and tar sands receive special study, the first panels were formed to address these tasks. Their working papers are available under separate cover as appendixes to this report; however, these topics are also covered sufficiently in the COSMAR report to satisfy the requirements of the law.

COSMAR also organized three subcommittees to address issues cross cutting all panel assignments and the charge to the Committee. The Environmental Subcommittee analyzed the environmental concerns expressed by many groups and individuals to identify those problems and concerns that were of national interest. The subcommittee arranged for a literature survey to document environmental problems and possible solutions, and enlisted the cooperation of knowledgeable individuals and organizations in assessing environmental impacts. This subcommittee also assigned liaison members to meet with each of the panels to ensure that environmental matters were fully considered and that the subcommittee was kept informed of the progress of each panel study. The Socioeconomic Subcommittee examined the social impacts and costs and benefits of surface mining, and the economic ramifications of controls on surface operations and reclamation. The Alternative Regulatory Mechanisms Subcommittee categorized the major alternative institutional approaches that can apply to the objectives of reclamation and the differences in mining methods and environmental conditions. Each subcommittee was chaired by a member of COSMAR, and an additional 20 people served on the subcommittees.

The Editorial Subcommittee composed of six COSMAR members who were also panel or subcommittee chairmen served as a steering committee and report drafting group.

A summary of the results and findings of the study precedes this chapter: it is cross-referenced to more detailed discussion elsewhere in the text. Technical background is provided in the next two chapters; Chapter 2 reviews the elements of current mining technology that bear most directly on reclamation, and Chapter 3 reviews the present state of waste control and reclamation efforts, results, and costs. Chapter 4 describes current controls on surface mining and reclamation. Chapters 5 and 6 respond to the four parts of the charge to the Committee: Chapter 5 analyzes the applicability of the provisions of PL 95-87 to the mining of minerals other than coal, and Chapter 6 considers alternative institutional approaches. The report of the Committee is followed by separate material on "Some Social Consequences of Surface Mining," presenting views on the subject as expressed by Dr. Ronald Little, in consultation with members of the Socioeconomic Subcommittee. This material is not accepted by COSMAR as a whole.

The index shows where, within each chapter, each provision of the law is discussed. In places, especially in Chapters 3 through 6, statutory provisions of PL 95-87 and other legislation are summarized or paraphrased, but only to the extent needed to convey the essential concepts of the legislative requirements. These summaries are intended for general readers to understand the broad intent of the legislative framework with respect to the technical discussion of non-coal mining.

Each chapter is, to a considerable degree, self-contained and important points are repeated to preserve continuity and to reduce reliance on cross-referencing.

1.3 HISTORICAL BACKGROUND OF THE STUDY

Concern for degradation of the environment by mining is not new. Down and Stocks (1977) give a brief history of environmental problems related to mining noting the description by Agricola in 1556 of the effects of mining in Germany. Agricola also pointed out that cut-over woods and glades could be reclaimed as grain fields.

It seems that formal, legal arrangements for reclaiming and restoring mined land for beneficial use began in England under private rather than governmental initiative (Down and Stocks 1977). A colliery lease of 1791 required that the shaft be filled when the colliery closed and "sown with Rye Grass seeds." Leases granted by private landowners after 1850 in the ironstone fields of the Midlands required topsoiling and restoration of agriculture after the field had been worked out by the miners.

Prior to the 20th century, environmental disruptions due to mining were usually isolated. Remedial measures were taken only for special reasons. Most metals and minerals were obtained from large numbers of mines worked by a few miners producing 10 to 20 tons per day from rich concentrations of ore minerals. Few mines produced as much as 500 tons of ore per day or employed hundreds of workers. Many operations were underground and labor-intensive. Working conditions were primitive, accidents were common, and many lives were lost.

Around 1900, mass markets for manufactured goods developed in Europe and North America through the spread of industrialization. Capital accumulated in previous generations was available, and there were rapid increases in technological development and labor productivity in mining, mineral dressing, smelting, and refining. Extraction operations for some minerals shifted from underground to open pits and a whole new family of large surface mines evolved. The growth of surface mining was at first particularly evident in the case of copper and iron; later it also became apparent for phosphate rock in Florida and for sedimentary ore in the West. These did not displace traditional operations but contributed greatly to satisfying the growing demand for minerals and metals. In the process, working conditions in large surface mines became safer than in underground mines and the mineral industries became more productive, capital intensive, and energy intensive than formerly.

Modern open-pit metal mining began about 1910 in Utah with the so-called porphyry copper deposits. Large open pits became possible when ore treatment methods advanced to the point that rock containing as little as 2 percent copper, with some gold and silver, could be made to yield concentrates suitable for use in existing smelting and refining plants. Large open pits were possible because railroad technology (heavy-gauge rails, large cars, powerful locomotives, rail-mounted shovels) was directly applicable to mining essentially flat deposits under shallow cover. These deposits had sufficiently large horizontal and vertical dimensions to ensure large volumes of ore. Single large mines replaced numerous small mines.

Over the next 50 years, a series of changes favored the increase in number and diversity of open-pit mines: growth of the electrical industry provided a large market for copper; ore concentration by gravity methods was superseded by froth-flotation methods; many improvements in flotation led to better recoveries and cleaner separations; power shovels were improved by using diesel, diesel-electric, and electric motors instead of steam engines; power shovels were made self-propelling and were no longer limited to railways; low-cost explosives (such as the mixture of ammonium nitrate and fuel oil known as ANFO) and drills capable of making large diameter (9 to 12 inch) holes displaced the earlier blasting techniques using dynamite and churn drills and wagon drills; development of heavy-duty trucks (at first with 30-ton capacity, gradually increasing to 250-300 ton capacity) gave greater haulage flexibility than a railroad and much lower costs; and the development of conveyors based on synthetic fibers, steel wire, and synthetic rubber made, and continues to make, ore movement more efficient. Rail haulage has not been completely displaced and is still used in conjunction with trucks in two copper pits.

Successful open-pit mining of large porphyry copper deposits (including deposits of copper which met the economic and technological criteria, but were not porphyry deposits in the geologic sense) resulted in so many technological improvements that small- and medium-sized copper deposits could be mined by the application of new technology. The technology was extended to include coal, uranium, phosphate, gold, mercury, molybdenum, fluorspar, and other deposits.

Concurrently with the growth of these mining operations, and in contrast to them, a great many comparatively small surface mines were opened to supply construction materials to a growing industrial country. These were the thousands of quarries for sand and gravel, crushed stone, clay, limestone, and the like that are now found in nearly every part of the nation. Although individually small, these quarries, together, handle at least as much mineral matter as the large mines.

With the widespread application of the new technologies, the environmental impacts of mining became conspicuous in some areas because of the movement of large volumes of waste rock and ore, and the generation of enormous quantities of process wastes. Many of the small mines that did not lend themselves to new technologies became uneconomic and were abandoned. Production, instead of being ubiquitous over the populated areas of the country, became largely concentrated. Large-scale surface mining of coal raised enough social, economic, and environmental problems to bring on corrective legislation. A number of bills submitted in the 1970s culminated in the enactment of PL 95-87, the Surface Mining Control and Reclamation Act of 1977.

1.4 ORIGINS AND HISTORY OF THE SURFACE MINING CONTROL AND RECLAMATION ACT OF 1977

Those who look back to the origins of the Surface Mining Control and Reclamation Act usually say that the Act was adopted after a seven-year struggle, dating its inception around the time of "Earth Day," 1970. But groundwork for the Act was laid in the 1960s, when the first bills were introduced in the Congress, and even as long ago as 1939, when West Virginia enacted the country's first law for control of surface coal mining (House Bill No. 390, Chapter 84, passed March 11, 1939). Still, the Act is largely a product of the 1970s, and its requirements clearly reflect the environmental goals of this decade. Thus, it is of interest to review briefly some of the events that preceded enactment of PL 95-87 as possible clues to its purposes.

In 1967, the Federal government published an elaborately illustrated account of the accumulated damage caused by digging up 4 million acres of the nation's land and by the general lack of corrective reclamation (U.S. Department of the Interior 1967). For many, the statistics were appalling: 20,000 miles of unreclaimed highwalls in the Appalachians, an Environmental Protection Agency estimate of between 4,000 and 5,000 acres of land newly disturbed each week (Gillette 1973), ten-fold and hundred-fold increases in pollution of streams (Collier and others 1970), and instances of catastrophic losses of life and property--as in 1972 at Buffalo creek, West Virginia, where 118 died when a dam built of coal-mine waste collapsed under heavy rain.

In the East, public concern over uncontrolled strip-mining had been aroused still earlier by findings in the early 1960s by the President's Appalachian Regional Commission (1964) on the effects of coal mining, especially the social and economic consequences, and by the writing of Caudill (1963). West Virginia's early lead in enacting a surface-mining law was followed by Indiana (1941), Illinois (1943), Pennsylvania (1945), and Ohio (1947). Kentucky's efforts to control strip-mining reached a peak of effectiveness in 1967, under a newly revised law, but then declined, just as the rest of the country was entering an unprecedented period of striving for environmental quality (Landy 1976). The desires for reclamation of surface coal mines in the East concentrated on backfilling, grading, and revegetating spoils from contour mining and area stripping; on stabilizing debris on steep slopes; on control of pollution from eroded sediment and acid drainage; and on the legacy of orphan lands that were mined and abandoned before reclamation was required.

In the West, fears about the impact of greatly expanded coal production were aroused by ambitious plans for power plants in the Southwest (Baldwin 1973) and the northern Great Plains (U.S. Bureau of Reclamation 1971), which would exploit the region's abundant resources of surface-mineable coal. Such plans spawned relatively detailed Federal and State studies of the coal and the supplies of water required to mine it, several copious environmental impact statements, and numerous rounds of heated debate. The plans also caused alarmed citizens to organize lobbies and call for laws to control surface mining (Josephy 1973). By 1975, all the concerned States, except Arizona, had adopted some form of legislation dealing with reclamation practices (Imhoff and others 1976). Concerns in the West centered on conflicts of surface coal mining with farming, ranching, and traditional patterns of land use, including the national forests and other lands thought to be unsuitable for mining; the preemption of surface ownership by reason of underlying Federal coal; the difficulty of reclaiming mined land in arid regions; and the impact of industrial development on the social and economic structures of a sparsely populated region.

The citizen lobbies that were formed in the East and West during the early 1970s brought their concerns to the Congress and did much to shape the legislation as it evolved. Also instrumental were: a study by the National Research Council (1974) on reclamation practices in the West, an assessment by the Council on Environmental Quality (1973) on the effect of slope-angle prohibitions on recovery of Eastern coal, and an investigation by the U.S. General Accounting Office (1972) into Federal enforcement of regulations for surface coal mining on public lands. Many other kinds of testimony were given. The resulting law (PL 95-87), however, is basically an environmental statute. It establishes what Congress understood to be a minimum set of standards for surface coal mining and reclamation, overcoming the unevenness in State laws, but allowing the States the opportunity to implement and enforce these standards, or standards that are more stringent. The many objectives of the Act are summarized in Section 5.1. The give-and-take between the Senate and the House in arriving at the ultimate language of the Act, through several sessions of the Congress, is concisely reported by the Congressional Research Service (Thompson and Agnew 1977).

The legislation initially before the Congress was an all-minerals bill for hard-rock surface mining and for mining of bedded deposits, in addition to coal (D. Michael Harvey, Chief Counsel, Committee on Energy and Natural Resources, U.S. Senate, statement to COSMAR, May 12, 1978). This inclusive approach proved to be impractical, and Senate bill S.425 introduced in 1973 was confined to coal. The statute finally adopted in 1977 can be said to deal with coal as a special case (Donald A. Crane, Office of Surface Mining, statement to COSMAR, June 8, 1978). Section 709 of the Act, which is addressed by this report, is the surviving remnant of the original all-minerals bill. Our analysis of the applicability of the Act to non-coal minerals and our understanding of alternative methods for governmental control of surface mining are presented in Chapters 5 and 6.

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CHAPTER 2

MINING AND RECLAMATION PROBLEMS

2.1 SCOPE

United States production of non-coal minerals and metals embraces nearly 80 mineral commodities, each derived from one or more mineral types and produced from more than 15,000 active mines. For each mineral commodity, the U.S. Bureau of Mines (USBM) publication "Mineral Facts and Problems," issued every five years, describes the industry and its historical background, giving information on ore reserves and resources and how these are mined and processed, supply-demand relations, consumption patterns, economic factors, environmental considerations, the outlook, and the industry's problems--technological, economic, social, and political. On an annual basis, statistical and technical data are reported by the Minerals Yearbook, Vol. I, for each mineral commodity, and Minerals Yearbook, Vol. II for the individual States.

The USBM also publishes Mineral Commodity Summaries early each calendar year, which provides information on nearly 90 non-fuel mineral commodities that are produced or imported for consumption in the United States. Data on energy minerals are reported in Department of Energy publications.

Table 2.1, compiled from a 1976 Yearbook preprint chapter, "Mining and Quarrying Trends in the Metal and Non-Metal Industries," shows the number of domestic metal and non-metal mines (excluding coal) in 1976, by commodity, and the tonnage of crude ore and wastes handled. Table 2.2, from the same preprint, shows the materials handled by State.

Ore came from 15,279 mines in 53 mineral types or groupings. Total material handled by all mines was 4.4 billion tons, of which 2.7 billion tons were crude ore and 1.7 billion tons were mine waste. Surface mines produced 95 percent of the ore and 99 percent of the mine waste. Underground mines were 4 percent of all mining operations and produced 5 percent of the ore and 1 percent of the mine waste. Processing of the crude ore rejected about 600

TABLE 2.1 Number of Mines and Material Handled at Surface and Underground Mines in 1976 by Commodity[1] (thousand short tons) SOURCE: U.S. Bureau of Mines (1976).

Commodity	Total number of mines	Surface			Underground			All mines[2]		
		Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total
METALS										
Bauxite	14	3,480	14,600	18,000	W	--	W	3,480	14,600	18,000
Copper	45	257,000	686,000	942,000	25,100	1,360	26,400	282,000	687,000	969,000
Gold:										
Lode	51	1,340	13,300	14,700	1,710	202	1,910	3,050	13,500	16,600
Placer	37	4,990	491	5,490	1	([3])	1	5,000	492	5,490
Iron ore	65	240,000	245,000	485,000	9,640	1,720	11,400	250,000	246,000	496,000
Lead	37	1	10	11	10,100	2,150	12,300	10,100	2,160	12,300
Mercury	6	83	656	738	W	--	W	83	656	738
Silver	63	983	354	1,340	774	317	1,090	1,760	671	2,430
Titanium, ilmenite	7	36,400	8,760	45,200	--	--	--	36,400	8,760	45,200
Tungsten	43	83	3	86	593	300	893	675	303	978
Uranium	212	5,070	253,000	258,000	3,850	4,260	8,110	8,910	257,000	266,000
Zinc	31	60	52	113	8,290	3,680	12,000	8,350	3,730	12,100
Other[4]	13	23,700	27,800	51,500	12,800	581	13,300	36,500	28,400	64,900
Total metals[2]	624	573,000	1,250,000	1,820,000	72,800	14,600	87,400	646,000	1,260,000	1,910,000
NONMETALS										
Abrasives[5]	14	331	376	707	74	--	74	405	376	781
Asbestos	4	2,040	250	2,290	W	--	W	2,040	250	2,290
Barite	37	1,120	995	2,110	W	W	W	1,120	995	2,110
Clays	1,132	47,500	[e]41,300	88,800	692	[e]10	702	48,200	41,300	89,500
Diatomite	14	852	6,480	7,330	--	--	--	852	6,480	7,330
Feldspar	25	1,360	144	1,510	W	W	W	1,360	144	1,510
Fluorspar	8	24	5	29	586	44	631	610	49	660
Gypsum	68	10,000	8,950	19,000	2,310	6	2,310	12,300	8,960	21,300
Mica (scrap)	13	591	406	997	--	--	--	591	406	997
Perlite	12	722	6	728	W	--	W	722	6	728
Phosphate rock	51	169,000	242,000	411,000	W	W	W	169,000	242,000	411,000
Potassium salts	9	--	--	--	17,300	357	17,700	17,300	357	17,700
Pumice	192	4,140	744	4,890	--	--	--	4,140	744	4,890
Salt	19	431	61	492	15,100	684	15,700	15,500	745	16,200
Sand and gravel	7,599	885,000	--	885,000	--	--	--	885,000	--	885,000
Sodium carbonate (natural)	4	--	--	--	9,600	4,660	14,300	9,600	4,660	14,300
Stone:										
Crushed and broken	4,950	864,000	[e]71,200	935,000	34,300	[e]250	34,600	898,000	71,500	970,000
Dimension	431	[e]3,050	[e]1,610	4,660	13	--	13	3,060	1,610	4,670
Talc, soapstone, pyrophyllite	40	894	2,530	3,480	78	2	80	972	2,530	3,510
Other[6]	31	6,850	15,600	22,500	379	35	415	7,230	15,700	22,900
Total nonmetals[2]	14,655	2,000,000	393,000	2,390,000	80,400	6,050	86,400	2,080,000	399,000	2,480,000
Grand total[2]	15,279	2,570,000	1,640,000	4,210,000	153,000	20,600	174,000	2,720,000	1,660,000	4,390,000

[e] Estimate. W Withheld to avoid disclosing individual company confidential data.

[1] Excludes material from wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

[3] Less than 1/2 unit.

[4] Antimony, beryllium, manganiferous ore, molybdenum, nickel, platinum-group metals, rare-earth metals, tin, vanadium, and quantity of metal items indicated by symbol W.

[5] Abrasive stone, emery, garnet, and tripoli.

[6] Aplite, boron minerals, graphite, greensand marl, iron oxide pigments (crude), kyanite, lithium minerals, magnesite, millstones, olivine, tube-mill liners, vermiculite, wollastonite, and quantity of nonmetal items indicated by symbol W.

TABLE 2.2 Material Handled at Surface and Underground Mines (Including Sand and Gravel and Stone) in 1976 by State[1]

State	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total
Alabama	38,100	101	38,200	W	--	W	38,100	101	38,200
Alaska	83,800	400	84,200	(3)	(3)	1	83,800	460	84,200
Arizona	200,000	373,000	573,000	18,800	1,060	19,900	218,000	374,000	593,000
Arkansas	37,000	17,000	54,000	521	4	526	37,600	17,000	54,500
California	150,000	54,100	204,000	1,000	181	1,180	151,000	54,300	205,000
Colorado	31,500	13,300	44,800	14,400	3,070	17,500	45,900	16,300	62,200
Connecticut	12,700	15	12,800	--	--	--	12,700	15	12,800
Delaware	1,130	--	1,130	--	--	--	1,130	--	1,130
Florida	231,000	170,000	400,000	--	--	--	231,000	170,000	400,000
Georgia	44,100	515	44,600	831	--	831	44,900	515	45,400
Hawaii	6,990	5	6,990	--	--	--	6,990	5	6,990
Idaho	16,600	30,000	46,600	1,790	393	2,180	18,400	30,400	48,800
Illinois	99,300	5	99,300	2,960	44	3,000	102,000	49	102,000
Indiana	54,700	--	54,700	1,410	--	1,410	56,100	--	56,100
Iowa	46,800	2,090	48,900	1,040	--	1,040	47,800	2,090	49,900
Kansas	27,700	--	27,700	2,780	--	2,780	30,500	--	30,500
Kentucky	35,900	--	35,900	7,370	--	7,370	43,300	--	43,300
Louisiana	32,800	--	32,800	6,580	133	6,710	39,400	133	39,600
Maine	11,900	--	11,800	W	W	W	11,900	--	11,900
Maryland	29,200	--	29,200	W	--	W	29,200	--	29,200
Massachusetts	24,100	--	24,100	--	--	--	24,100	--	24,100
Michigan	139,000	31,900	171,000	7,150	230	7,380	147,000	32,100	179,000
Minnesota	208,000	163,000	372,000	--	--	--	208,000	163,000	372,000
Mississippi	15,500	--	15,500	--	--	--	15,500	--	15,500
Missouri	57,100	662	57,700	21,200	2,910	24,100	78,300	3,570	81,800
Montana	26,800	47,400	74,200	388	52	441	27,100	47,500	74,600
Nebraska	18,400	--	18,400	W	--	W	18,400	--	18,400
Nevada	26,900	37,200	64,100	197	279	476	27,100	37,400	64,600
New Hampshire	6,960	--	6,960	--	--	--	6,960	--	6,960
New Jersey	33,600	7,340	40,900	208	--	208	33,300	7,340	41,200
New Mexico	49,800	193,000	243,000	20,400	1,910	22,300	70,200	195,000	265,000
New York	61,000	3,320	64,300	5,290	117	5,410	66,300	3,430	69,800
North Carolina	49,400	31,700	81,100	--	--	--	49,400	31,700	81,100
North Dakota	5,210	--	5,210	--	--	--	5,210	--	5,210
Ohio	84,800	6	84,800	4,190	436	4,630	85,000	442	89,400
Oklahoma	30,600	156	30,800	906	--	906	31,500	156	31,700
Oregon	42,600	1,920	44,600	(3)	11	11	42,600	1,930	44,600
Pennsylvania	81,500	2	81,500	6,010	602	6,620	87,500	604	88,100
Rhode Island	3,260	--	3,260	--	--	--	3,260	--	3,260
South Carolina	23,600	--	23,600	--	--	--	23,600	--	23,600
South Dakota	9,870	--	9,370	1,650	165	1,820	11,500	165	11,700
Tennessee	52,100	7,320	59,400	6,630	892	7,520	58,700	8,210	66,900
Texas	111,000	75,000	186,000	319	--	319	111,000	75,000	186,000
Utah	48,000	117,000	165,000	1,290	1,900	3,190	49,300	119,000	168,000
Vermont	5,480	200	5,680	W	W	W	5,480	200	5,680
Virginia	46,400	15	46,400	2,610	930	3,540	49,000	945	50,000
Washington	30,400	3,760	34,200	431	34	464	30,900	3,790	34,700
West Virginia	13,000	--	13,000	2,680	--	2,680	15,700	--	15,700
Wisconsin	53,900	7,760	61,700	W	--	W	53,900	7,760	61,700
Wyoming	18,900	138,000	157,000	10,700	4,910	15,600	29,600	143,000	173,000
Undistributed[4]	1,670	114,000	116,000	1,430	350	1,780	3,100	114,000	118,000
Total[2]	2,570,000	1,640,000	4,210,000	153,000	20,600	174,000	2,720,000	1,660,000	4,390,000

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Excludes material from wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

[3] Less than 1/2 unit.

[4] Includes estimated data in table 2.

SOURCE: U.S. Bureau of Mines (1976).

million tons of milling waste (tailings), mostly from copper, iron, and phosphate rock.

Significantly, 14,180 of the mines (93 percent), supply construction materials--sand, gravel, stone, clay, and gypsum. Except for gypsum, the mines are located mostly near urban centers. Encroachment of residential development on mines and expansion of mines to meet growing needs for construction materials has resulted in increasing use of zoning for resolving conflicts in land use. Identification and mapping of such resources in advance of urban development would be important aids to planning.

In terms of total material handled, 9 mineral types each exceeded 20 million tons in 1976, for a cumulative total of 4.15 billion tons, equivalent to 95 percent of all the material mined. Details on these 9 types are shown in Table 2.3. The numbers and locations of mines producing many of the "other" minerals are shown in Table 2.4.

To recapitulate U.S. mine operations and production; the regional mines producing copper, iron, phosphate, uranium, and titanium represent only 2 percent of the mines, but they excavate 27 percent of the ore, 87 percent of the waste, and 50 percent of the total mined material. The construction material mines and quarries (stone, sand and gravel, clay, and gypsum) represent 93 percent of the mines and excavate 68 percent of the ore, 7 percent of the waste, and 45 percent of the total mined material. The remaining 5 percent of the mines (mainly asbestos, barite, bauxite, diatomite, feldspar, fluorspar, gold, lead, potash, salt, silver, soda ash, talc, tungsten, and zinc) excavate 5 percent of the ore, 6 percent of the waste, and 5 percent of the total mined material. About two-thirds of the underground mines are in the "remaining 5 percent category." All or most of the fluorspar, lead, potash, soda ash, salt, tungsten, and zinc that is mined comes from underground operations.

Mining and minerals processing terminology is defined in a USBM mining dictionary (USBM 1968). Mining is conducted by a variety of surface, underground, and in situ procedures.

Surface mining includes quarrying, open-pit, opencut, opencast, stripping, placering, and dredging operations. The USBM dictionary definitions provide no clear distinctions between quarrying, open-pit, opencut, opencast, and strip mining. A tenuous preference can be discerned for using the word "quarrying" in connection with surface mining of stone, although it often is used for all construction materials. Strip mining appears to be the preferred term for surface mining by successive parallel cuts that are filled, in turn, with overburden. Besides coal, phosphate

TABLE 2.3 Data on Mining Nine Mineral Types that Exceeded 20 Million Tons of Combined Ore and Waste in 1976

Commodity	Total Materials (Million S. Tons)	Number of Mines					Main Location (State)
		Total	Size Range - Annual Tons Ore				
			Less than 10,000	10,000 to 1 Million	1 Million to 10 Million	Over 10 Million	
Crushed and Broken Stone	970	4,950	1,253	3,565	131	1	All states; Ill. and Tex. each 6%.
Copper	969	45	5	9	21	10	Ariz. (65%), Utah, N. Mex., Mont., Nev., Mich., Tenn.
Sand and Gravel	885	7,599	1,596	5,942	59	2	All states; Mich. 6% of total.
Iron	496	65	8	29	23	5	Minn. (70%), Mich. (20%), Calif., Mo., Nev., Pa., Tex., Utah, Wyo., Wis.
Phosphate Rock	411	51	9	21	16	5	Fla. and N. C. (85%), Calif., Idaho-Mo.-Mont., Utah-Wyo. (11%), Tenn. (4%).
Uranium	266	212	128	83	1	-	N. Mex. (46%), Wyo. (31%), Ariz., Colo., Tex., Utah, Wash.
Clays	89	1,132	364	768	-	-	Common clay, 70% of total, produced in 4 states; Tex. 10% of total common clay; Wyo. 70% of Bentonite clay.
Ilmenite	45	7	-	1	6	-	Fla., N. J., N. Y.
Gypsum	21	68	8	60	-	-	Mich., Tex., Calif., Iowa, Okla., Nev. (70% of total).
Other[1]	238	1,150	789	329	30	2	
Totals	4,390	15,279	4,160	10,807	287	25	

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[1] 44 mineral commodities or groups; includes mine output designated "W" in Table 2.1; does not include by-product metals.

SOURCE: USBM (1976).

TABLE 2.4 Location of Principal Mines for Selected Minerals in "Other" Category of Table 2.3

Mineral	No. of Mines	Location
Asbestos	4	California, Vermont, Arizona, North Carolina
Barite	37	Nevada (76%), Arkansas, Missouri, 6 others
Bauxite	14	Arkansas (84%), Alabama, Georgia
Beryllium	1	Utah
Boron	2	Also from lake brine; all California
Diatomite	14	Mainly California; also Kansas, Nevada, Oregon, Washington
Feldspar	25	North Carolina, Connecticut, Georgia, California, Oklahoma
Fluorspar	8	Illinois and Kentucky (85%), also Arizona, Montana, Nevada, Texas, Utah
Gold	88	South Dakota, Nevada, Alaska, California
Lead	37	Missouri (83%), Idaho (8%), Colorado (4%), Utah (2%)
Mercury	6	Mainly Nevada; also California
Mica	13	North Carolina (52%), Alabama, Arizona, Connecticut, South Carolina, South Dakota

Molybdenum	3	Mainly Colorado; also New Mexico
Perlite	12	Arizona, California, Colorado, Idaho, Nevada, New Mexico
Potash	9	New Mexico (85%), Utah. California and also Utah produce from lake brine
Pumice	192	Oregon, California, Arizona (62%)
Rare-earth Metals	1	California. Also monazite by-product from ilmenite in Florida
Salt	19	Louisiana, Texas, New York, Michigan, Ohio
Silver	63	Idaho (40%), Arizona (18%), Colorado (12%), Utah, Montana,
Sodium Carbonate	4	Wyoming
Stone (dimension)	431	Indiana, Georgia, Vermont, Ohio, Massachusetts (56%); also 39 other states
Sulfur	11	Texas and Louisiana produced 6.2 million long tons from Frasch mines
Talc Group	40	Vermont, Montana, New York, Texas (90% of total)
Tungsten	43	90% from 1 tungsten mine in California and 1 molybdenum mine in Colorado
Vanadium	1	Arkansas. Also by-product from uranium and phosphate rock
Vermiculite	-	Mostly from 1 pit in Montana; also several pits in South Carolina
Zinc	31	Tennessee (20%), Missouri (18%), New York (16%), Colorado (10%), New Jersey (7%) All underground mines

SOURCE: USBM (1976).

rock in Florida and North Carolina, red-bed copper in Oklahoma, bauxite in Arkansas, kaolin clay in Georgia, and some other deposits are mined in this way.

The terms "open pit" and "opencut" identify surface mines other than quarries, strip mines, and placers, but are often applied to these types also. The term open-pit is used more specifically for surface mines in relatively thick ore bodies characterized by permanent waste disposal of wastes and terraced or benched slopes. Figure 2.1 shows a typical, large open pit for mining of a massive, disseminated ore body. Figure 2.2 shows the less symetrical pit form in mining of discontinuous bedded ore bodies.

Placering, which employs a variety of equipment and techniques including dredging, is used in mining and concentration of alluvial gravels and elevated beach sands. The numerous methods are summarized by Cummins and Given (1973). All the ilmenite production in Florida and New Jersey is obtained by dredging of elevated beach sand deposits. Phosphate pebble deposits in North Carolina are strip mined with floating dredges, and numerous sand and gravel deposits also are operated by dredging. Although hydraulic placer mining of gold in California was enjoined by court decree in the 1880s, placering for gold, using less environmentally damaging procedures, continues in California and Alaska.

The crude ores of 32 commodities are produced entirely by surface mining, and most of the copper, iron, and stone also come from surface mines.

Underground mining is conducted through adits or shafts by a variety of methods that include room-and-pillar, block caving, timbered stopes, open stopes, shrinkage stopes, sublevel stopes, and others (Cummins and Given 1973). Underground mining usually is independent of surface mining, but sometimes precedes or follows it. Waste removal is proportionately much less in underground than in surface mining (see Table 2.1), but still requires surface waste disposal areas (Figure 2.3). Underground mines supplied substantially all lead, zinc, potash, and natural soda ash mined in 1976.

In situ mining procedures include Frasch mining of sulfur, solution mining of salt and potash, leaching of uranium and copper, and proposals for in-the-ground (in-situ) retorting of oil shale. Sulfur production from 11 Frasch operations in Texas and Louisiana was 6 million long tons in 1976. An undisclosed tonnage of potash was recovered by solution mining of a former underground mine in Utah, and from lake brines in Utah and California. The lake brines also were sources of assorted by-product chemicals. Bromine was produced by nine plants in Michigan and Oklahoma

FIGURE 2.1 Part of the Sahuarita district south of Tucson, Arizona, where low-grade copper deposits are mined on a large scale by open-pit methods. Some processing facilities for one operation are adjacent to the pit in the foreground. Dumps of waste rock form the more distant terraced landscape. The nearly white areas in the left distance are surfaces of tailings ponds.

FIGURE 2.2 View of the Anaconda North Jackpile Uranium Pit looking toward Gavilon Mesa, Grants, Mining District, New Mexico.

FIGURE 2.3 Early and contemporary views of the Animas River Valley, San Juan Mountains, Colorado, showing effects of waste disposal from underground mining.

A. The valley as photographed in 1875 by W. H. Jackson, U.S. Geological Survey.

FIGURE 2.3 (continued)

B. The valley after activities of the Sunnyside Mine as photographed in 1978 by Mark Klett, Rephotographic Survey Project, Sun Valley, Idaho.

from underground brines. Several hundred tons of copper were produced by in-place leaching of caved workings in an underground mine in Arizona.

Land, water, and air disturbance occurs when minerals are mined and processed. The nature and degree of disturbance and of its effects are dependent on a variety of conditions that include the size, shape, depth, and grade of ore bodies; production rates and production economics; the physical and chemical characteristics of the ore and waste rock; the mining and processing methods; mine and mill waste-to-ore ratio; the social, political, air, water, vegetative and wildlife setting; the geology, topography, hydrology, altitude and climate; and the amount and nature of solid, liquid, and gaseous wastes, and the technical means for their control.

The nature of the environmental disturbance caused by mining also is influenced by the heterogeneous character of the mineral deposits. Differences exist not only between mineral occurrences, but also on a foot-by-foot basis within the same mineral deposit. Also, economic factors of mining and waste control vary markedly between ore types and among deposits of the same mineral. Nonetheless, for analogous mineral commodities similarities are apparent in ore minerology, treatment methods and response, mining and milling waste, and economic factors.

A growing body of environmental protection legislation enacted in recent years by the several levels of government has attempted to curb the adverse environmental effects of mining. More effective coordination among the diverse governmental agencies at the same and different levels of government could have a number of constructive consequences (see Chapter 4). These could include more effective environmental protection by facilitation of premining planning; reduction in the time and expense of obtaining permits; and improvements in the exercise of environmental controls, monitoring of performance requirements, and enforcement of regulations.

Although many adverse effects of mining are responding to controls, an enhanced response might be obtained by more appropriate institutional approaches and regulatory mechanisms and by more diligent monitoring and enforcement (see Chapter 6). Such alternative institutional approaches and mechanisms might help clarify trade-offs between land use decisions and assure understanding that selection of a non-mining use may be at the expense of making later mining more expensive or impossible.

Environmental problems from abandoned non-coal mining operations are addressed in PL 95-87 (Sec. 409(a)), but are assigned a lower priority than reclamation of abandoned coal mines. Legislation passed by Congress in November 1978 (PL 95-604, Uranium Mill Tailings Radiation Control Act of 1978) directs that inactive tailings impoundments from milling of uranium ores are to be reclaimed.

Mining not only affects the physical environment (and concomitantly the human, animal, and vegetative communities), but it has important, critical impacts on the economic, social, and political fabrics of the locality, State, and nation. Although some of the effects of mining operations are now subject to control by Federal, State, and local laws, existing operating practices, site-specific factors, missing knowledge, and in some cases, the lack of effective enforcement, leave a range of concerns that include the following:

1. Pre-emption of existing land use, particularly fragile wetlands, arctic and upland ecosystems, and disturbance of fish, game, and other wildlife habitats;

2. Social and economic effects including land use conflicts, costs imposed on local government by mining operations, negative aesthetics, and the nuisance of noise and vibrations from truck haulage and blasting;

3. Release of radioactivity to the atmosphere from mining, mineral processing, and waste disposal;

4. Nuisance and health effects of fugitive dust from roads, mining, milling, stockpiles, wastepiles, and tailings, and of air contaminants from on-site processing;

5. Alteration of ground-water quality or quantity by interconnection of aquifers via boreholes, and contamination by mine water, dump leachates, seepage from tailings, impounded waste solutions, and deep well disposal of waste solution;

6. Surface-water quality alteration caused by drainage from mine waste-piles or tailings, or process waste solutions containing deleterious chemicals, radioactivity, or sediment;

7. Surface subsidence and hydrological disturbance caused by caving of workings in underground mines, by solution mining, and by in situ retorting;

8. Difficulty in reclaiming or revegetating disturbed land because of climatic, physical, or chemical conditions.

The thousands of mostly small mines that meet local needs for construction materials, often over a span of several generations, have markedly different environmental and social effects than the enormous regional mining operations, such as southwest copper, Lake Superior iron, Florida phosphate, and Rocky Mountain uranium and oil shale. These two categories of mining also contrast markedly with the relatively brief strip-mine fill-sequence of most surface coal mines. Section 5.4 of this report focuses on the contrasting situations and effects, and Chapter 6 focuses on the corollary need for appropriately different institutional approaches.

This chapter describes and discusses mining technology and its effects--environmental, economic, and social. Mitigating and reclaiming procedures for control of adverse effects of mining are described in Chapter 3.

2.2 MINING TECHNOLOGY

2.2.1 Introduction

To a miner, "ore" is a mineral that can be mined at a profit (USBM 1968). Implicit in this definition is an economic constraint on the size and number of machines and the complexity of methods that can be used in mining. Mining technology is composed of those excavating systems that can profitably excavate, or extract, an ore; thus, a discussion of mining technology cannot ignore aspects of cost. Within these limits, the following discussion gives a broad outline of the individual mining practices by analyzing the elements of mining rather than the individual machines.

In some circumstances mining seems to merge with subsequent processing and refining. Further, many mine or quarry units, such as sand and gravel, crushed stone, and cement, sell a finished product directly to the final fabricator. Sections 2.2.4 and 2.2.5 describe mining and processing operations further.

2.2.2 Elements in the Life of a Mine

Where a mineral deposit is isolated and totally recoverable, such as the bonanza gold of the nineteenth century, a mine goes through a well-defined life cycle. This simple circumstance rarely exists today, particularly in surface mining. Modern metal mines are designed to recover large, low-grade deposits whose boundaries shrink and swell with variations in market price and production cost. The subsequent discussion on cut-off grade explains this variability of mining boundaries. Although the life cycle is presented as if there are five discrete and sequential steps, it should be borne in mind that a project can be halted at any time it is projected to lose money, and, in most cases, resumed under sufficiently profitable long-range conditions that justify a reopening. Conversely, if original plans and projections underestimate size and value, mine planners go back to an earlier phase in the cycle in order to prepare for mine expansion.

The goal of the nineteenth-century miner was extraction, usually from underground workings at a minimum direct or internal cost, with general disregard for external cost. Under continuing statutory and social pressure, modern mining companies have come to accept many of these external costs as a necessary part of their production. Where mandated by law, miner health and safety, mine drainage control, and surface coal-mine reclamation are accepted as part of the mine plan. The five steps of the life cycle cover well these external concerns.

1. A deposit is found by an act of discovery resulting from prospecting. This can occur by happenstance, by well-ordered geological or geochemical investigation and interpretation, by sophisticated and expensive geophysical search, or, as is most likely today, by some combination of the three.

Entirely new deposits can be discovered as well as unknown extensions of previous discoveries. An essential goal of the mining industry is to replace depleted or exhausted deposits by finding new deposits, extending known deposits, and reworking old deposits. Such efforts are financed by injecting new capital or by improving cash flow from existing operations by price increases.

2. When the existence of a mineral deposit is suspected, the area is tested further by exploration and evaluation. The word exploration is used with several meanings. In the broadest sense, it covers all activities within steps 1 and 2. From the narrower perspective of the miner, it means those data-gathering activities that are used to expand knowledge about a presumed discovery. Samples are obtained from test pits, drill cores, or pilot excavations into the deposit. These data are assembled into a mathematical or physical model of the deposit's mineral and geological characteristics, which is used first to evaluate the deposit and then to determine whether the deposit can be economically mined.

The decision to mine is based on a comparison of the gross deposit value, which is a function of contained material and its expected selling price with a combination of all expected costs. In addition to direct mining and processing costs, an estimate is made of the loss of material due to technical inefficiencies, which is expressed as percentage recovery, and the financial rate of return expected by the company is projected (see Section 2.4.1.1). Estimates of mining cost stem from preliminary mining plans designed for optimum extraction. Such plans take into account the physical factors of shape, depth, continuity, rock strength, presence of water, and the like, as well as considerations of environmental protection and reclamation. Similarly to geological data, information should also be gathered on baseline environmental conditions so that the mine's effect on the environment can be predicted and suitable controls planned. Processing costs are projected in a similar fashion, recognizing that the nature of the ore strongly influences the methods to be used and the amount to be handled.

3. If the estimates of step 2 favor continued investment, plans for mine development are refined and activities that precede the production phase are begun. A modern surface mine may require for its development, depending upon size and complexity, 10 to 100 dollars per annual installed ton of capacity. Development implies the physical steps that prepare the mine for ore production. They include the construction of surface facilities such as offices, shops, worker changing areas, and the mill. They also include the establishment of a transportation network. The biggest part, however, is preparing for the removal of waste overburden and establishment of waste dumps and tailings ponds, which is one of the major cost elements for many mines. In underground mining, development refers to the driving of those openings (shafts, adits, drifts, raises, places from which to mine ore, etc.) needed to reach the ore body.

4. After ore is uncovered, further development is integrated with the step of production (extraction or exploitation) whereby ore is excavated in a timely manner to meet market needs. Production, with attendant reclamation needs, is the major activity throughout the life of a mine, following the ore body to its economic limit or to the boundary of ownership.

5. Eventually, by reason of mining costs, lowered recovery, actual depletion, or other factors (e.g., lower market prices), a decision is made to abandon the mine. Abandonment is not merely closure; it implies a decision on the part of the current operator to give up ownership and not to reopen. Mines are frequently shut down temporarily because of fluctuations in demand for the product. They are abandoned, however, only when there is not reasonable hope of their being reopened. At some later time, these expectations may change, and mining under new auspices may resume. Hence, abandonment is a circumstance of economic as well as geological conditions, and these circumstances can be expected to change with time so long as mineral matter remains to be extracted.

In today's world, where abandonment becomes less a phenomenon of desertion and more a matter of reclaiming the site for further use, a careful analysis of mineral depletion must be made before the mine is closed. Reclamation may create features whose subsequent removal may not be socially or environmentally acceptable, and such removal would represent additional development cost in the event that the mine is reopened. An example of this additional cost is the reclamation practice of backfilling against a highwall up to the original contour. From the point of view of Appalachian surface coal-mine operations, this represented not only an additional direct production cost, but the loss of opportunity to recover additional coal should there be a small rise in price. In short, abandonment is less reversible now than in the past.

2.2.3 Integration of Planning into the Mining Cycle

The traditional five-step life cycle of a mine does not necessarily now prevail. Instead, economic competition and new legislative requirements call for continual modernization of mining plans, reserve estimates, production schedules, and other technical systems. Market conditions and even geologic knowledge of the ore deposit can change substantially and rapidly from first projections.

Modern mining has come under a growing body of rules and guidelines. Mining decisions now incorporate the direct control costs and the indirect costs, which allow for design, permitting, and implementation of these required control procedures. Permits may concern air emissions, mine drainage, reclamation, mine safety, ground control plans, and the like; they are not confined solely to environmental protection, but cover the entire regulatory array of worker health and safety and land-use conflicts. It is obviously efficient to coordinate these requirements with development of the mine in order to expedite the operation (Ramani and Clar 1978, Riddle and Saperstein 1978).

Thus, current requirements have caused the exploration phase to be expanded to include baseline information on social and environmental factors in addition to information on the mineral itself. Development and extraction systems can be designed at this stage to comply with existing or even potential requirements. Occasionally, foresight combined with a fortunate mine location and favorable site conditions will create a compliance plan which gives additional financial return from reclaimed land. The exploration phase should consider the characteristics of the area or region to create a suitable rehabilitation plan. Ultimately, accomplishment of the rehabilitation plan is evidence of readiness of the mine site for abandonment. In a long-lived mine, such as those in the Bingham District in

Utah or the Butte District in Montana (both copper), the initial mine plan will change many times during the life of an operation, leading at the end to a result that could not at first be imagined. The same holds true for the underground operations of the Mesabi Iron Range, now mostly all replaced by open pits. There are still some underground iron mines on the Mesabi Iron Range, mostly (in terms of tonnage) in Michigan's Upper Peninsula.

2.2.4 Cyclical Unit Operations of Mining

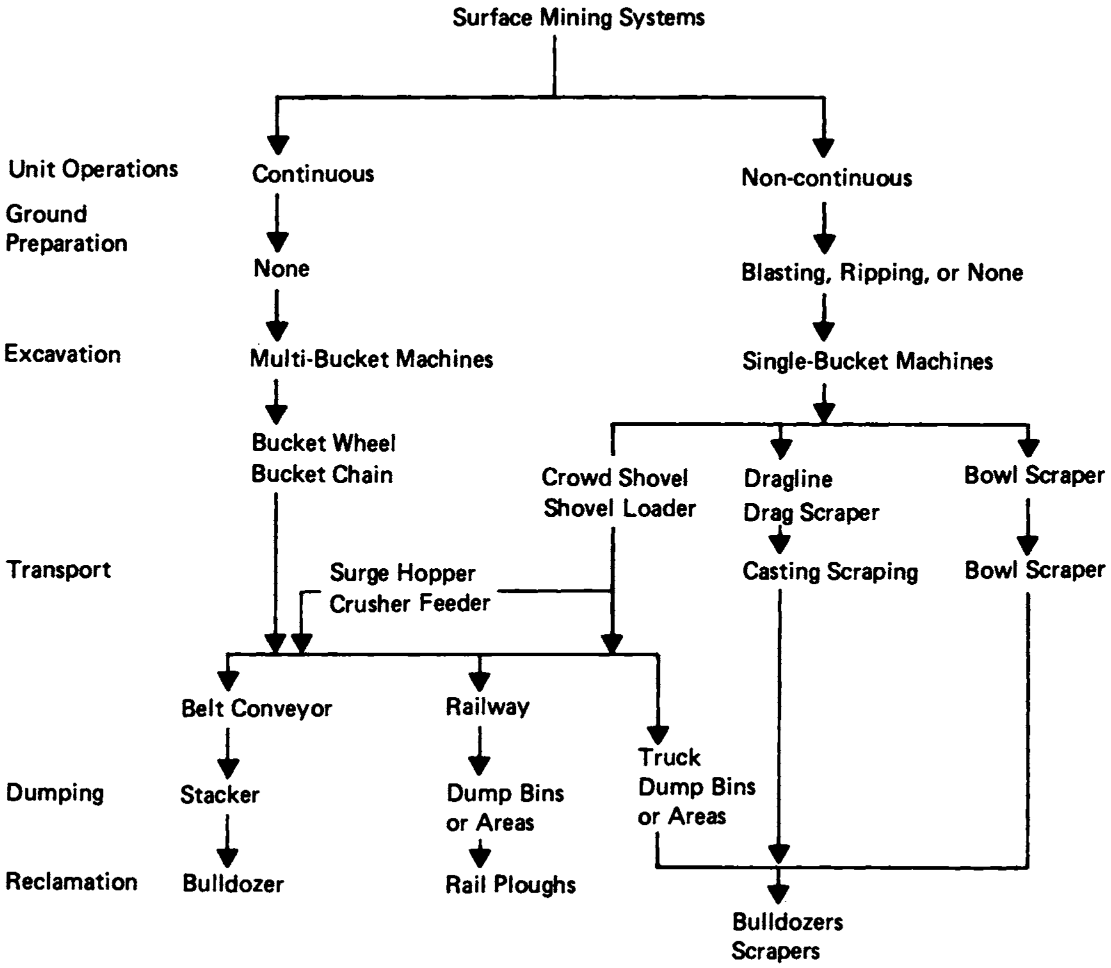
Mining machines and mining systems are obviously quite complex, but the general mining process can be described in a few individual steps, which are known as unit operations. These operations apply, in most instances, to underground mining, surface mining, and to general excavation practices. Mining is a materials-handling venture whose objective is to excavate minerals efficiently. Thus mining differs from excavations made for highways, canals, foundations, and the like by being limited by the mineral matter actually recovered, rather than by a required configuration. Further, in excavations for non-mining purposes, time is of the essence--not minimum unit costs.

Most excavation processes include six unit operations: (1) site preparation, (2) fragmentation, (3) excavating and loading, (4) hauling, (5) ground control, and (6) supporting activities (provisions for utilities, mine drainage, communications, crushing, etc.).

The use of machines and mining systems in these operations is shown diagrammatically in Figure 2.4, and further information on these practices is widely available (Nichols 1962, Pfleider 1968, Peurifoy 1970, and Skelly and Loy 1975).

Mining is a cyclical operation, each operation being done only once at a given place and time. Where the location of mining shifts, however, as at a moving face, each operation is repeated. In practice, these successive operations are integrated into a production system so as to avoid bottlenecks or delays. As mines become more sophisticated and costly, computer simulators are virtually a necessity in order to achieve efficient coordination (Ramani and Manula 1978).

Fragmentation (drilling and blasting), the first mining step after preparing the site, has three major purposes: (1) to separate the raw material from its place in the earth; (2) to provide pieces of a size suitable for loading or for efficient subsequent processing; and (3) to leave unfragmented rock in a stable or desired form (a procedure



SOURCE: T. Atkinson (1971) *Trans Inst. Min. Metall.* Sec. A80(776):101-129.

FIGURE 2.4 Use of machines and mining systems to accomplish unit operations required in mining.

known as ground control), as in shaping the wall of a pit or the cross section of a tunnel.

If the material to be excavated is soft, such as soil or alluvium, then it can be fragmented with the teeth of an excavating or loading machine. The "continuous" branch of Figure 2.4 is for this possibility. For moderately consolidated materials, such as hard-pan soils or weakly indurated sedimentary rocks, a ripping tooth attached to the rear of a tractor can be used. Harder rocks are normally broken by drilling and blasting. The drill holes are made in a suitable pattern, filled with appropriate explosive, and then fired in a sequence to give the desired fragmentation but with a minimum of vibration and throw.

Excavating and loading is done with three classes of machines, which either load into a haulage device or which themselves haul the excavated material. One class of machine is that typified by the familiar loading shovel ("crowd shovel" on Figure 2.4), which efficiently scoops up material with a bucket supported on a fixed boom. Power shovels, as they are sometimes called, are commonly seen at open-pit mines. Large and relatively immobile stripping machines, which are characterized by the dragline, stripping shovel, and bucket-wheel excavator, represent the second class. Because of their size, hence their dumping reach, they work without a separate haulage unit. Bucket-wheel excavators are most efficient but work well only in boulder-free, non-indurated material. The third class is that of mobile loading machines, the two most popular being the front-end loader and the scraper. Front-end loaders can be used alone to load and carry unconsolidated material or blasted rock over short distances or with haul trucks for longer trips. In practice, they require better fragmentation than a loading shovel of equivalent size. A scraper is a combined loading and hauling machine that is very effective in soils and other unconsolidated or finely fragmented materials.

Haulage or transportation, when not combined with loading, is the fourth unit operation. Transport can be continuous, as with conveyor belts or, less commonly, by hydraulic or pneumatic methods. Trucks are the most common means of moving excavated material. Trains, though less common, are used when large amounts of material are carried between fixed points.

Ground control, or shaping of the unfragmented and unexcavated material, and other auxiliary processes, allows mining to continue unimpeded. Ground control begins passively as a result of mine design and layout, but soon results in activities such as face cleaning and erection of artificial supports.

Reclamation, in and of itself, is not a separate unit operation. Rather, it represents a manipulation of the excavation process to achieve a desired land form at the time of abandonment. Reclamation may include some rehandling of overburden, additional drainage control, restoration of the growth potential of the surface, and so forth. Thus, reclamation is the installation of the various designs and controls required for effective environmental compatibility and is carried out in all unit operations. How and where the haulage operators dump waste may have a more significant impact on the postmining environment than does the selection of plant species for revegetation.

These unit operations apply to any surface mining system, indeed, in concept, to underground systems also. The system used depends on the geologic attitude of the deposit and the machines selected to mine it. Area strip mining is used for a thin flat-bedded deposit in level terrain which is mined by large excavators working in long cuts or strips. Contour strip mining is used on flat-bedded deposits which outcrop in irregular terrain; it tends to use highly mobile machinery. Open-pit mining recovers relatively thick deposits and is characterized by stepped or terraced pit walls and permanent waste disposal areas. Quarries are mines within deposits of stone which are used for construction materials. In any of these systems, the flow of the unit operations can be traced.

2.2.5 Unit Operations of Processing

After the mineral raw material (ore, sand and gravel, stone, etc.) is mined, it is usually subjected to further processing operations that concentrate valuable components by the removal of undesirable constituents. A component may have value because of its contained metal (the metallic ores), or for its inherent chemical properties (many of the non-metallics such as phosphate, fluorspar, or the soluble salts), or even for its physical characteristics (construction aggregate). Whether the valuable component is a major part of what is mined or is only a small fraction, the processing system for that component will incorporate a number of operations. Processing has a number of synonyms, including beneficiation, preparation, cleaning, concentrating, and washing.

As in mining, there are certain well-accepted unit operations in processing: (a) comminution, commonly called crushing and grinding; (b) sizing; (c) separation by density, surface properties, or other physical characteristics; (d) fluid-solid separation, including recovery of process water; (e) waste disposal; and (f) the ancillary operations of material handling (Gaudin 1939). Like other major process plants, such as most chemical plants and petroleum refineries, a mineral processing plant is sized for an average output but must have storage areas for raw material feed and finished material output to be able to accommodate surges before, during, and after processing. The unit operations are linked by material handling devices such as chutes, conveyor belts, or other feeding devices for dry solids, or pumps and pipes for liquids and liquid-like hydraulic slurries. The blueprint or map of all of the steps and their linkages is called a flow sheet.

Comminution is usually accomplished in several stages and is a function of in-the-mine fragmentation and the desired size of the output. Primary crushers such as jaw crushers, gyratory crushers, or roll crushers (for softer material) take run-of-mine rock and reduce it to an average size of several inches. Secondary crushers or tertiary crushers in large plants take the output of the primary ones and further reduce the rock size to usually less than one inch. This rock may now be fed to the grinding circuit, usually rod and/or ball mills. These mills use the tumbling action of steel rods or balls in a large rotating drum to effect the size reduction. Where a large-sized product is desired, such as crushed stone, the grinding step is omitted. On the other hand, where a very fine (talcum-like) powder is needed (as in the case of most metallic ores and portland cement), comminution becomes a substantial activity and is often the most costly unit operation of mineral processing.

Sizing is done to effect a separation of particles on the basis of size. Obviously, mineral matter does not break into perfect geometric shapes, therefore the size categories are ranges that encompass average sized particles. Odd or elongated shapes sometimes defy convenient size categorization. In the case of construction aggregate, this sizing is done to obtain finished product of coarse (4 inches or larger), medium (1 to 4 inches), or fine (less than 1 inch) size. In processing copper and most other ores, however, the principal use for size separation is to obtain those rock fragments that have been reduced to such a size that the discrete grains of minerals to be recovered are freed from the accompanying waste. The sizing step also produces a particle size compatible with the subsequent grinding or concentrating operation. Sizing is ordinarily done with large mechanical screens or, for fine material, by hydraulic devices called classifiers. Material larger than the given screening or classifying size is returned to the comminution device for further grinding.

Once particles are reduced in size, i.e., discrete particles of the valuable mineral and waste are produced, they are sent to a separation process. Separation can be effected by gravity techniques (sink-float, jigging, tabling, etc.) when the densities of mineral and waste are sufficiently different. Magnetic properties are useful to effect separation for certain iron minerals. Where distinctly different hardnesses prevail between two components, the sizing may simultaneously effect a mineral separation. Color and texture have been used in the past, as in hand sorting, but they are little used at present.

Another major concentration process is mineral froth flotation, which relies upon the surface chemistry of the materials for separation. Fine particles of the desired material in a dilute water slurry are made to adhere to the surface of induced bubbles and thus "float" to the surface, from which they may be skimmed. Waste tailings that are not floated are removed from the bottom or end of the flotation cell. The reverse flotation process may be suitable for some materials. In this mode the unwanted component or tailing is floated and discarded while the product is removed from the bottom of the flotation cell. Froth flotation is an important process that, by the nature of additive chemicals, can be used on a vast array of metallic and non-metallic substances. However, the feed material to the flotation cells must be finely ground for the process to work efficiently.

Although water is a very necessary part of mineral processing, it too becomes an unwanted waste after it has done its job. Hence, to reduce weight, improve shipping and storage, and, in arid regions, to recover valuable water, a fluid-solid separation follows most wet processes. Water can be removed from coarse material on vibrating screens. Fine material, with its high proportions of surface, must undergo more vigorous treatment. Dewatering steps include settling in lagoons or in mechanical thickeners, followed by filtration and even thermal drying. Frequently, the process water is laden with process chemicals or fine mineral material that has escaped the filters. This water undergoes its own separate treatment to purify it for reuse. Dry processing has the separate problem of dust suppression and recovery.

The final processing step of waste disposal may be the most significant as far as the COSMAR report is concerned. By now, it should be clear that mineral processing is a concentration of valuable mineral constituents through separation and exclusion of waste material. Somewhere, these wastes must be placed into permanent storage.

The construction of an effective disposal area is a well-studied subject (U.S. Department of the Interior 1975) with its roots in the eighteenth century. When this knowledge is used carefully in well-designed disposal areas, then the structure is normally sound. A special problem is the long time over which the disposal site is constructed.

Today's engineering design can affect the stability of a pile that is still expanding in the next century. Amendments to the original design, made without careful analysis, can obviate all the good work inherent in the original design. Although written for coal wastes, the U.S. Department of the Interior's Engineering and Design Manual, Coal Refuse Disposal Facilities (1975) includes a thorough review of design principles for all mineral waste disposal areas. Concern is shown for foundation stability, slope stability, fluid flow, contained contaminants, and ultimate shape. These factors influence the disposal site's safety, pollution potential, and potential for subsequent land use. As evidenced by the disposal problems of phosphate slimes, additional research is still required for the safe storage of very fine, clay-like materials.

The assemblage of the processing unit operations into a workable plant must take into account a variety of design goals. Purity of product may be antithetical to overall recovery. Therefore plant design balances product purity against percentage of valuable product contained in the waste, which is an indirect measure of recovery. Because most processing operations consume large amounts of energy, a great deal of thought is given to minimizing treatment. Ore feed is screened before crushing so that undersize material can bypass the crushing step and thus save energy. Finally, good processing procedures recognize that waste is a product whose value has not yet been set. Therefore, it is a substance to be husbanded and protected as a resource for the future.

2.2.6 Engineering Analysis of Cost

2.2.6.1 Owning And Operating

Obviously, it costs money to run a mine: labor is paid, and machines, power, fuel, and supplies are bought. Cost accounting analyzes costs of a particular unit operation (Sections 2.2.4 and 2.2.5) and determines the distribution of expenses. The purpose of cost accounting is to identify operating efficiencies and, thus, to reduce expenses and increase profits. Cost engineers analyze expenses, and financial analysts deal with profits, which are a matter of keeping costs lower than income. In a typical cost analysis (Caterpillar Tractor Company 1978) the cost of a unit operation is divided by the amount produced to give a unit cost. The unit of production in mining is usually a ton of ore. Thus, over a given period of time, the following kinds of costs are aggregated: (a) a proportionate share of acquisition, installation, and erection costs; (b) a like share of the cost of capital needed for the operation; (c) taxes and insurance; (d) labor costs; (e) cost of energy;

(f) purchase of supplies; and (g) maintenance and parts replacement.

Although such costs can be calculated for a single machine, the usual practice is to account for the total unit operation, including all workers and machines that are assigned. Occasionally, cost engineering methods are used to determine costs that are common to all operations, such as training, health and safety, environmental control, etc. Further, the accounting of several unit operations may be combined in order to compare aggregate costs of development with those of production, or to determine costs of reclamation, and so forth.

2.2.6.2 Cut-Off Grade

There are certain irreducible costs in mining and processing that determine the minimum grade (concentration of valuable material) of ore that can be profitably mined, namely: milling, smelting, basic mining costs, and overhead costs for other processing, but not the costs of the initial overburden removal that uncovers the ore. If the mineral material does not produce sufficient value to pay for its mining and subsequent processing, then the material is considered to be waste and is either left in place or is removed in order to reach underlying or adjacent higher-grade material. This minimum value is expressed as cut-off grade.

As production costs are reduced over the long term, as by improvements in processing technology, the cut-off grade for a given deposit can be reduced and the mine life and total tonnage are extended. A rise in price paid for the product has the same effect. On the other hand, in a competitive market, increases in cost have the effect of raising cut-off grade, reducing mine life, and reducing recovery, unless the selling price can be raised to cover the increased cost. If all operators are doing business on the same basis, the portion of the additional costs passed on to consumers, for meeting expenses for pollution control, for instance, depends on the price sensitivity of demand. If demand is insensitive to price, all cost increases can be passed on as higher prices, and the percentage of recovery may be unchanged. On the other hand, if demand is highly sensitive to price because of the availability of ready substitutes, all mines may become uneconomic. New regulations will create a competitive advantage for those operators who can comply at a lower cost than others.

2.2.6.3 Stripping Ratio

The pinnacle of cost accounting is found in the concept of the stripping ratio, a number that signifies the amount of overburden to be removed when extracting a unit of ore, expressed as a ratio of overburden to ore. The important consideration is that the stripping ratio is rarely fixed by geologic conditions, except for certain ore deposits of limited thickness: a layer of gravel, for example. Instead, geology determines the upper limit to the stripping ratio while mine techniques and economics fix the practical ratio. Pit slope angles, cut-off grade, and break-even economics have as much to do with the stripping ratio as does the physical location and grade of the deposit in the earth's crust. Thus "stripping ratio" implies several concepts. The broadest idea is that of the "overall" stripping ratio, which is a simple measure of the amount of waste produced per unit of ore produced over a given period of time.

As a planning number, costs and profits are inserted into the notion of stripping ratio to produce the "break-even" stripping ratio. This ratio reflects the value of a ton of ore, based on grade and market price and reduced by fixed costs, relative to the cost of removing the overburden and processing to marketable form. It is a fact of mining that no ore can be taken from a surface mine without first removing the overburden. Thus, even though the cost to excavate a ton of rock at a surface mine is usually less than the excavation cost for an equivalent amount at an underground mine, the total excavating cost of the surface mine may be comparatively large because of removal of overburden. Normal practice at a surface mine is to expand the mine until the break-even (no profit) stripping ratio is reached.

The last use of stripping ratio is in determining, for an ore body with extensive depth, the depth limit to an open pit. At this limit, it becomes more cost effective to open an underground mine. The underground vs. surface stripping ratio compares the cost of extracting a ton of ore by the appropriate underground method with a surface method. Presuming the underground method is more expensive, the difference in cost can be applied to overburden removal. This cost analysis is sophisticated and should be figured in conjunction with the break-even ratio, which includes profits.

Because the economics of mining is fundamentally based on the value of the ore, the tendency is to increase the stripping ratio and the volume of excavated material as the selling price increases. Added profit comes more from the increased tonnage than from any increase in profit per ton. An economical stripping ratio is related to ore and mineral material production costs as well as to the value of the ore. Pollution control and reclamation costs reduce the stripping ratio in two ways: first by increasing the ore production costs, and second by adding to the stripping cost of removing a given overburden quantity. Ore production costs increase through the expense of implementing and maintaining control procedures. Costs of removing overburden are increased by adopting new procedures for material handling, such as segregation of material, burial of toxic substances, and compaction of spoils. As in calculating cut-off grade, such increases in cost reduce the stripping ratio and, hence, resource recovery, provided that the selling price remains the same and no economies in technology are realized.

2.3 ENVIRONMENTAL EFFECTS OF MINING

Minerals exploration, and any subsequent mining and mine-site processing, impinges on the environment in a multiplicity of ways. Conspicuous among these are the changes in land use and landscape and in the potential for degradation of surface and underground waters by drainage and seepage from operating and abandoned mines, waste dumps, and mill tailings. Of unknown consequences is the threat of radioactive contamination by radon emission and wind-blown dust from uranium mill tailings, ore haulage, ore piles, and waste dumps. Whether radon-bearing ventilation air discharged from underground uranium mines and wind-blown radon from surface uranium mines pose a threat to public health is not now known. To a lesser extent, because of lower uranium content, phosphate rock mining may pose a threat of radioactivity contamination. In addition, the phosphate fertilizer made from the rock for wide distribution on land, is weakly radioactive. Other concerns relate to difficulty in revegetating certain disturbed areas, damage to fish and wildlife habitat, surface subsidence, negative aesthetics, dust, noise, and vibration. A single common action, such as building an access road or removing vegetation and topsoil in preparation for construction or mining, alters the appearance of the landscape, and increases the potential for erosion, stream siltation, and wind-blown dust. In certain localities, alteration or deterioration of any of the three physical components of the environment is disruptive to fish and wildlife habitats.

The subsections that follow discuss the effects of mining on the land and landscape, on water, on air, and on fish and wildlife. In the land and water sections, environmental disturbances are specifically related to a corresponding mining step or mining type in the following order: exploration, surface mining, underground mining, in situ and solution mining, and mine-site processing of minerals. The sections on air, wildlife, and other significant environmental problems are more general. Mining effects cited are intrinsic to the use of current technology and in keeping with applicable regulatory requirements. Mention is made, as appropriate, to residual effects from past operations and to potential effects in the future from on-going and proposed mining developments.

2.3.1 Land and Landscape

Surface mining is one of the major land use components of the comprehensive land use pattern of the nation. Like the other major land uses, surface mining is essential to the economy, is conspicuous where it takes place, occurs in a wide variety of regional and local environments across the nation, and occupies land divided among a great number and variety of owners. More than most other land uses, it changes irreversibly the land it occupies.

Part of the environmental impact of a surface mine comes simply from the presence of the mine among neighboring, competing, and commonly incompatible land uses. The degree to which mines are isolated, or could be isolated by planning and zoning, depends upon how large a share of the nation's land resource the industry requires and where the mines are located in the geography of the nation's over-all natural resource and settlement base. Location in the resource and settlement pattern is important because it affects not only the nature of environmental control measures necessary when a mine is operating but also the extent to which the land will be needed for other uses when it is no longer mined.

Land utilization in the mining industry has been summarized by USBM (Paone and others 1974). Data on the amount of land use by the mining industry are displayed in various ways in Tables 2.5, 2.6, and 2.7. The land use data in the USBM publication includes the surface mine excavation, surface area used for disposal of waste and tailings from surface or underground mines, and the surface area subsided or disturbed as a result of underground workings. Unreclaimed land for which mining has been completed and where reclamation is now possible is not separately reported in the tables. Much of the land defined as being disturbed is part of existing operations, and cannot be reclaimed until mining is completed. Land disturbed by mineral exploration, access roads, haulage roads, and mills and camp sites are not included. Mined lands that have been put to some other use without formal reclamation by the mine operator are also not included. Lands quarried for construction minerals in populated areas

TABLE 2.5 Land Utilized and Reclaimed by the Mining Industry in the United States in 1930-1971, by Area of Mining Activity

Type of use	Metals		Nonmetals		Fossil fuels[1]		Total[2]	
	Utilized	Reclaimed	Utilized	Reclaimed	Utilized	Reclaimed	Utilized	Reclaimed
Surface area mined (area of excavation only)...........	145,000	17,400	1,060,000	253,000	966,000	716,000	2,170,000	987,000
Area used for disposal of overburden and other mine waste from surface mining...	123,000	5,270	291,000	129,000	320,000	268,000	733,000	402,000
Surface area subsided or disturbed as a result of underground workings........	12,200	1,780	4,570	100	87,900	4,000	105,000	5,870
Surface area used for disposal of underground mine waste.....................	21,900	1,500	2,080	180	166,000	20,000	190,000	21,600
Surface area used for disposal of mill or processing waste.....................	221,000	17,300	201,000	23,300	31,900	6,480	454,000	47,100
Total[2].................	524,000	43,300	1,560,000	406,000	1,570,000	1,010,000	3,650,000	1,460,000

[1] Excludes oil and gas operations.

[2] Data may not add to totals shown because of independent rounding.

SOURCE: Paone and others (1974).

TABLE 2.6 Land[1] Utilized by the Mining Industry in the United States in 1930-1971, by State and Selected Commodity (acres)

State	Bituminous coal	Clays	Copper	Iron ore	Phosphate rock	Sand and gravel	Stone	Uranium	All other commodities	Total[2]
Alabama.......	34,900	6,390	-	7,540	-	5,280	10,700	-	280	65,100
Alaska........	3,600	10	220	-	-	9,520	390	10	15,900	29,600
Arizona.......	220	630	84,000	5	-	10,800	2,140	620	3,970	102,000
Arkansas......	3,100	2,040	-	5	-	8,870	9,580	-	5,950	29,500
California....	30	10,400	-	2,720	-	81,000	31,300	5	101,000	227,000
Colorado......	8,630	1,590	30	50	-	14,700	5,630	330	17,900	48,800
Connecticut...	-	830	-	-	-	6,350	4,980	-	150	12,300
Delaware......	-	80	-	-	-	1,130	120	-	-	1,330
Florida.......	-	1,710	-	-	47,900	5,970	22,100	-	11,100	88,800
Georgia.......	40	13,700	-	370	-	2,580	15,000	-	2,640	34,300
Hawaii........	-	60	-	-	-	520	3,470	-	760	4,810
Idaho.........	10	120	30	5	8,220	7,350	2,070	5	23,500	41,300
Illinois......	234,000	7,880	-	-	-	31,700	21,900	-	900	297,000
Indiana.......	130,000	5,420	-	-	-	19,400	19,200	-	620	175,000
Iowa..........	8,600	3,390	-	-	-	14,000	25,200	-	4,110	55,300
Kansas........	19,700	2,760	-	-	-	10,100	4,960	-	6,490	44,000
Kentucky......	210,000	3,740	-	-	-	5,060	14,800	-	270	234,000
Louisiana.....	-	2,460	-	-	-	11,300	4,320	-	120	18,200
Maine.........	-	140	-	-	-	9,260	920	-	220	10,500
Maryland......	4,610	2,550	-	-	-	10,400	7,880	-	190	25,600
Massachusetts.	-	520	-	-	-	13,100	6,680	-	10	20,300
Michigan......	560	6,700	4,800	4,770	-	40,500	33,200	-	8,980	99,500
Minnesota.....	-	560	-	80,300	-	28,400	3,880	-	23,100	136,000
Mississippi...	-	3,500	-	-	-	6,510	710	-	-	10,700
Missouri......	33,500	8,790	-	520	-	9,550	22,600	-	27,400	102,000
Montana.......	6,820	300	10,900	10	2,660	12,300	3,310	5	6,500	42,800
Nebraska......	-	500	-	-	-	9,820	2,510	-	20	12,800
Nevada........	-	30	12,800	540	-	5,830	1,360	10	20,600	41,100
New Hampshire.	-	130	-	-	-	4,760	210	-	200	5,300
New Jersey....	-	2,100	-	630	-	12,600	9,880	-	3,170	28,400
New Mexico....	8,260	230	13,000	30	-	6,950	1,690	6,670	11,000	47,800
New York......	-	4,670	-	1,830	-	30,600	28,300	-	30,900	96,300
North Carolina	-	8,200	-	5	190	8,790	14,800	-	4,670	36,600
North Dakota..	27,200	140	-	-	-	7,540	100	20	10	35,100
Ohio..........	207,000	17,300	-	-	-	31,300	35,500	-	860	292,000
Oklahoma......	13,800	2,370	340	-	-	4,810	11,700	-	2,490	35,500
Oregon........	20	830	10	-	-	14,000	12,100	20	7,110	34,000
Pennsylvania..	247,000	11,700	-	770	-	16,500	6,260	-	98,300	381,000
Rhode Island..	-	-	-	-	-	1,550	420	-	370	2,330
South Carolina	-	4,800	-	-	-	3,090	5,540	-	1,100	14,500
South Dakota..	310	940	-	5	-	11,400	2,220	260	1,320	16,500
Tennessee.....	17,900	4,420	940	20	16,200	6,420	19,100	-	2,850	67,800
Texas.........	770	11,600	5	1,010	-	27,400	28,800	240	8,130	78,000
Utah..........	3,220	840	38,900	3,310	1,530	8,990	2,560	20	7,340	66,700
Vermont.......	-	40	200	-	-	1,960	1,410	-	3,780	7,380
Virginia......	34,800	3,560	5	10	10	9,100	20,800	-	10,500	78,800
Washington....	1,370	890	110	5	-	20,500	10,400	350	2,330	35,900
West Virginia.	196,000	1,230	-	-	-	5,230	7,640	-	70	210,000
Wisconsin.....	-	440	-	1,740	-	29,900	14,000	-	810	46,900
Wyoming.......	10,100	3,900	-	1,430	650	5,640	1,850	4,300	440	28,300
Total[2]...	1,470,000	167,000	166,000	108,000	77,300	660,000	516,000	12,800	480,000	3,650,000

[1] Includes area of surface mine excavation, area used for disposal of surface mine waste, surface area subsided or disturbed as a result of underground workings, surface area used for disposal of underground waste, and surface area used for disposal of mill or processing waste.

[2] Data may not add to totals shown because of independent rounding.

SOURCE: Paone and others (1974).

TABLE 2.7 Acreage Disturbed by Non-Coal Surface Mining Ranked by State and by Relative Disturbance

Acreage Disturbed by Non-Coal Surface Mining, 1930-1971			Relative Disturbance			
Thousands	Rank	State	Rank	Index	Pop. per sq. mi. (1970)	Acres per 10,000
227	1	California	7	3.72	128	23
136	2	Minnesota	10	1.63	48	27
134	3	Pennsylvania	1	15.66	262	47
102	4	Arizona	14	0.28	16	14
99	5	Michigan	4	5.33	156	27
96	6	New York	2	14.98	381	31
89	7	Florida	6	4.13	126	26
85	8	Ohio	3	10.56	260	32
77	9	Texas	15	0.24	43	5
63	10	Utah	16	0.19	13	12
63	11	Illinois	5	4.53	199	18
50	12	Tennessee	8	2.29	95	19
50	13	Wisconsin	9	1.70	81	14
47	14	Iowa	12	0.83	51	13
41	15	Idaho	18	0.09	9	8
41	16	Nevada	20	0.03	4	6
40	17	Colorado	17	0.16	21	6
40	18	New Mexico	19	0.05	8	5
36	19	Montana	21	0.02	5	4
34	20	Georgia	11	1.15	79	9
25	21	Washington	13	0.36	51	6
18	21	Wyoming	22	0.01	3	3
2187	-	U.S.	-	1.00	69	12

States with largest acreage disturbed by non-coal surface mining compared in terms of percentage of state land area disturbed and average state population density. "Indices of disturbance" = (% of land area disturbed) x (average population density) adjusted so index for U.S. as a whole is 1.

SOURCE: Paone et al (1974); U.S. Department of Commerce, 1978.

frequently have been put to some other use without formal reclamation by the mine operator.

About 2.1 million acres of the total U.S. land mass of 2.3 billion acres, including Alaska and Hawaii, were used in the non-coal mining industry, and 1.6 million additional acres were used in coal mining. If processing plants, other surface facilities, and roads were added, the total for all mining would increase by an estimated maximum of about 5 to 10 percent, to a total of about 3.9 to 4.1 million acres. By comparison, built-up urban areas comprise 69 million acres, airports and railroads each use 3 million acres, and the primary road system has 21 million acres in right of way, with 8 million acres paved.

Sand and gravel, stone, and clay account for use of 1.3 million acres, equivalent to 60 percent of the total land use for non-coal mining. Land use estimates as of 1977 or 1978 were developed by COSMAR for several commodities from diverse information sources. The State of Minnesota found 60,000 acres in use for iron mining in 1969, and an increase to 71,000 or 72,000 acres in 1975. An estimate of land now in use for iron mining in Minnesota is 80,000 acres--the same as shown in Table 2.6. For strip-mining of phosphate land in Florida, the 48,000 acres in the table increased to 166,000 acres disturbed through 1977. The current stripping rate is about 6,000 acres a year. About 35,000 acres of the phosphate lands have been reclaimed. For uranium mining the total disturbed land in all States has increased from 13,000 acres (Table 2.6) to between 40,000 and 70,000 acres. Land disturbed by bentonite mining in Wyoming, including haulage roads, is estimated at 50,000 to 60,000 acres.

If the surface (1.9 billion acres) of the 48 contiguous States were divided into 10,000 acre sections, surface mining would disturb an average of 12 acres of each section. However, the mine workings comprise a more significant share of the land within their local environs. For example, by 1990 the disturbed area along the Mesabi Iron Range will be equal to about one percent of the 12,000-square-mile commuting area that defines the functional "neighborhood" surrounding the Range (Brown and others 1976, Minnesota State Planning Agency 1978). The share disturbed by mining (mainly tailings) will reach several times its present level by the year 2200. Meanwhile, the share of the same district devoted to urban uses today is about 0.14 percent, and that could rise to one percent by the year 2200. In the seven-county phosphate mining area of central Florida, the phosphate pits together with all other quarries had disturbed about 3.12 percent of the total area by 1975, compared with about 9 percent devoted to urban structures and grounds, and about 22 percent in forest, water surface, or wetland habitat (Texas Instruments, Inc. 1977). Similar impacts on regional land use patterns are observed with surface mines of clays and bauxite, construction materials, uranium, and, potentially, oil shale (Paone and others 1974, unpublished information from DOE, and Working Paper VIII).

Non-coal surface mining is set within a great variety of State and local land use conditions. Twenty-two States contain more than 18,000 acres of land disturbed by non-coal surface mining since 1930 (Table 2.7). The area disturbed ranges from 227,000 acres in California to 18,000 in Wyoming. But there are great differences among those States in other respects--notably the total land area of the State and the density of settlement.

The share of total land area which has been disturbed by mining operations varies among different States by an order of magnitude; from 47 acres per 10,000 in Pennsylvania to 4.6 per 10,000 in Texas, from 23 acres per 10,000 in California to 2.8 in Wyoming. There are even greater differences in the population density of these States. The result is an understandably great difference in the perception of problems associated with surface mining--which problems are emphasized, how much, and by whom.

2.3.1.1 Land Uses: Duration, Extent, and Conflicts

There are further differences between States in terms of the geographical localization of mining activity and its duration. In part, the lifetime of a mining operation in any given locality is determined by the demand for the commodity. But it is also dictated by the geological occurrence of the mineral deposit. Even for a commodity with a large, sustained level of demand, the duration of mining at any given location may be relatively short if the deposits tend to be thin, flat-lying, and either extensive or discontinuous. If they are deep and numerous, duration may be relatively long. For example, although Minnesota, Illinois, and Florida have similar percentages of their total land area disturbed by non-coal surface mining, 70 percent of the disturbed area in Minnesota is concentrated on 1/4 of 1 percent of the State's local land area, on the Mesabi Range. And that is in a forest region sparsely populated except for the settlements of people who operate the iron mines. The geographical extent of the surface mining zone is constrained by the geological extent of the iron formation. Although mining has continued there for nearly a century and may well continue for two centuries more, it can only increase in concentration and depth within essentially the same district. Meanwhile, market forces have been gradually separating the rest of the urban settlements from the mines and processing plants (see Working Paper V).

In contrast, surface mining disturbance in Illinois and Florida is associated with the recovery of widespread, shallow, relatively thin deposits of sand, gravel, sedimentary bedrock, or phosphate pebbles. Continuing demand and long-term production means exhausting the deposits in one locality and shifting laterally to the next. The area of exploitation becomes wider rather than deeper. In Illinois, the deposits generally underlie prime farm land; in Florida they commonly underlie potential cropland or residential land.

Thus, there are widely differing degrees and types of conflict between surface mining and wildlife habitat, agriculture, forest, residential, commercial, and industrial land uses.

2.3.1.2 Problem of Conversion to New Land Uses

Some kinds of surface mining leave behind land more difficult either to prepare for new uses or restore to old uses than almost any other type of current development. As a result, while future reclamation is not a problem unique to mining, it is an especially difficult one. Reclamation of non-coal surface mines is still relatively limited, but activity is increasing rapidly as State laws come into effect. About one-fourth of the disturbed lands from non-coal surface mining have been the subject of some kind of reclamation, compared with two-thirds of the area disturbed by coal surface mines (Paone and others 1974), but most non-coal surface mines have a much longer life span than surface coal mines, and final reclamation cannot be achieved until the mining operation ceases (see Section 2.3.1). Interim partial reclamation is possible, however (Section 3.5). The nature and amount of reclamation varies greatly among different regions, commodities, and companies. For example, an estimated 21 percent of the land disturbed by phosphate mining on the southeastern coastal plains has been subject to reclamation (see Working Paper II). In the Lake Superior iron mining region, active revegetation programs, mainly on taconite tailings deposits, account for perhaps 3 to 6 percent of the total disturbed area. But natural revegetation and flooding of abandoned or inactive mines accounts for 60 percent of the disturbed land (see Working Paper V). Generally, across the country, reclamation programs are scattered. Documentation is far from complete, and most experience is still limited.

There is a wide range of demand for land in the disturbed areas. The Lake Superior region, Illinois, and Florida again provide examples. In the northern Great Lakes area, there is a potential demand for recreational lakes developed from flooded abandoned pits and timber land from reforestation of extensive tailings basins. Those demands will not sustain high reclamation costs. In the agricultural heartland of the Midwest there is always a demand for prime crop land. But there is also desire for "islands" of rough, wooded land, with scattered ponds, for residential development; and such areas may well substitute for other residential subdivisions that are displacing farm crops from prime cropland. In central Florida, rapid growth of both urban population and agriculture leads to great pressure to re-use the land or hold it as wildlife habitat and public open space. Demands there are likely to sustain higher reclamation costs.

Thus, there are great variations in the inherent local and regional pressure for reclamation. One basic question in the future is likely to be when to avoid mining a given deposit in deference to a foreseeable high-priority competing land use, in order to avoid expensive reclamation. A second basic question will be what geologic areas should be zoned exclusively for mineral development to avoid conflicting interim development and needless future expenditures to convert the land for mining. A third basic question will be what type of reclamation is best to meet probable future demands for land in any given region of the country. These questions are addressed in Chapter 4.

2.3.1.3 Diverse Ownership

There is a great diversity of land ownership patterns among the different surface mining districts. Conditions range from the roughly even distribution among the State, the mining companies, and hundreds of private fee owners in the Minnesota Iron Range (see Working Paper V) to the virtually exclusive operation on claims under the 1872 Mining Law in some districts of the West. As for uranium lands, 57 percent of them operate under 1872 Mining Law claims, 22 percent are leased from private owners, 17 percent are leased from the States, 1 percent operate under Federal leases, and 3 percent operate under Indian land leases (unpublished information from DOE). Of the total 730 million acres of Federal lands administered by civilian agencies, about a fourth (188 million acres) are administered by the Forest Service, and about five-eighths (470 million acres) are administered by the Bureau of Land Management (BLM). Much of the Forest Service and BLM lands are available for mining. Thus, there is a wide range of potential participants in the process of planning and management of mineral resources.

2.3.1.4 Exploration

Effects of mineral exploration on land use and landscape are principally those from access roads, drill pads, and the small excavation, typically 2 x 6 x 4 feet deep, made to hold drilling fluid. If initial prospecting is favorable, more extensive drilling, tunnelling, or shaft sinking may be done to delineate the ore body, investigate mining methods, and obtain samples for metallurgical testing. Shaft sinking and tunnelling would have effects similar to those from small mining operations.

The land and associated vegetation disturbed by a single drill site amounts to about half an acre. Because a level surface is needed, scraping may be required on sloping ground. Activity at a site may continue from 1 to 30 days. At the conclusion of drilling, Forest Service and some State regulations require that the hole be plugged in a way that prevents mingling of water from different aquifers if more than one aquifer was penetrated. Access road and drill pad reclamation requirements vary for the Forest Service and States that stipulate reclamation. Scars are largely self-sealing in many areas, but may be long-lasting on alpine, desert, and tundra terrain.

The BLM has yet to promulgate regulations for control of surface disturbance while prospecting for minerals under the 1872 Mining Law.

Tables 2.8 and 2.9 show the number of feet of exploration by method, commodity, and State. Data shown for uranium exploration are not valid, because they are based on only a partial survey. Of the total 3.8 million feet explored for gold, 2.8 million feet were done by percussion drilling in South Dakota. Only 67,000 feet were trenched, and about half of that was done for gold in Nevada.

Exploration drilling (not including development drilling) for uranium as reported by DOE (Chenoweth 1978) amounted to 20.4 million feet in 1976 and 28 million additional feet in 1977. The average hole depth was 506 feet in 1976 and 436 feet in 1977; 40,000 holes were drilled in 1976 and 64,000 in 1977.

In the early 1950s, considerable bulldozing was done in search of uranium outcrops along canyon rims in Colorado and Utah. Bulldozers were also used to cut the 10-cubic-feet discovery pits required for each claim under State mining laws for the establishment of mineral discovery. A drill hole 50 feet deep now is accepted for mineral discovery by all States in validating claims on Federal lands, but visual evidence remains of the thousands of pits dug or bulldozed to meet the earlier requirements of the mining laws. Unless specifically prohibited under terms of a prospecting or mining permit, bulldozing may still be done for prospecting and claim validation on Federal lands.

TABLE 2.8 Exploration and Development in 1976, by Method and Selected Metals and Non-Metals (feet)

Commodity	Development				Exploration						
	Shaft and winze sinking	Raising	Drifting, cross-cutting, or tunneling	Total[1]	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other drilling	Trenching	Total[1]
METALS											
Bauxite	--	--	--	--	--	--	31,500	--	64,900	--	96,400
Copper	10,200	64,700	116,000	191,000	561,000	515	75,900	30,500	206	4,390	673,000
Gold	1,130	12,700	47,800	61,600	154,000	1,320	105,000	2,790,090	7,000	36,000	3,090,000
Iron ore	--	329	66,000	66,900	46,500	--	14,200	28,300	1,570	--	90,600
Lead	397	5,020	56,700	62,100	198,000	34,600	--	22,200	99,200	176	354,000
Molybdenum	--	W	W	W	137,000	--	16,400	--	--	--	153,000
Nickel	--	--	--	--	11,100	--	--	--	--	--	11,100
Silver	370	6,040	18,300	22,700	83,700	--	5,920	28,300	3,100	7,850	126,000
Tungsten	75	1,710	21,400	23,100	--	--	--	1,280	--	150	1,430
Uranium	6,540	30,200	392,000	429,000	143,000	--	7,390,000	798,000	144,000	10,800	8,430,000
Zinc	2,680	15,200	85,700	104,000	329,000	--	61,200	97,800	378	260	489,000
Other[2]	--	8,460	50,800	59,800	18,300	--	17,100	--	30,900	3,500	69,800
Total[1]	21,400	144,000	858,000	1,020,000	1,680,000	36,400	7,710,000	3,790,000	352,000	62,100	13,600,000
NONMETALS											
Barite	W	W	--	W	--	--	26,000	3,050	--	3,500	32,600
Boron minerals	--	--	--	--	2,200	--	38,900	--	--	--	41,100
Clays	--	--	--	--	126	--	5,560	--	783	--	6,470
Fluorspar	--	1,550	4,100	5,650	305,000	--	--	--	2,590	--	308,000
Gypsum	305	--	365	670	--	--	--	--	--	--	--
Phosphate rock	--	110	7,100	7,210	5,870	--	342,000	--	--	1,100	348,000
Sodium carbonate (natural)	--	--	W	W	6,830	--	109,000	--	--	--	116,000
Other[3]	15,000	1,162	532,000	548,000	31,400		13,800	2,770		185	58,200
Total[1]	15,900	2,820	544,000	562,000	351,000	--	540,000	5,820	3,380	4,790	905,000
Grand total[1]	36,700	147,000	1,400,000	1,580,000	2,030,000	36,400	8,250,000	3,800,000	355,000	66,900	14,500,000

W Withheld to avoid disclosing individual company confidential data; included with "Other."

[1] Data may not add to totals shown because of independent rounding.

[2] Antimony, beryllium, columbium and tantalum, rare-earth metals, tin, and titanium (ilmenite).

[3] Asbestos, mica (scrap), potassium salts, salt, stone (crushed and broken), stone (dimension), talc, soapstone, pyrophyllite, tripoli, and wollastonite.

SOURCE: U.S. Bureau of Mines (1976).

TABLE 2.9 Exploration and Development in 1976, by Method and State (feet)

State	Development				Exploration						
	Shaft and winze sinking	Raising	Drifting, cross-cutting, or tunneling	Total[1]	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other drilling	Trenching	Total[1]
Alaska	--	--	24	24	27,800	126	--	580	70	7,760	36,300
Arizona	271	64,200	100,000	165,000	162,000	--	47,200	5,800	--	7,020	222,000
Arkansas	--	--	--	--	610	--	31,500	--	--	--	32,100
California	15,000	3,480	7,030	25,500	4,980	1,020	55,400	35	96	924	62,400
Colorado	999	19,200	104,000	124,000	152,000	--	1,340,000	138,000	4,210	535	1,630,000
Florida	--	--	--	--	--	--	272,000	--	--	--	272,000
Georgia	--	--	--	--	1,210	--	8,300	--	--	--	9,510
Idaho	791	6,970	32,000	39,700	56,600	--	18,700	1,700	1,320	610	79,000
Illinois	--	1,400	4,100	5,500	152,000	--	--	--	--	--	152,000
Kentucky	--	--	--	--	85,500	--	--	--	--	--	85,500
Maine	--	--	W	W	8,670	--	--	--	--	--	8,670
Michigan	305	--	13,000	13,300	81,100	--	2,940	--	--	--	84,000
Minnesota	--	--	--	--	31,300	--	1,360	229	783	--	33,700
Missouri	--	359	80,100	80,500	188,000	34,600	27,300	39,500	99,200	1,400	390,000
Montana	35	450	10,100	10,500	66,300	515	312,000	2,800	--	630	383,000
Nevada	2,790	1,140	24,100	28,000	63,600	180	52,400	41,600	5,540	31,700	195,000
New Mexico	4,590	15,300	298,000	318,000	249,000	--	1,570,000	640,000	136,000	4,900	2,600,000
New York	--	7,260	36,400	43,600	83,400	--	--	--	--	--	83,400
Oregon	--	170	2,550	2,720	14,700	--	9,350	12,200	4,000	1,000	41,300
South Dakota	W	W	W	W	73,900	--	713,000	2,760,000	--	--	3,540,000
Tennessee	2,160	2,690	31,200	36,000	266,000	--	51,000	88,500	--	--	405,000
Texas	--	--	--	--	--	--	122,000	--	--	--	122,000
Utah	8,470	8,100	40,800	56,900	62,300	--	411,000	55,600	6,090	10,300	546,000
Wisconsin	--	--	--	--	27,300	--	18,500	--	--	--	45,800
Wyoming	1,150	3,410	557,000	562,000	39,800	--	2,850,000	2,000	--	--	2,890,000
Undistributed[2]	164	13,000	56,000	69,200	136,000	--	340,000	9,980	97,300	125	584,000
Total[1]	36,700	147,000	1,400,000	1,580,000	2,030,000	36,400	8,250,000	3,800,000	355,000	66,900	14,500,000

W Withheld to avoid disclosing individual company confidential data; included in "Undistributed."

[1] Data may not add to totals shown because of independent rounding.

[2] Alabama, Kansas, North Carolina, Oklahoma, Pennsylvania, South Carolina, Vermont, Virginia, Washington, and items indicated by symbol W.

SOURCE: U.S. Bureau of Mines (1976).

To facilitate access to favorable uranium areas, an extensive road net was built in the 1950s by the U.S. Atomic Energy Commission (AEC) and by industry under a Federal program. The AEC sponsored construction of 1,253 miles of road on 90 projects in Arizona, Colorado, New Mexico, South Dakota, Utah, and Wyoming. The miles of access and secondary roads built by industry is unknown, but could be more than the miles built by the government. In each producing area, one or more of these roads have become haul roads. Reclamation of unused roads has not been practiced, but some of the roads are in active mining areas.

2.3.1.5 Surface Mining

Effects of surface mining on land use and landscape vary widely with the terrain; ore-body depth, size, and shape; and waste-to-ore ratio. Removal of overburden and waste rock to expose the ore body and maintain safe pit slopes requires surface storage or disposal of soil and mine waste. Vegetation is destroyed in the pit, storage and disposal areas, and also in areas in which support facilities are erected. Occasionally, as in sequential mining of contiguous ore bodies, a worked-out pit may be conveniently available for storage of waste from an operating pit. Still, even with contiguous ore bodies, sequential pit opening may not be feasible, because necessity for ore-grade control and resource conservation requires mining from selected parts of one or several bodies simultaneously. Such blending requirements are common in mining of beryllium, clay, cement rock, and uranium.

For some minerals--copper, gold, and uranium, for example--leaching of selected waste dumps for recovery of low-grade values may be economical. Individual copper-waste dumps being leached exceed hundreds of millions of tons in size. About 2 billion tons are available for leaching at the Bingham pit in Utah. Leaching of copper waste dumps may continue for decades. It is usually conducted by repetitive, alternate cycles of solution percolation, followed by air oxidation. More waste commonly is added to the leach piles when metal extraction declines (Sheffer and Evans 1968).

All, or almost all, of the material excavated from stone quarries, sand and gravel pits, and certain clay pits, is sold as product. Still, substantial waste piles occur on the surface in some areas, with resultant alteration of scenic views. The operation may have a life of decades, and on completion leaves a hole with steep sides, and, frequently, water at the bottom. Such pits have been used beneficially for water supply; ground-water recharge; flood control; wild life habitat; waste disposal; and sites for industry, business, and housing. Unreclaimed, unused, and untended pits may be eyesores and "attractive nuisances."

Strip-mining by successive cuts, analogous to coal strip mining, has been practiced on red-bed copper ore in Oklahoma and on land-pebble phosphate in Florida and North Carolina. Filling of the excavated cut is followed by grading and vegetation.

Some State regulations require certain pits to be filled or pit walls to be graded and revegetated where appropriate. Lands that have been mined for kaolin in Georgia are generally returned to a rolling topography similar to premining topography and are subsequently revegetated. Shallow bentonite clay pits in Wyoming are now required to be filled and vegetated.

Reclamation of bentonite clay pits in Wyoming by filling, contouring, restoring surface soil, and revegetating, as required by State law since 1972, has had varying degrees of success. Generally vegetation has been reestablished in areas that are underlain with relatively coarse shales and have 10 inches or more of precipitation annually. The permeability of such shales appears to overcome the adverse effects on vegetation of high sodium content in the overlaying clay. Lack of drainage through the impermeable clays in the bentonite region results in a white efflorescence of sodium salts on the surface of disturbed lands.

Grading and vegetation of the amenable completed waste piles are becoming more common. Waste piles containing sulfide minerals, and piles in arid areas, are often difficult to vegetate. Numerous test programs to perfect vegetation techniques are active (Anderson and others 1976, Colorado State University 1976, Sorensen and others 1975, Donovan and others 1976, Keiley 1979).

Spillage and dust from haul trucks, if not suitably covered, may fringe the roads with scattered crude ores. Evidence of past spillage by trucks hauling uranium ore is indicated by weak radioactive anomalies along the haul roads. Truck spillage is a cause of complaints about sand, gravel, and stone producers in metropolitan areas.

2.3.1.6 Underground Mining

The principal effect of underground mining on the land surface, aside from destruction of vegetation and alteration of the terrain by roads, support facilities, and mine waste storage, is surface subsidence. Collapse of the surface may be part of a planned block-caving mining system, or may occur during or after completion of mining because of failure of underground support. Subsidence that occurs in mountainous or rugged terrain, such as that at Climax, Colorado and San Manuel, Arizona is less defacing than subsidence in level terrain. Some roads and structures have been damaged by subsidence. Procedures to cope with this damaging and disfiguring phenomenon need to be developed (letter and attachments to James Boyd from L. Lewis, Mining Investment and Local Impact Fund Board, State of Wisconsin, May 21, 1979).

2.3.1.7 In Situ and Solution Mining

The main surface effects of in situ and solution mining are disturbance by access roads, processing and support facilities, ponds for salt crystallization and recovery, storage piles for product (salts and sulfur), and disposal piles for waste salts. Damaging subsidence has been known to occur in agricultural and residential areas overlying solution-mined salt and Frasch-mined sulfur deposits. Methods for preventing or coping with such subsidence need to be developed.

One of the procedures proposed for shale oil recovery is "modified in situ retorting." This provides for removal of 20 to 30 percent of the shale by underground mining, and subsequent surface storage or retorting of the mined shale. Such extensive surface storage could become a dominant terrain feature.

2.3.1.8 Mine-Site Processing

Tailings impoundment is the major use of land associated with ore processing. Water or leach solution, used in transporting the tailings to the disposal area, often is recovered for reuse in the mill. Where operations are prolonged for decades, vertical growth and lateral spread of accumulated tailings may result in a conspicuous terrain feature.

In copper ore milling at typical concentration ratios of between 15:1 and 30:1, from 14 to 29 tons of tailings are discarded for every ton of copper concentrate produced. In milling 256 million tons of copper ore in 1976, about 245 million tons of tailings were discarded. Tailings impoundments at major open-pit copper operations now total about 50,000 acres. This compares with about 30,000 acres in waste dumps, which usually have a greater height than tailings ponds, and 13,000 acres in pit excavation.

In milling 243 million tons of iron ore in 1976, about 160 million tons of tailings were produced. Active iron tailings in Minnesota cover about 20,000 acres (31 square miles) compared with 10,000 acres of active mine pits.

In milling 9 million tons of uranium ore in 1976, over 8 million tons of tailings were impounded at 17 active sites. By 1978 there were 20 active sites covering about 3,000 acres. Environmental and health hazards from past and future uranium mill tailings and their mitigation are comprehensively reviewed in a report by the Western Interstate Nuclear Board (1977). The report shows 134 million tons of uranium tailings at 16 operating mills, 23 inactive sites, and 3 stand-by mills. The area covered by inactive tailings piles is estimated at about 1,200 acres. Additionally, 2,000 to 4,000 acres have been contaminated to some extent by low-level radioactive ore and wastes at mill sites and ore-storage areas.

In October 1978, Congress authorized DOE to clean up all the inactive tailings piles. The Federal government would pay 90 percent of the total cost, estimated at $140 million, with the States that contain the tailings paying the other 10 percent of the cost. Tailings at four sites on Indian lands would be cleaned up without charge to the tribes. Current Nuclear Regulatory Commission requirements for tailings management are intended to internalize the reclamation cost to the operator (Martin 1978).

To reduce erosion and improve appearance, the sloping sides of active tailings impoundments are frequently vegetated. A network of ditches may be needed above the impoundment to intercept and divert surface drainage.

Most mill tailings are composed of finely ground rock or chemical precipitates that, when dry, are readily airborne. A prominent exception is oil shale retort residues, which vary from fine particles to chunks as large as 3 inches. Most tailings lack the nutrients and micro-organisms needed to sustain vegetative growth. Almost every mill tailing has its singular disposal or future land use problem. Some typical examples follow.

Bauxite (Bayer Process)--Tailings or "red mud" are generated and stored at two mine-site operations in Arkansas, and at a number of plants elsewhere in the United States that treat imported ore. Solid particles are of ultra-fine size and the accompanying waste solution is highly alkaline. Suitable technology for dewatering and vegetating the muds remains to be developed (Parekh and Goldberger 1976).

Copper--Tailings from large mills may occupy an area of many square miles. Water accompanying the tailings is initially alkaline, but long-term weathering converts sulfide minerals in the tailings to sulfates and sulfuric acid. Subsequent vegetation of such surfaces, especially in the arid West, has had indifferent success (Brown 1976, Nielson and Peterson 1972).

Iron Ore (taconite)--Tailings from large mills in Minnesota and Michigan occupy about 40 square miles. Unlike copper tailings, they contain no acid-forming sulfides, and hence are more amenable to revegetation. Disposal of tailings by Reserve Mining Company into Lake Superior at Silver Bay was halted by court order in 1974 because of possible water pollution. The Company now stores its tailings on land (Weston 1971, Weston and Woldman 1971, Rowell 1977).

Lead-Zinc-Copper--Tailings from ore mined underground in southeastern Missouri differ markedly from the copper tailings of the West in being composed principally of limestone rather than of silicate minerals. The sand fraction of the Missouri tailings frequently is sold to meet local demand for agricultural limestone.

Oil Shale--Retort residue occupies about 25 percent more volume than oil shale in the ground because the shale expands when fragmented and heated. Hence, the mine's void space, even if filling is feasible, could not hold all the retort residue. Large permanent storage areas near the retorts will be required to accommodate the residue from production of oil from oil shale in surface retorts (Harbert and Berg 1978).

Phosphate--Clay tailings in Florida and North Carolina swell when wetted and tenaciously retain the absorbed water. Wet slimes must be stored for many years in large settling areas surrounded by earthen dams about 40 feet high before enough drying takes place to permit vegetation of the slime pond surface or other activity. Recent cooperative research by the USBM and the industry has developed new approaches that may be useful in accelerating the dewatering of the slimes (Stanczyk and others 1971, Terichow and others 1975, Moudgil 1976, Osford and Bromwell 1977); see Section 3.4.4.3.

Potash--Tailings discarded by beneficiation plants in New Mexico are a mixture of common salt (sodium chloride) and clay. Separation of the potash salt from the waste constituents in the underground mined ore takes place in a saturated brine solution. Waste-salt piles and brine ponds occupy several thousand acres of surface area. Because ground and surface waters in the potash area of New Mexico are naturally saline, contamination from waste salt and brine is not apparent. Leakage of salt solution into the Colorado River from salt tailings piles at Moab, Utah, has not been detected. A major rainstorm, coupled with failure of protective dikes, could wash salt into the river.

2.3.2 Effects of Mining on Water

Degradation of water quality is a pervasive and persistent environmental effect of many mining operations. The potential for damage is particularly severe in the mining and processing of ores that contain sulfide components subject to oxidation and solubilization. Growth in uranium ore mining and milling has increased the potential for water contamination by radioactive and heavy metal nuclei. Inactive underground mines in particular may cause water contamination, but many do not. Water pollution from mining and control procedures are comprehensively reviewed by the U.S. Environmental Protection Agency (1973). Although the report is regionally oriented to coal mining in the East, extensive coverage of metal and non-metal mining in all parts of the United States is included.

2.3.2.1 Exploration

Extensive drilling for uranium in the Rocky Mountain States during the 1950s and 1960s, much of which was done without sealing off discrete aquifers, probably resulted in mingling of ground waters. Information on the extent of mixing and on adverse effects is lacking. Boreholes, improperly plugged in the vicinity of underground mines, are potential sources of water entry that may contribute to pollution from mine drainage, especially after active mining has ceased. Inter-aquifer communication caused by drilling and mining may be difficult to distinguish from that created by natural fractures.

Water siltation resulting from accelerated erosion is commonly correlative with destruction of vegetation and with soil disturbance when roads or support facilities are provided for any phase of mineral production.

2.3.2.2 Surface Mining

In the humid East, where construction material pits and quarries abound, water pumped from the pits has been troublesome in the past, but removal of contaminated silt before discharge is now widely practiced. Most process water used by the construction minerals industry is now recycled and hence does not enter local drainage systems. Iron ore mining and use of process water have had little effect on water quality and availability in the Lake Superior district, but water supplies could become short in the next century (Section 5.2.3). Phosphate mine dewatering and process use of water has lowered the regional water table in Florida by 40 feet, with some disruption of water courses, destruction of wetlands, and water quality deterioration. In the arid West, most pits accumulate little or no water. Small flows may be used in sprinkling for dust control, or pumped outside the pit for dissipation by evaporation, or added to the water used in milling of ore. Dewatering of a surface mine lowers the water table sometimes to the detriment of other water users. In arid regions the flow of springs and streams, surface vegetation, fish, and wildlife may be adversely affected by lowering of the water table. (Dames and Moore 1976; U.S. Environmental Protection Agency 1971, 1975b; Hallowell and others 1973a, 1973b; Hird 1971a, 1971b; Jarrett and Kirby 1978; Kaufmann and Bliss 1977; Mohammad 1977; National Enforcement Investigations Center 1975; Scott and Hays 1975; U.S. Geological Survey 1977; Wilson 1977).

Because of the virtual absence of sulfides and soluble salts in deposits of construction materials, water discharged from those pits contains no significant concentrations of dissolved heavy metals or other noxious constituents. Desilting by settling in retaining ponds, usually in the pit, is required by Federal law before discharging to public waters (U.S. Environmental Protection Agency 1975a). However, water discharged from sulfide metal or uranium ore pits, or that drains from associated surface waste piles, may contain heavy metals, diverse salts, and radioactive components. Regulations require that such contaminated waste waters be suitably purified before discharge to public streams. Ground-water contamination from waste dump and pit drainage appears possible, depending on the local hydrology and terrain.

2.3.2.3 Underground Mining

Labyrinthine openings in underground mines, with extensive exposure of ore and wall rock to an oxidizing and humid atmosphere, promotes the formation of acids and solubilization of metals and chemicals. In current practice, active-mine water-treatment stops and the control procedures to limit water entry may fail when active mining ends. Subsidence that may occur long after mining ceases may provide new sources of water entry into the mine. Unless prevented by appropriate mine design, operating practice, and closure procedure, gravity drainage of contaminated mine waters may damage surface and underground waters. The extent of ground-water pollution from active and inactive underground mines is largely unknown.

Dewatering of underground mines in preparation for and during mining tends to lower the area water table with the same adverse effects as those caused by dewatering of surface mines (Scott and Hayes 1975; Bolter and Tibbs 1970, 1971; U.S. Environmental Protection Agency 1972; Gries and Rafn 1974; Mink and others 1971; Mohammad 1977; Norbeck and others 1974; Proctor and Sinha 1978; U.S. Geological Survey

1976; U.S. Department of the Interior 1974; Wilson 1977; Wixson and Chen 1970).

2.3.2.4 In Situ and Solution Mining

Uranium is produced by in situ leaching from a number of operations in Texas and Wyoming. Leaching is done with an oxidizing, alkaline solution. The use of oxidizing sulfuric acid solutions is being contemplated for some deposits. Adverse effects on ground water by leakage of uranium-bearing solution from the leach field are possible (see Section 5.2.7.1). State laws require peripheral monitoring wells to warn of escaping leach solution, and require restoration of the aquifer to the pre-mining condition when mining ceases. The technique is still new and little operating experience has been gained. Serious excursions of leach solution have not been recorded to date (Taylor 1979).

Solution mining of evaporite salts and Frasch mining of sulfur are not known to directly damage surface or underground waters. Contaminated bleed water must be controlled by treatment, ponding, and evaporation, or by deep well injection. Because surface subsidence occurs during solution mining of sulfur, hydrologic changes could occur through entry of surface water into the collapsed ground.

In situ retorting of oil shale, proposed to start in the near future, poses a serious threat of ground-water pollution as discussed in Section 3.2.4.1 because of the formation of possibly hazardous compounds in the underground retort.

2.3.2.5 Mine-site Processing

Drainage and seepage from tailings impoundments from milling of metal sulfide and uranium ores may cause surface and ground-water contamination. As described for drainage from underground mines, the potential for damage remains and may be worsened when active operations cease. Current Environmental Protection Agency regulations either allow no overflow of tailings solution, or require treatment for removal of contaminants before releasing the discharge to public waters. Orphaned tailings remain a long-term threat to water quality. Depending on the sealing characteristics of the clays in the tailings and the geologic nature of the impoundment terrain, damaging seepage of tailings solution into the ground water may or may not occur. Ground water moves at variable rates, but exceedingly slowly as compared with surface streams. Pollutants may be removed or added by interaction of ground water with the enclosing strata. Because ground-water data are meager in many localities, little is known about the extent of such damage (Hallowell and others 1973a, 1973b; Kaufman and Bliss 1977; Kaufman and others 1975, 1977); see Section 3.2.3.1.

Stream contamination by accidental discharges of waste solutions and tailings slurry (from failure of retaining dams and breaks in tailings pipes and flumes) occurs sporadically. Some spills, particularly of phosphate slimes and uranium tailings, have been serious.

Slag from copper smelting, often at locations near the mine site, is basically inert, artificial rock that does not affect water quality. The slags are sometimes sold as crushed stone, or retained for future reprocessing. Gypsum residues from acidulation of phosphate concentrate at locations near the mine site are appreciably less radioactive than uranium mill tailings, but disposal procedures should recognize the possible radioactive hazard (Kaufman and Bliss 1977); see Section 5.2.7.2.

2.3.3 Effects of Mining on Air Quality

Dust from roads, mine-waste piles, and pit operation, and exhaust fumes from equipment, vehicular traffic, and truck haulage create nuisances of various degrees. The possibility of air quality being harmed by radon in exhaust air from underground uranium mines, or by wind-blown radon emitted from open-pit ore and waste piles, is being studied by Environmental Protection Agency and DOE. Gaseous emissions from future retorting of oil shale could contain pollutants (Section 3.3.3.1). Smelter emissions from locations near the mine site may contain troublesome quantities of sulfur dioxide (SO_2), lead, arsenic, and other noxious constituents.

Major impacts on air as a result of processing derive from heavy concentrations of wind-blown dust from large tailings impoundments. Such dust can contain heavy metals, which may damage vegetation in the vicinity. The problem is more serious when uranium tailings are involved because of the radioactive nature of the dust and accompanying radon gas. An attempt is made to keep the surface of operational tailings ponds moist, but this is not always possible in hot, dry weather. Nuclear Regulatory Commission regulations require that completed uranium tailings impoundments be covered with sufficient earth to reduce gamma radiation to background level and radon emanation to twice background level. Dust from crushing, grinding, and product drying in mills is generally controlled by collectors and scrubbers.

A relatively minor pollution threat stems from sulfur dioxide (SO_2) emissions by acid manufacturing plants at uranium mills and phosphoric acid plants. The addition of several more plants in the Idaho phosphate area in the next decade or two would probably cause Idaho's air quality standards to be exceeded for SO_2, particulates, and fluorides, unless additional control measures are adopted at the processing plants (Eugene Farmer, U.S. Forest Service, personal communication).

A detailed discussion of air pollution from uranium mining and milling is contained in Assessment of Environmental Aspects of Uranium Mining and Milling (U.S. Environmental Protection Agency 1976). Many of the principles are applicable to other minerals.

2.3.4 Effects of Mining on Fish and Wildlife

Disturbance of wildlife habitat, on and off site, is a common effect of mining. Damage is caused by: the intrusion of man, machines, odor, and noise; destruction of vegetation and other terrestrial habitats; and changes in water flow and in water and air quality. The extent of long-lasting damage depends on the nature of the mining operation and controls. Deterioration of habitat may stem from destruction of wetlands; added sediment from operation of sand, gravel, and placer mines near fish spawning areas; chemical pollution of streams and ground water from mine drainage and process wastes; stream channelization and altered flood drainage; and pollution of air. Tailings ponds may contain toxic solutions and oil scums that are hazards to wildlife, especially migrating water fowl (Blum 1975, Catchpole and Tydeman 1975, Layne and others 1977, Samuel and others 1978, Spaulding and Ogden 1968).

Long-term effects depend on the adequacy of premining planning and operating controls, and on the success of reclamation. After reclamation, an area damaged by mining may show increased carrying capacity for wildlife, especially if revegetated with mixed plant types. Lakes created by surface mining--especially sand and gravel operations--may provide new habitat for water fowl and other aquatic species. A steady increase in the deer and elk population in the vicinity of the Henderson Molybdenum Mine in Colorado is attributed to game management practices that compensate for mining's adverse effects on these species.

2.3.5 Significant Environmental Problems Caused by Mining

A number of mining's adverse effects, identified in the preceding discussion, may pose serious threats to public health and to existing social and environmental systems, unless prevented or substantially mitigated. Such prevention or mitigation is not always possible with the technology on hand (Chapter 3). Furthermore, adequate information often is lacking on the precise nature of the environmental effects and of the harm to human health. Potentially significant environmental and other problems caused by mining were derived from the list of environmental concerns given in Section 2.1. They are listed below, not in order of relative importance.

1. Alteration of surface and ground water by drainage and seepage from active and inactive mines, waste and leach dumps, and mill tailings.

2. Air contamination by radioactive emissions and dust from uranium mill tailings, mines and mills, ore haulage, ore piles, and waste dumps; to a lesser extent, phosphate mining and processing also pose a threat of radioactive contamination.

3. Alteration of ground-water quality caused by boreholes drilled for minerals exploration and development.

4. Difficulty in reclaiming disturbed land, especially by revegetation, because of adverse climatic, physical, or geochemical factors.

5. Disturbance of wetlands and other wildlife habitat by destruction of vegetation, lowering of the water table, and rechanneling of surface waters.

6. Increased stream siltation through accelerated erosion of bare mine slopes and waste dumps and tailings.

7. Adverse social, economic, and aesthetic changes, with resultant adverse effects on lifestyle and outlook, caused by such factors as land use pre-emption, boom towns, visual blight, blasting, and truck haulage.

2.4 ECONOMICS

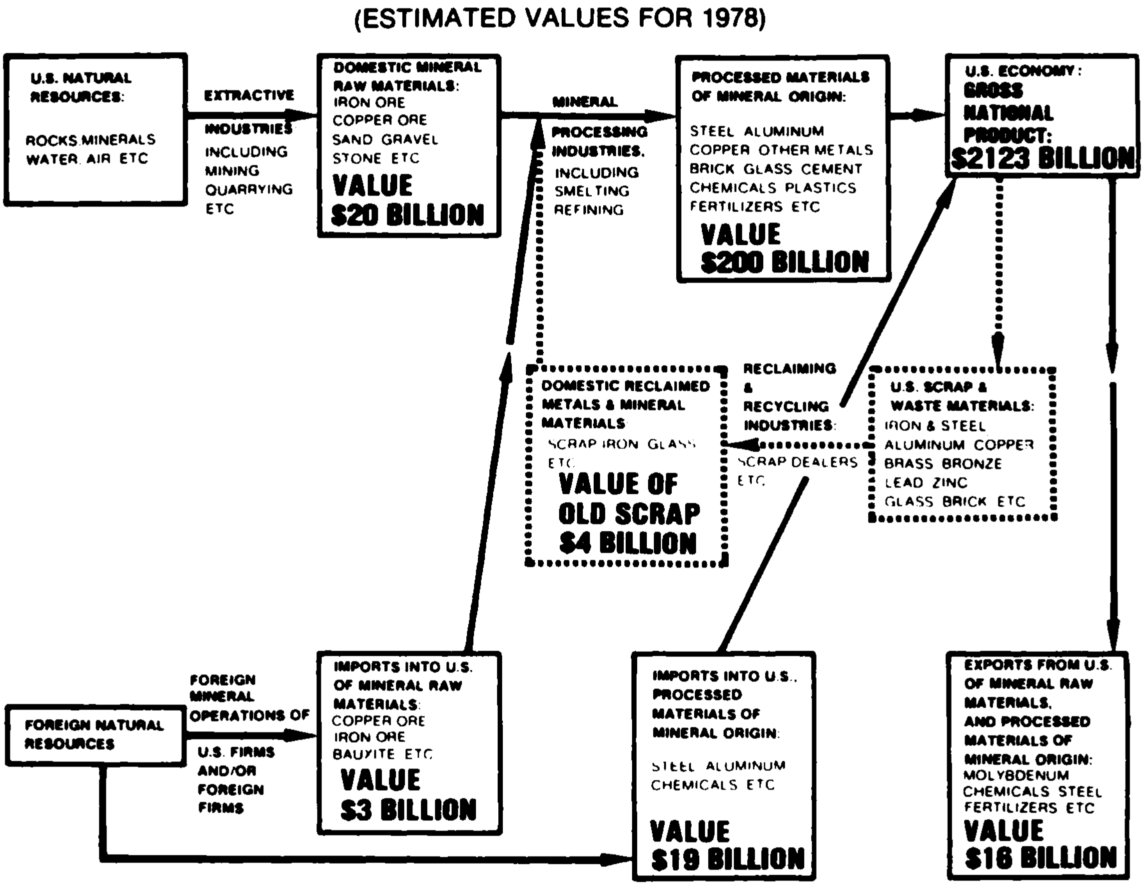
In this section, an approach to economic evaluation of mining and reclamation is described, and an attempt is made to identify costs associated with applying the reclamation requirements in PL 95-87 to non-coal mining. The criterion of economic efficiency is that production or other activities--such as reclamation--be extended to the point where benefits of the last unit of production or activity are equal to their costs. Considerations in mining decisions include the value of the ore deposit, the cost of mining it relative to costs of competing mines, and the rate of return required to attract investment in the operation.

In this section, we assume that the minimum acceptable return is a real rate of 15 percent after accounting for effects of inflation. This rate, which is higher than many other rates of return on investments, such as those on government bonds, reflects the relatively high risk associated with investment in mining.

Comparing marginal benefits and marginal costs is a reliable way to determine an appropriate level of reclamation. As long as marginal benefits of reclamation exceed marginal costs, the additional investment in reclamation and environmental improvement is justified. When marginal benefits no longer exceed marginal costs, further investment in reclamation is no longer economically justified. Although the criterion seems simple and straightforward, it is difficult in practice to measure benefits and costs accurately and to determine the point at which marginal benefits no longer exceed marginal costs.

The task of evaluating economic impact in terms of costs and benefits of any particular set of environmental requirements is beyond the scope of this study, which can only point out some general principles and describe types of analysis needed for a full evaluation. Some economic data are provided on costs of meeting the requirements for reclamation in PL 95-87, but a similar assessment of benefits was not possible because of difficulties in quantification. Benefits are the result of eliminating costs that would have been imposed on the community as a whole in the absence of reclamation. Adverse impacts on community facilities, the environment, and health and safety, and loss of long-term productivity of the land are costs whose prevention can be measured as benefits of reclamation. Benefits, which are described in PL 95-87 and recognized in the enactment of many State reclamation laws, could include the elimination of water pollution related to the mining, the protection of wildlife and fish habitat, and the preservation of aesthetic values. Some of these benefits are quantifiable; others are difficult to quantify. They are described in non-economic terms in Chapters 2, 3, and 5 as problems that would be eliminated by environmental controls of surface mining. The more efficient use of resources that result from planning to meet State and Federal requirements has been termed the "single most important benefit of environmental regulations" (Largarias and Hazard 1979).

The role of the non-fuels mineral industry in the U.S. economy is depicted in Figure 2.5. The value of the nearly 80 minerals (other than coal, oil and gas) that are produced domestically is approximately $20 billion, 1 percent of the Gross National Product (GNP). By comparison, the annual market value of coal alone is about $13 billion. The non-fuel raw materials, when processed for eventual use,



BUREAU OF MINES U.S. DEPARTMENT OF THE INTERIOR (based in part on U.S. Department of Commerce data)

SOURCE: U.S. Bureau of Mines (1979).

FIGURE 2.5 The role of nonfuel minerals in the U.S. economy.

contribute 10 percent or $200 billion to the GNP. When these processed materials eventually find use in agriculture, manufacturing, or commerce, the additional cost of the products and services derived from them represents an even larger portion of the $2 trillion GNP of the United States.

New reclamation regulations would impose direct changes in operating and capital costs on the mining industry, and would add to the final cost of the product. The extent to which cost increases can be "passed on" in the form of higher prices to the consumer depends on the responsiveness of demand to changes in price, the extent of substitution of other materials, and on the extent of competition from foreign producers. If demand is reduced by price increases the result would be reduced output, income, and employment within a specific industry. If demand is not reduced by price increases in a commodity, and consumers of the commodity, as a result, spend more overall in buying it, reduction will be felt in other industries as customers adjust their consumption to their available income. If the increased price results in reduced demand for one commodity, it may be replaced by cheaper products from another industry. Higher costs frequently lead an operator to mine higher grade portions of the ore deposit, leaving lower grade material behind either for future recovery or as lost resources. On the other hand, reclaimed land may have increased economic value that offsets all or part of the reclamation cost.

Rarely can all costs be passed on to the consumer. This is particularly the case if the product is sold in international markets where other producers are not similarly regulated, or if the market itself is regulated by foreign governments and protective measures are not imposed by the U.S. Government. In these cases, increased reclamation costs are likely to reduce domestic capacity and employment, and to increase imports of the cheaper foreign product.

Regulations involving reclamation, by adding to the operating costs, may similarly reduce the quantity of ore that can be economically recovered by increasing the cost of mining low-grade ores or removing waste rock. Balancing such costs against benefits of reclamation is a matter for legislative judgment; this is elaborated on in Chapter 6.

2.4.1 The Economics of a Mine

This section summarizes the economic principles involved in finding, developing, and operating mines. It specifically discusses those economic elements that are different for coal than for other mined materials, and how these economic elements would be affected if a law similar to PL 95-87 should be enacted for minerals other than coal.

2.4.1.1 Investment, Costs, and Cash-Flow Relations

The activities associated with each stage in the life cycle of the mine described in Section 2.2.2 must be translated into economic terms to relate them to investment decisions. This procedure involves estimation of revenues, capital and operating costs, and the use of these estimates to calculate "net cash flow" expected over the life of the mining operation. A pattern of cash flows, like the one shown in Figure 2.6, is calculated; this particular pattern of cash flows is based on evaluation of a uranium mining project, but it is used more generally here. The cash-flow pattern is the difference between revenues and costs. It is the economic expression of the physical aspects of the mining activity. Revenues from sales less all cash costs of production yields a positive net cash flow from operations. The positive operating net cash flows are a means of amortizing and paying a return on the investment shown in Figure 2.6. These cash flows are then discounted to account for the time value of money. If the present value or rate of return on the project calculated in this way is high enough, the investor will usually proceed with the project.

Capital and operating costs, revenues, and royalties and taxes change markedly during the life of a mine, which in Figure 2.6 is assumed to be 22 years. Usually, work continues on mine development throughout most of the life of a mine. In the illustrated example, reclamation begins with production and continues beyond the active life of the mine. Beginning in the eighteenth year, reclamation expenditures are designed to minimize long-term environmental impacts following mining. Cessation of production at the end of the nineteenth year allows full reclamation of tailings ponds, mine openings, and waste dumps. For large copper or iron ore operations this period of reclamation may extend 50 or more years from the date of initial production.

Production continues from the tenth through the nineteenth year; hence--revenues are derived from the sale of the mine product during the period. After revenues are established, royalties and all costs, including taxes, are deducted. The result is the net cash flow from operations. The net cash flow from operations and the investment cash flows are discounted at a rate approximating the company's marginal cost of capital. Projections of this kind are used by companies to decide whether or not mineral deposits can be profitably mined.

The negative cash flows shown in the diagram are investments. They are based on estimated costs, beginning

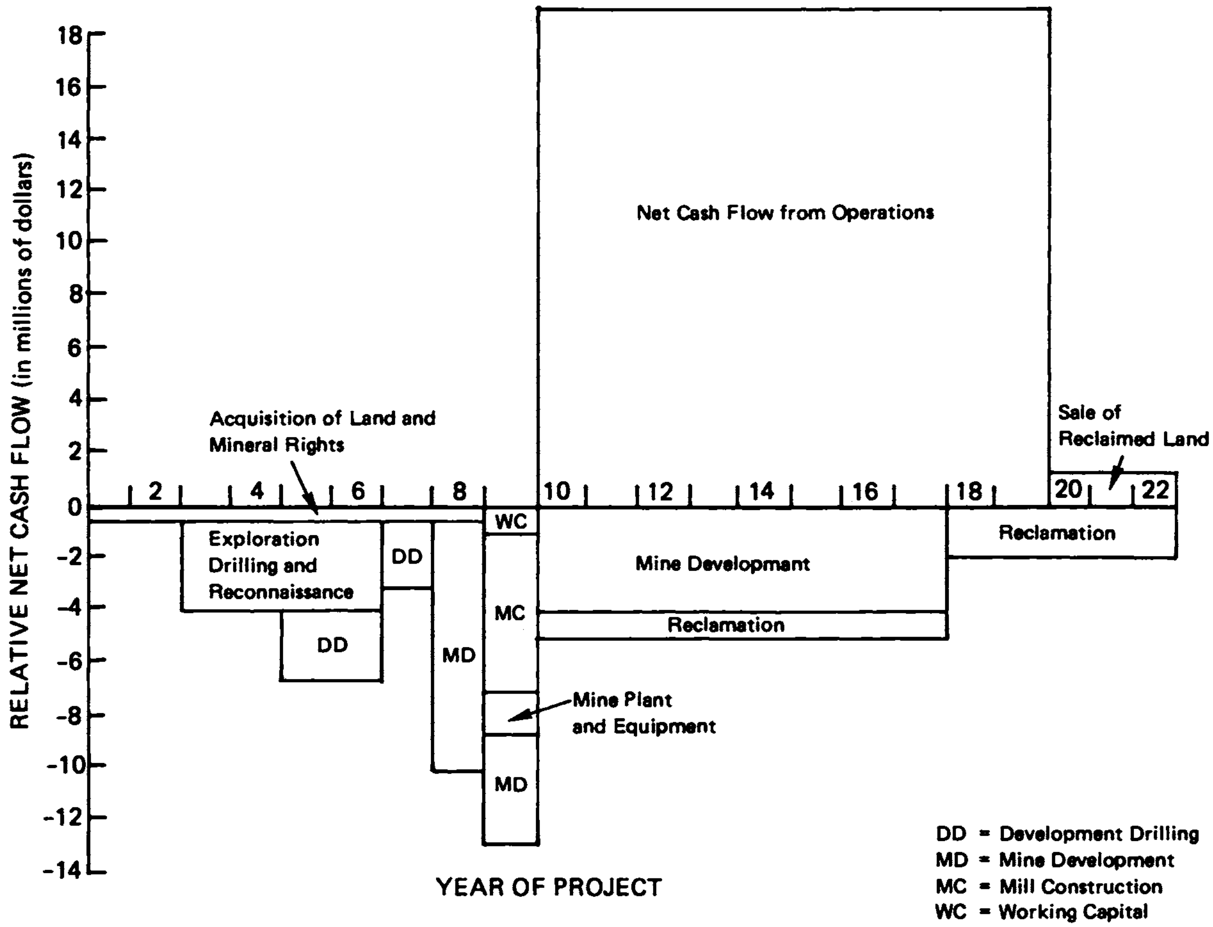


FIGURE 2.6 Pattern of cash flows for a mining project.

with initial land acquisition and including reconnaissance, and exploration drilling; development drilling; mine development; mill construction; and working capital. They include a period of reclamation of disturbed lands and tailings ponds which may be delayed until the end of the project. On the average, a period of 9 years elapses between initial land acquisition and the beginning of production. The illustrated pattern of cash flow shown may be typical for a medium-size uranium mine, but the time span required for a large copper mine would be much longer.

2.4.1.2 Price, Cost, and Ore Reserves

The ore reserve for the project shown in Figure 2.6 is not a fixed quantity. As the price of the product goes up, or the costs of mining are reduced, the minimum metal content of a ton of ore that can be mined economically goes down. The ore body is larger because of the more favorable economic relationships. For example, if the price of copper is $0.90 per pound and a producer can recover 10 pounds of copper from one ton of ore, he can afford to spend $9.00 to mine, mill, smelt, and refine the copper in that ton of ore. This represents a break-even cost. If the market price of the copper rises to $1.00 per pound and the producer can hold his costs to $9.00 per ton, he can afford now to mine and process a ton of lower grade ore from which 9 pounds of copper are recovered. The process also works in reverse. If capital or operating costs go up without a parallel increase in price, only higher grade ores will be economically recoverable, and the lifespan of the mining operation will decrease.

Changing economics often dictate that portions of ore bodies left behind in the past because they were uneconomic become economically available at some future time. One reason for this may be increased demand due to economic growth as supplies are diminished through depletion of the highest quality, most easily available deposits. Another reason is the development of new mining or metallurgical technology that improves the efficiency of recovery or diminishes production costs. Reopening of old mines may also be the result of the demand for by-products or changes in the price of by-products that can make the abandoned deposit economic once again.

If the lower grade materials left behind are buried due to the backfilling requirements in PL 95-87, the cost of recovering them in the future may be so high that they become entirely lost as a domestic resource.

The creation of economic reserves over time owing to price increases is not limited to the ore body itself. No metallurgist can extract all of the valuable product from the rock. As a result, waste rock or tailings from an existing mine are often reworked using more efficient technology, and this is usually considered in planning mine operations and the placement of waste rock and tailings. The backfilling requirement in PL 95-87 may result in the loss of this additional resource. The material taken from the mine itself and placed on "low grade" dumps has become economic with the development of leaching technology.

Often ore from six or eight pits or mines is blended in order to maximize efficiency and minimize processing costs. This procedure extends the life span of each mine and delays the period of reclamation. This situation contrasts markedly with a coal mine in which overburden is stripped, coal is removed, and the mined-out area is reclaimed in a single orderly sequence.

2.4.1.3 Capital Costs and Inflation

Projects in the mining industry are characterized by large capital investments approach $1 billion or more. In addition, these projects require 3 to 10 years of construction before production can begin. The return on investment may not be realized for another 10 years. Inflation from 1973 to 1979 increased the dollar requirements during this period substantially, doubling or tripling capital costs for many mining projects. The impact on the industry has been an increase in the amount of debt incurred, especially for those facing depressed markets during the same time period. Any delay in projects with such high initial investments--whether due to delayed permitting, litigation, or depressed markets for the products--can be disastrous to project economics. The threat of such delays has frequently created enough uncertainty to cut off projects at the exploration phase. The impact of delays is exaggerated by the increased cost of money (the interest rate). The higher the cost of money, the more severe the impact of a delay during the investment phase of a mining project.

Each mining project is site specific and therefore must be represented by a unique cash flow pattern. A variety of mineral markets and geological and engineering conditions determine capital and operating costs. These basic economic variables are further complicated by those created by environmental conditions of air, water, climate, population, and altitude, which dictate the type, cost, and effectiveness of reclamation. An "order-of-magnitude" estimate of the economic impact of surface mine regulations is impossible without detailed study. Those that have received some study for the copper and iron ore industries do provide estimates in orders of magnitude. For example, backfilling to original contour would require doubling the cost of loading and hauling, the largest components of mining costs.

The panel working papers prepared for COSMAR provide estimates of the costs of compliance with reclamation laws. The estimates are speculative and far from a complete estimate of costs, but they do indicate widely differing possible impacts on mineral supply. The estimates differ because of different assumptions about possible reclamation requirements.

2.4.2 Impact of Reclamation Requirements on Mine Economics

The type of analysis necessary to evaluate the impact of the alternative reclamation requirements for non-coal mine economics should include:

1. Examination of current costs and price relationships to identify the probable impact of higher capital and operating costs on the economics of mining.

2. Estimation of the activities necessary to meet proposed reclamation requirements. Calculation of the net cost effects of the new activities, using standard cost estimation procedures.

3. Assessment of the cumulative effect of reclamation and other environmental regulations on the industry. These are measured in terms of incremental direct capital and operating costs and the impacts on employment, balance of payments, and productive capacity of the industry.

The assumption of backfilling to original contour leads to some of the highest estimates of costs, ranging from $55 million to $3.2 billion per mine for individual metal mines (Table 3.6).

Furthermore, waste and tailings resulting from mining and processing expand an average of about 30 to 40 percent, and very few mines take out enough ore to leave space in the mine workings to backfill all waste and tailings. Thus, even if the huge cost of backfilling were incurred, waste and tailings would still remain on the surface at many mines (see Section 5.2.2.2). In those operations where the entire deposit is consumed, as in construction mineral mining, insufficient waste is generated to backfill the mined out area.

Another reclamation problem in the metals industry is tailings ponds. The panel working papers indicate reclamation costs for tailings ponds ranging from $500 to $64,000 per acre, but these costs were not developed using standard cost estimating procedures, nor do they attempt to indicate how these changes in costs would affect investment decisions.

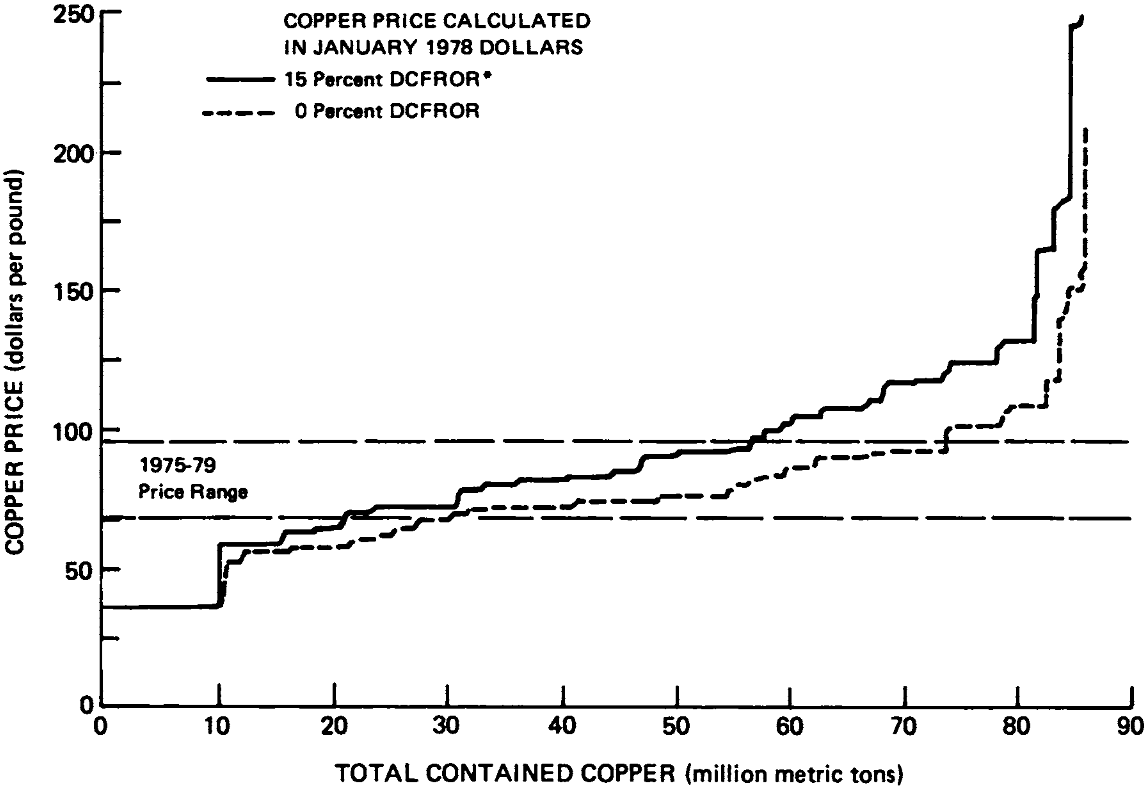
Studies of the type necessary to fully evaluate all the possible alternatives for regulating non-coal mines do not exist. COSMAR identified some relevant studies and cost estimates for particular mining operations. These studies and estimates are summarized below.

2.4.2.1 Large Open-Pit Copper Mines

In the desert Southwest of the United States, the copper industry is the dominant mineral producer. The value of production of the copper industry in 1977 was approximately $2 billion, and 90 percent of this production was located in the arid States of Arizona, New Mexico, Utah, and Nevada.

The copper industry has been operating at a below-normal level since 1974 because of lower demand, large stocks, and foreign competition. Therefore, the industry invested in no new production facilities in 1977, and many projects were held in abeyance. Prices have increased somewhat in 1979, but conditions are still not conducive to full capacity operation. Although the United States holds 32 percent of world reserves, there is no guarantee of self-sufficiency. During the last four years a soft market has prevented the higher prices justified by higher costs, and as a result, most projects are uneconomic. The January 1979 curve for potential domestic copper production developed by the minerals availability system of the U.S. Bureau of Mines is shown in Figure 2.7. The curve shows the amount of copper, economically available at various prices, contained in ores likely to be produced through 1990. It is not a schedule of copper supply to be expected in a single year.

The prices indicated are adjusted to cover regulation established through 1978, although these regulations are not as stringent as those that apply to coal in PL 95-87. Reclamation requirements are included, but they are not as detailed as those specified for coal in PL 95-87. The curve in Figure 2.7 is based on the costs of all U.S. copper deposits expected to be producing by 1990. Two prices are calculated: one that would yield a zero percent discounted cash flow rate of return and a second that would yield a 15 percent discounted cash-flow rate of return. The first price is one that would cover operating costs, royalties, depreciation, and amortization, but provides no return on investment. The second price is sufficient to cover all costs and provide a 15 percent return on investment. This curve of potential production covers 99 percent of the copper operations in the United States, 90 percent of which are located in the arid western States. The cost data and



*DCFROR = Discounted Cash Flow Rate of Return.
SOURCE: Courtesy of U.S. Bureau of Mines.

FIGURE 2.7 Total contained copper available from selected domestic deposits.

analysis can be considered an excellent representation of the 1978 cost range of the industry.

The price of electrolytic copper reached a high of 77.1 cents per pound in 1974, fell to 64.5 cents in 1975, and then rose to 69.6 cents in 1976 and to $1.00 in April of 1979.

The following inferences can be drawn from the history of these prices and from the curve shown in Figure 2.7.

1. A change of 5 to 15 cents per pound in the price of copper can reduce the discounted cash flow rate of return (DCFROR) on a copper project from an acceptable 15 percent to an unacceptable zero percent.

2. During the period from 1973 to 1978 the price ranged between 64 and 70 cents per pound. At these prices, one-half to three-quarters of the U.S. copper-producing and potential copper properties did or would have experienced losses from their copper producing units. This condition existed because of these low prices and the rapid inflation in production costs. Even at the $1.00 per pound price, one-third of the potential U.S. copper supply through 1990 will be uneconomic with the costs assumed in this calculation.

3. The effect of an increase in cost due to additional requirements for environmental protection can be represented by an upward shift in the existing supply curve. In a "seller's" market, these costs may be passed on to the copper consumer unless imports or substitutes for domestic supplies are available. When demand is depressed, as it has been for the last four years, producers may not be able to pass on cost increases. This in turn may reduce profitability and investment.

4. A large portion of U.S. copper is included in the middle portion of the curve between 10 and 70 million metric tons. In this portion of the curve, an increase in price from about $0.60 to $1.30 per pound makes an additional 60 million metric tons of copper economic. Thus, in general, we can say that for each increase of 10 cents per pound, 8.6 million metric tons of copper become economic. Alternatively, an increase in total cost of 10 cents per pound without a higher market price makes 8.6 million metric tons of copper uneconomic.

The economic impact of existing environmental regulations on copper has been studied and evaluated (A.D. Little, Inc. 1978, Industry and Trade Administration 1979). An econometric model was used to project price, employment, production, and net imports of copper over the 1978-1987 period under assumptions with and without environmental regulations. The analysis indicated that environmental regulation would add 22.7 to 29.9 cents per pound by 1987, measured in 1974 dollars. Environmental Protection Agency regulations principally involve installation of air pollution control equipment at smelters, according to the required schedules. A backlog of needed investment for such smelters exists, which is comparatively larger than for any other industry. Other impacts described include production and employment declines of 25 to 33 percent, imports increases of 16 to 21 percent, and consumption declines of 8 to 11 percent. The A.D. Little study made no attempt to evaluate the cost effectiveness of environmental regulations, nor did it attempt to quantify national economic benefits and costs associated with alternative regulatory strategies. The A.D. Little study concluded that such increases in cost without corresponding increases in price would make three-fourths of the U.S. copper industry unprofitable.

Another estimate was made in terms of cost per pound by the economics subgroup of COSMAR's Socioeconomic Subcommittee. The backfilling requirement of PL 95-87, if applied to open-pit copper mining, would raise the cost of producing a pound of copper by 3 cents, and this would be added to a 27 to 30 cents per pound cost for complying with other environmental regulations related to milling, smelting, and refining of copper ore. For an industry where the difference between a zero percent and a 15 percent return on investment is 5 to 15 cents per pound, both the 3 cents and the 30 cents must be deemed large.

Copper, even though most of the domestic production is consumed internally, is traded internationally and the U.S. market is relatively open to foreign producers. The international market is profoundly influenced by the actions of foreign governments. The U.S. Government has also taken actions that influence the market, such as stockpile purchase and sales and voluntary or imposed price controls. Environmental costs that are imposed in one country and not in another inevitably have an influence on the manner in which the market operates and on the ability of the affected companies to compete.

We have treated the copper industry in detail because a number of recent reports (A.D. Little, Inc. 1978, National Science Foundation 1978, Industry and Trade Administration 1979) have used that industry to illustrate the costs involved. Thus the cumulative impact of environmental regulation on the copper industry has been well documented. Much of the economic impact of environmental regulation applied to the copper industry relates to control of emissions resulting from the smelting of metal sulfides at smelters close to the mine. Some of the other mineral industries do not have this sulfide processing problem. The probable impact of future regulations on mineral industries other than copper requires additional study similar to that done for copper in the A.D. Little study. Still, the principles outlined for copper apply in part and in varying degrees to all mineral industries. They apply least to those mineral industries that operate entirely in local markets such as sand and gravel and more in those which are traded internationally. Because of the great diversity between mineral industries, we present a few other examples to illustrate these differences.

2.4.2.2 Uranium Deposits

Before 1973, uranium prices were low, so that this industry--like the copper industry--found little incentive to explore for or develop new deposits. Exploration and development was minimal and many operators worked at or below break-even prices. After 1973, the price of uranium oxide (U_3O_8) increased from $6.00 to more than $43.00 per pound in 1979.

The new economics for uranium may be deceptive. Rapid cost inflation and uncertainty in the market already are eroding the price advantage gained after 1973. In addition, the price increase itself is bringing about some change in the industry. Producers often respond to a higher price by mining lower grade material in existing mines and exploring for lower-grade, higher-cost ore bodies. However, the ability of the industry to expand on the basis of lower grade ores is limited. Expanded production to date has come from regions that were productive in the past. Ore discoveries in other regions of the United States have not been large, and production is from 5 to 10 years in the future depending on still higher prices to be economic. Lack of huge amounts of low grade material ("halos") around or surrounding known ore occurrences places a limit on expansion of operating scale that might yield lower operating costs. Further, the mining of lower grade ore bodies is likely to involve much larger mining operations whose reclamation problems will be different from those of existing operations.

Uncertainty in future nuclear fuel requirements could again cause the price of uranium to fall relative to cost. Because of long lead times of from 7 to 15 years between initial exploration and production, a marginal industry would lead to shortages of nuclear fuels for the high energy consuming economy of the United States.

Filling of pits mined for uranium in 1977 would when done cost the equivalent of $55 million in 1977 dollars. Delivery of approximately 36 million pounds of uranium oxide in 1977 means that this $55 million would add $1.53 to the cost per pound at a time when average contract prices were $17.45/pound and spot market prices were $34.00/pound. By 1985, because of increased surface mining, the annual cost for pit filing would have doubled to $110 million (see Working Paper IV).

2.4.2.3 Phosphate Deposits and Construction Minerals

Most of the phosphate mined in the United States comes from the coastal plains of Florida (81 percent in 1977). Phosphate operations are highly visible. They cover significantly large areas and have some difficult environmental problems. For these reasons, phosphate mining has been coming under more and more sophisticated control by the State. Land reclamation expenses are, therefore, already built into the costs and consequently the price structure. These figures are discussed in Chapter 3. The cost of environmental regulations for phosphate mines in Florida is reported to be more than $1.00 per ton of product for existing mines and more than $2.00 per ton of product for new mines. If backfilling were required, another $0.35 per ton would be added. There are now estimated to be 1.1 billion tons of phosphate recoverable at a cost of $20.00 per ton (Working Paper XI). The cost of backfilling alone would be an additional cost of $385 million (Working Paper II). These reserves, if mined at the present rate, can maintain the industry for nearly 10 years. New mines would allow a 3 percent annual growth for the next 25 years from identified deposits (Working Paper II).

Working Paper III indicates that the provisions of PL 95-87 in most instances would have minimal economic impact on the construction mineral industry. The Act's provisions on restoration to approximate original contour, blasting, and operations in alluvial valley floors are exceptions (Working Paper III). The cost of backfilling the limestone and clay pits of the cement industry alone is estimated at $2.9 billion (Table 3.6).

2.4.2.4 Minnesota Open-Pit Iron Mines

The economic characteristics of iron mining in the Lake Superior district are as follows:

1. Large capital outlays from $200 million to $1 billion are required to develop a large open-pit iron ore mine. In order to be competitive with foreign sources of iron ore, high rates of mining with associated large capital outlays are a necessity. These large mines often require up to 10 years for exploration and development and another 10 years to recover the initial capital investment. The mining

methods often preclude reclamation for 20 to 50 years from initial development.

2. In the United States, 96 percent of iron ore output comes from open-pit mines, which are located mostly in Minnesota and Michigan. Ninety-eight percent of the ore must be processed into pellets to produce a product competitive with imported "direct shipping ore," i.e., raw ore of such grade and texture that it is sold as mined.

3. USBM statistics indicate that one-third of the ore required by the U.S. iron and steel industry is supplied from foreign sources. Long-term projections indicate U.S. self-sufficiency may increase through the end of this century, but the United States will still produce only 70 to 80 percent of expected domestic demand. The price and availability of foreign ores might also be influenced by organizations of foreign producers, such as the Association of Iron Ore Exporting Countries.

4. In the past, steel mills were located close to iron ore and coal deposits in areas that had ready access to major markets, which explains the development of steel mills in Pittsburgh and Gary. However, as the high grade direct shipping ores of the United States were depleted and developing countries wanted steel mills to reflect national economic ambitions, mines and mills have been developed in foreign countries.

The effect of reclamation costs on iron ore mining can be measured in terms of current production costs. Production costs including processing in 1978 were $18.00 to $25.00 per ton of pellets with an estimated average of $20.00 per ton. These costs include current reclamation practice, which includes covering of terraced waste rock surfaces that constitute the wall of the open pit with overburden and revegetating the surfaces, grading surface dumps and vegetating them, and vegetating and providing temporary stabilization of taconite tailings. Sequential filling of pits mined for taconite is not generally practiced, because the pits are underlain by potentially economic iron bearing formations containing about 33 percent iron. The costs of current reclamation practices add 0.5 to 1 percent to the cost of pellet production. These figures suggest that the price increase associated with present reclamation practice is small. Backfilling cost obtained from industry estimates, however, would require large capital outlays. The cost would vary from $3.87 to $11.84 per ton of iron ore (Working Paper V). Such increases in cost represent from 19 to 59 percent of total production costs, depending on whether the operation is large or small (Section 5.2.2.2). In addition, the Panel on Large Open-Pit Mining in Humid Environments (Working Paper V) indicated that there is not enough material available to refill most pits on the Mesabi Range, because little overburden is removed and much of the material mined from these deposits is sold.

Small companies typically mine ore that would be lost to the large-scale producer because it cannot be mined by large-scale methods. Reclamation requirements, if adopted, should be sensitive to the important role played by the small miner and to his particular operating conditions. The effect of new reclamation laws on small operators would depend on the actual requirements. If detailed operating plans were required, with long-term schedules for drilling, blasting, loading, and hauling, small mines would probably have difficulty mining the dispersed small deposits as they have been.

2.4.3 Economic Effects of Mining on Local Governments

An initial result of development of a large new mine is a complex of problems for local governments. The demand for water, roads, sanitation facilities, schools, and medical and recreational facilities outstrips revenues from taxes (see Section 2.5).

A second problem that mining can bring to nearby communities is its impact on existing community facilities. Provisions of PL 95-87 are designed to prevent or minimize such impacts as pollution, land subsidence, and loss of water supplies, wildlife, and recreational and cultural facilities. The provisions are designed to protect the health and safety of the local population and to preserve or reclaim the long-term productivity of the land.

The long-term economic benefits to a community are expressed in terms of costs that are avoided if these provisions are effective. Their estimation with respect to non-coal mining is beyond the scope of this report. There is an existing literature on benefits and costs of reclamation and environmental improvement (Kneese and Schultze 1975, Schellenberg 1973, Brooks 1966, Sassone and Schaffer 1978, Krutilla and Fisher 1975, Down and Stocks 1977, U.S. Department of the Interior 1977).

Along with the potential disruptions that a new mine brings to the accustomed life of a non-mining community, there are potential benefits, such as new jobs and increased economic activity. The technology required in mining brings new skills to the community that can aid it in the solution of its problems and an enlarged tax base. These are measurable benefits, whereas the disruption to the tranquility of a community is not so easily measured.

2.4.4 Regional-Interstate Competition

The extent of regulations, compliance, the cost of compliance, and the success of reclamation varies from one region of the United States to another, from one State to another, or even between adjacent properties producing the same commodity. Uniformity in physical requirement does not lead to uniformity in costs. For example, reclamation of the tailings pond at the AMAX-URAD Mine in Colorado is aided by the availability of development rock from the nearby Henderson Mine. The rock is needed to cover the finely divided tailings prior to replacing topsoil and vegetation. The cost of any type of "backfilling" is dependent on how far the miner must go to get the fill and whether that fill comes from stripping of another mine. In coal mining, the fill may come from the adjacent panel, but in other mines it may have to be hauled a long distance. The cost of hauling material is one of the principal costs of mining.

One criticism of State and local reclamation laws is that competition for industrial development may cause State or local government to lower reclamation requirements to attract industry. This idea may have validity when applied to the manufacturing sector, but mining is site specific. While the profitability of firms may be significantly affected, it is unlikely that environmental laws alone will basically alter the dominance of Arizona, Michigan, Montana, New Mexico, and Utah in copper production. Nor are they likely to alter the dominance of Arkansas in bauxite, Florida in phosphate, Minnesota and Michigan in iron ore, or the potential of Colorado in oil shale because geologic factors determine the location of ore bodies.

Competition in development of many minerals also takes place in the international marketplace between areas of the world where unique combinations of geological conditions and events have created ore bodies. For other minerals, such as the construction minerals, competition is domestic, but it is severely limited by transportation costs. For this reason, the amount of interstate competition is limited to construction markets close to State borders.

2.4.5 Summary

The economic impact of regulating non-coal mining in the same way as coal mining cannot be fully evaluated without an analysis of benefits and costs that is beyond the scope of this study. Marginal operators sensitive to additional costs from environmental regulations may become uneconomic. Others, at least in the short term, may be able to absorb or pass on the cost increase.

2.5 SOME SOCIAL CONSEQUENCES OF MINING

2.5.1 A Neglected Subject

The social impacts of mining, like the environmental impacts, are often difficult to define and quantify, and, for the most part, have not been considered in the past as part of decisions about whether, where, and how to mine. The provisions of PL 95-87 that address social impacts of coal mining concern: the property rights of adjacent owners; direct impacts on health and safety; impact of mining on existing land use plans; public participation in the permitting process; and designation of lands unsuitable for mining (Sec. 508(a)(8); Sec. 513(a)(b); Sec. 522(a)(3)). In addition, PL 95-87 expresses concern for the impact of coal mining on the quality of life in local communities (Sec. 101(c)), and provides specifically for the reclamation of prime farm lands (Sec. 515(b)(7)) and the protection of alluvial valley floors in arid and semi-arid areas (Sec. 515(b)(10)(F)). Both of the latter provisions were included in PL 95-87 in part on the basis of social considerations.

To the extent that social impacts are considered in mining decisions, it is primarily in the context of local land use or zoning decisions. However, many local governments in rural areas of the country especially in the West do not have zoning, many others have inadequate zoning, and local zoning generally does not apply to Federal lands. In addition, local governments often have limited technical and financial capabilities, and the mechanism of zoning may not be applicable to all impacts of mining on society.

Mining activities are most likely to affect 5 aspects of society: (1) population patterns, (2) personality systems, (3) social systems, (4) cultural systems, and (5) technological systems (Dunlap and Catton 1978). The extent of the impacts of mining on these social aspects is likely to be determined in large part by three groups of participants and their actions: (1) government (environmental standards; taxation powers and policies; aid to impacted areas; zoning; coordination between levels of government); (2) the mining industry (size of requisite labor force; duration of project; technology employed; geographic relationships between local populations; policies for avoiding or mitigating social impact); and (3) the local population (size and distribution; infrastructure development; economy; community social structure and composition; political structure).

It is through the interaction of the three major participants that mining decisions are made that recognize both public and private interests. The interests of the local population, however, are often underrepresented except in those communities with well conceived planning and zoning ordinances. Because of this, communities sometimes absorb hidden costs associated with development (Clemente 1975, U.S. Department of Housing and Urban Development 1976).

The range of social impacts of mining and conditions in which they occur is broad. Generally, such impacts are most noticeable and the ability to cope with them is most limited when large new mines are developed or existing mines are greatly expanded in sparsely populated areas.

The consequences of such development--commonly known as the boom-town syndrome--have been extensively studied by sociologists, environmental psychologists, anthropologists, and political scientists. Much of their research has emphasized the impact of industrialization, including coal mining, on rural Western communities. For the minerals with which COSMAR is concerned, this kind of development is most likely to occur when large mines are opened or expanded in rural areas. Recent examples of this kind of development are the growth of trona mining in Wyoming and of uranium mining in Wyoming and New Mexico. Future developments could include oil shale mining in Colorado and Utah.

Boom towns have been associated with mining and timber industries in frontier regions throughout our history and social disruption has, to a large extent, been gradually accepted as one of the costs of economic and industrial growth. But now recognition of these costs and ways to mitigate them are emerging, even at the expense of slowing economic growth and inhibiting mobility. This is particularly true where concern focuses on rapid growth in small farming or ranching communities with little or no previous industrial development. Only a few boom town situations are likely to occur in a given decade, but the nature and extent of their adverse social effects justify the following discussion about how to avoid or mitigate those effects.

2.5.2 Community Change

The single most important factor determining the extent of social impact in a mining community is the size of the new labor force relative to the existing population. The greater the number of new workers and new residents, the greater the strains on the original community.

In reality, a new community is forming within the older, original one. Compared with the old community, the new one is larger, has a different economic base, is a polyglot of people with different backgrounds, and is at the outset virtually unorganized. As a result, social strain and stress develop quickly between and within both the disrupted old community and the embryonic new one.

Evidence in Western communities under the impact of energy development indicates that most of them experience social strain when the population growth rate exceeds 4 to 5 percent per year (Gilmore and Duff 1975, U.S. Department of Health, Education and Welfare 1976). The strain becomes severe when the growth rate exceeds 10 to 15 percent per year. Communities under this level of stress are not only not desirable places to live, they are likely to be unfavorable locations for business (Gilmore 1976, Gold 1978).

Nevertheless, small rural communities appear initially to encourage mining development. Freudenburg and others (1977), Clemente and Krannich (1976), Little (1975), and Andrews and Bauder (1968) have all noted strong support for several types of rural industrialization, including mining. For example, over 80 percent of the residents of Hardin, Montana, originally supported past energy development. Time and experience, however, apparently changed that attitude. Only 55 percent of those sampled in Hardin favored hypothetical future projects (Little 1977). A similar decline in enthusiasm for additional development appears to have occurred among local residents in Craig, Colorado (Fradkin 1977, Freudenburg 1979).

The strains within these growing communities reflect several major problems. For one thing, a new occupational structure tends to supplant the old, and the result can be sudden changes in the relative work patterns and pay status of new and long-time residents.

Improvements in the local economy are frequently cited by industry, government, and residents as reasons for approving or supporting a new mining development (Little 1977, Andrews and Bauder 1968). It should be noted, however, that personal economic gain, real or perceived, is not the only factor that influences local citizen support for new or additional projects. Contributing to national needs, satisfying job requirements for kin, and maintaining the local social structure are all sources of additional motivation (Little and Lovejoy 1979, Seyfrit 1977, Summers and others 1976, Andrews and Bauder 1968). Some studies have projected that as many as 40 to 50 percent of the new jobs would go to local residents (Mountain West Research, Inc. 1975), but most evidence indicates that in fact only 20 percent or less of the new jobs are actually captured by local residents in rural areas. The proportion of jobs going to local residents will be higher when the mining operations are located in urban areas with their larger, more diverse labor pools (Little and Lovejoy 1979, Summers 1973, Gray 1969, Andrews and Bauder 1968).

Part of the in-migrants' success in obtaining the new jobs is due to their superior educational attainment or their possession of requisite technical skills (Little and Lovejoy 1979, Chinitz 1971, Somers 1958, Maitland and Cowhig 1958). In some cases, jobs filled by in-migrants are denied to local people, as are the associated economic benefits (Little and Lovejoy 1979, Summers and others 1976). In other situations, especially where annual employment growth exceeds 4 to 5 percent, new jobs are often filled by the in-migrants in any event.

Although existing businesses in a rural community may prosper economically from industrialization in their area, there are exceptions in which the older, existing business community may be overwhelmed by the new one, causing rapid changes in the status of long established firms. Even when local business prospers, local townspeople and ranchers may perceive the business people as the only local beneficiaries of industrial development and experience hostility toward them for that reason (Freudenburg 1979, Andrews and Bauder 1968).

At the same time, local businessmen themselves must conduct their operations in the more formal, less relaxed set of circumstances brought about by the influx of newcomers (Cortese and Jones 1977, Freudenburg 1979). The arrival of chain store operations that offer higher wages and benefits entice employees away from the established businesses, drain off revenues that might otherwise be received by indigenous businesses, and contribute to local business failures (Cortese and Jones 1977, Freudenburg 1979 Summers and others 1976, Wadsworth and Conrad 1966, Denver Research Institute 1975, Krannich 1977, Longbrake and Geyler 1979).

Both rapid growth and increased wage demands on old businesses are reflections of the limited local labor supply and the changes in the economic base that accompany new development. In turn, high industry wages and increased demand for goods and services push local prices up. Unskilled locals, the aged, those on fixed incomes, women, and minorities are most likely to be worse off financially than before the arrival of the new industry (Clemente 1973, Clemente and Summers 1973, Summers and others 1976).

Rapid growth in a boom town also affects local schools, roads, and health care and recreational facilities. Planning and infrastructure development in such communities lag behind needs, and few small communities have the excess funds or the bonding capacity to finance early planning or required improvements in support of sudden expansion (Gilmore and Moore 1975, Gilmore and others 1976, U.S. Department of Energy 1978a).

Lack of funds to build public facilities in growing rural communities is caused in part by the fact that mining often takes place in one taxing jurisdiction, like a county, while the costs of meeting infrastructure requirements fall on another jurisdiction, like a town. In addition, tax revenues from mining accrue slowly over many years, whereas the necessary expenditures precede actual mining. Thus, at least during the early phases of mining, communities may, in effect, be subsidizing mining by absorbing social as well as direct economic costs (Brock 1969, U.S. Department of Housing and Urban Development 1976).

The number of business failures, new jobs, and in-migrants represent only a small part of the social disorganization. Boom-town growth rapidly increases the incidence of social problems for individuals, families, and larger institutions, like schools, churches, and the government.

One measure of strain on a social system is the change in crime rate. The general pattern in boom communities is that there is a high, positive correlation between population growth and crime (Little 1977). A study of 188 boom-towns of various size scattered throughout Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming (Federal District VIII) found that during a 3-year period, crime against property increased 2.22 times while crimes against persons increased 9 times (U.S. Department of Health, Education and Welfare 1976). Other indicators of stress in a social system include increases in suicide attempts, alcoholism, divorce rate, spouse abuse, and depression (Freudenberg and others 1977, Mountain West Research, Inc. 1975, Kohrs 1974).

Social problems affecting the general population are quickly reflected in the schools, where the old and the new populations interact first and most intensely. There is conflict between local students and newcomers in values, commitments, and life styles, and school administrators must spend time integrating new students into the classroom (Cortese and Jones 1977).

Like the educational structure, the political structure in a small community is also strained when new economic activities, especially large-scale ones, bring old and new populations together. Elected officials experience personal stress, and the quality of services and the administration of justice often deteriorate (Kiernash 1972). City council members and mayors are often part-time officials in small towns, who serve for only slight monetary rewards. If new constituents differ dramatically from long-term residents, many local officials simply quit their jobs when their services are no longer appreciated (Eulau and Prewitt 1973). Citizens' views in changing communities become more difficult to represent adequately at the same time that willing public officials become more difficult to recruit (Verba and Nie 1972).

Andrews and Bauder (1968) found a tendency for the in-migrants to fill elected, as well as civic and religious positions, formerly held by long-time residents. The possibility of electing newcomers is also enhanced by their higher educational attainment (Summers and others 1976) and the fact that the in-migrants frequently share common political or economic philosophies that differ from those of the original residents. By voting in numbers the newcomers may thus shift the traditional community power structure (Nellis 1974, Gold 1978) and exacerbate intracommunity conflicts. Such conflicts and hostilities, which alter and reflect changes in patterns of social behavior, have been documented in energy boom towns (Gold 1978, Kohrs 1974, Little 1975, Freudenburg and others 1977, Freudenburg 1979).

2.5.3 Reducing Disruption

The two main sources of boom-town social problems appear to be lag in development of public facilities and lags in people's adjustment to rapid changes in the population and the economy. Such problems are not new. The boom-town days on Minnesota's Mesabi Iron Range have been extensively documented (Landis 1938, 1933; Berman 1963; Smith 1963; Chambers 1963). Problems of public improvements and social stress were abundant, although in retrospect it is also possible to point out currently valued institutions and ideas that emerged from the tumultuous early period. Amelioration of the tensions of that historical boom-town situation came about over time in two ways: (1) heavy investment in public improvements through a combination of direct contributions from the mining companies and taxes of mining properties, and (2) maturation of the community as people and institutions adjusted to one another and to their new environment.

How might such amelioration of social problems be accelerated in current and future boom towns? The Mesabi Range experience suggests that answers lie in measures to accelerate investment in public facilities and increase the flow of information necessary to speed social adjustment to new conditions. Recent experience in the western United States suggests the same answers. Strategies for coping with the lag in public investment have included creating special taxing districts and the pre-payment of taxes by industry (Wilson 1976, U.S. Department of Housing and Urban Develoment 1976, Rapp 1976, Gilmore and Moore 1975). Solutions must ultimately be resolved on a site-by-site basis. Meanwhile, communities must possess a minimum degree of technical sophistication if they are to participate in development decisions and address the complex social issues that are raised by mining development. Most communities, however, do not at present have this sophistication. Small rural towns, which usually bear the greatest social impacts, seldom have the financial capacity to obtain the necessary experience. Yet if they are to participate effectively in the planning and scheduling of surface mining develoment, communities and individual citizens must have access to both adequate staff support and unbiased sources of information.

2.6 INFORMATION AND RESEARCH NEEDS

Existing regulation of mining by government is presumably predicated on protecting the public adequately from mining's adverse effects at costs, including losses of mine production, that do not exceed the benefits of regulation. To meet such an objective, regulatory requirements must be based on comprehensive knowledge of the effects of mining and the technology available for minimizing adverse effects. In the absence of such knowledge, regulations may be either imprudently lax or needlessly restrictive.

To assist regulators in promulgating reasonable and effective directives and to aid mine operators in designing and conducting environmentally sound projects, we have identified areas where improved information or technology would be helpful. In developing the following list of information and research needs, attention is given to the waste management and reclamation practices and problems described in Chapters 3 and 5 and to the environmental concerns in Section 2.1, to the significant environmental problems associated with mining in Section 2.3.5, and to a similar assessment in the Uranium Mining and Milling Environmental Development Package of the U.S. Department of Energy (1978b).

1. Methods to predict ground-water pollution from mining and the health effects of specific pollutants;

2. methods to prevent ground-water pollution from tailings, leach dumps, waste dumps, and mines;

3. methods of sealing inactive underground mines to prevent surface and ground-water pollution;

4. methods to control erosion and sediment discharges from mining;

5. methods for improved success in revegetation of mine, waste dump, and tailings sites, under adverse conditions of aridity, sparse or absent soil, high alkalinity-acidity or sodicity, and high altitude;

6. methods to determine heavy metal uptake by various plants and effects on livestock and wildlife;

7. methods to determine the mobility of stable and radioactive contaminants from uranium (and phosphate) mining and milling, and how these respond to changes in environment;

8. methods to monitor and evaluate the adequacy of uranium waste containment methods;

9. methods to monitor and evaluate the radioactive air emissions from uranium (and phosphate) mining, milling, waste and leach dumps, and tailings;

10. methods for preventing unplanned subsidence in underground mining and for repairing unplanned surface subsidence.

11. landscape designs for placement of large volumes of rock waste and tailings in a manner that provides for beneficial postmining land use and improves the aesthetic impact of the waste piles or dumps;

12. methods to improve the predictability and control of effects of in situ and solution mining;

13. research to identify and quantify where possible the benefits and cost of alternative reclamation requirements; and

14. methods to measure the social impacts of large-scale mining development.

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CHAPTER 3

WASTE MANAGEMENT AND RECLAMATION PRACTICES

3.1 SCOPE

The management of wastes produced by mining and processing of non-coal minerals, and the rehabilitation of sites disturbed by these activities, has stimulated substantial research and development during the past several years--in industry, in government laboratories, and in academic institutions. Based largely on current practices and results, various procedures for control of water pollution, air pollution, and solid waste, and techniques for land reclamation, together with estimates of their range in cost, are summarized below. Waste management is primarily needed during the course of an operation, but the effectiveness of the practice used can influence whether postmining controls are also needed. In contrast, land reclamation is carried out mainly after mining is completed, although placement of solid wastes and the conduct of mining may themselves be done to achieve an anticipated postmining land use, and opportunities for shaping and revegetation may be found during mining activities.

In some cases the wastes generated by several kinds of mining and processing are generally similar, and technologies for their control are more or less the same--for example, control of sulfur dioxide emissions by use of wet scrubbers. In other cases, environmental problems exist that are peculiar to a commodity or a mining method. We describe the waste-control practices that are broadly applied in extracting most commodities and then discuss specific technologies that deal with particular problems.

The rehabilitation of disturbed sites, although broadly aimed at establishing beneficial postmining land uses and at preventing off-site impacts, is strongly influenced in its methods and results by differences in mining techniques, geography, climate, and postmining needs. Reclamation plans must necessarily reckon with these differences. For instance, solid wastes that cannot be economically rehandled can nonetheless be placed in a manner to achieve a beneficial postmining land use. We discuss general principles for reclamation, particularly revegetation practices, and give some examples of site-specific efforts.

The costs for waste control and reclamation are hard to estimate accurately in that accounting methods are highly variable. Often these costs are not even segregated. During the past decade, especially, control procedures commonly have been incorporated in the total operation, and integrated facilities have been designed with greater emphasis on environmental management. Similarly, personnel may serve dual roles in production and environmental control. These costs also vary according to characteristics of a site, according to regional differences in the standards to be met, and according to the date when control procedures were begun. These differing circumstances typically reflect the variable difficulty of achieving control, or of meeting a standard perceived at a particular time and place, and hence influence cost.

Despite these uncertainties, we summarize the best available estimates for the costs of waste control and reclamation, usually with reference to a particular site or region, or with respect to the installation and operating cost of a control device or procedure.

3.2 WATER POLLUTION CONTROL

Pollution of water by mining and mineral processing differs considerably among the many mineral commodities, although nearly all have the general problem of controlling discharge of sediment. In addition, mines that extract metallic sulfides may produce mineralized and acidic water, and waste piles and tailings ponds may contribute dissolved mineral matter to surface water and ground water. This waste water, which may be contaminated with sediment and dissolved constituents, is produced at the mine itself and at the processing plant. We discuss waste water from the vantage point of both mining and processing. Also, the processing of certain non-coal minerals, notably oil shale and uranium, generate other effluents that pose problems in control of water pollution. We discuss these effluents as special problems.

3.2.1 Mining Effluents

Water is not used in significant quantities in mining, except for solution mining, hydraulic mining, and in certain sand and gravel operations. Rather, water that enters the mine must be discharged, reinjected, or evaporated. The amount of water is a function of the local hydrology and is typically small in arid regions. The water arrives as seepage from ground water or as surface runoff and may be variously contaminated with dissolved mineral matter and sediment, depending on the local geology and hydrology. The water is pumped or drained from the mine and if required, under current regulations, is treated before being discharged to a stream. (Waste water that is disposed of by being pumped down a well--that is, by reinjection--is not yet regulated by the Federal government and is not generally subject to regulation by the States.) Treatment of the waste water, as described in a later part of this section, is the usual method of control, but the amount and quality of mine water can also be made more manageable by grouting of fissures in underground mines and by timely reclamation of the disturbed surface.

Control of drainage from underground mines, whether by grouting or by treating the water, is primarily a matter decided in current practice by comparing costs. Of course, such control is warranted only where the mine drainage is adversely contaminated. Considerations of sealing or treatment also could be applied to the pervasive problem of drainage from deactivated or abandoned underground mines, a source of pollution that apparently can be prevented only by sealing the portal or by perpetual treatment of the drainage. Neither approach is now practiced regularly.

For surface mines, effective reclamation is the only long-term means of controlling water pollution (Section 3.5.1), but contamination of water by runoff can also be controlled during mining by diverting runoff to a water treatment facility. Alternatively, this water can be used in processing, thus conserving the available water and collecting all water for treatment in one place. Placement of landfills and solid waste in a manner to reduce contact with surface water, as part of a reclamation plan, can also control the degree of water pollution.

3.2.2 Process Water

Waste water from processing includes water from washing, transport, wet scrubbers, and from milling. In some processes, very large amounts of water are used and discharged--for example, from 150 to 250 gallons per ton of iron ore in the processing of taconite pellets (Section 5.2.3). Where water is scarce, however, much of the water can be recycled, and little if any may be discharged. Washing can produce water containing dissolved salts, metals, and sediment. The same contaminants can be added to water used to transport pulverized ore in various processing steps. The water combined in slurries from wet scrubbers, which are used in controlling emissions of sulfur oxides (Section 3.3.2), may be especially rich in sulfate salts. By far the largest use of process water, however, is for milling, a process that involves wet screening, grinding, gravity separation, flotation, and sometimes leaching. This water may itself come from ground water already laden with more dissolved solids than can be discharged without treatment under current regulations (Section 3.2.1). During milling, it accumulates dissolved salts, metals, and reagents used in beneficiation, such as sodium silicate, xanthates, pine oils, and small amounts of other organic and inorganic substances, as well as a great deal of finely ground sediment.

3.2.3 Treatment of Waste Water

Waste water from processing, as well as water collected at mines, can be treated by the methods outlined below. The methods described first are in current use in various combinations, depending on the particular needs at a site, but we further mention emerging techniques for treatment that anticipate stringent requirements for control of water pollution under standards for Best Available Technology (Section 4.4.1).

3.2.3.1 Settling Ponds and Impoundments

Suspended sediment in waste water is most commonly controlled by installing settling ponds. Such ponds function by holding water long enough for much of the sediment to settle and, hence, must be designed with respect to predicted frequency and volume of discharge. Impoundments can also be constructed to function solely as evaporation ponds. For impoundments that trap surface water, discharge is governed by drainage area and by the expected runoff, an amount that in turn depends on the probable occurrence of large-magnitude storms. For tailings ponds, unless the pond is also used to collect runoff, the design is related simply to the quantity of process water and its suspended sediment. A series of settling ponds is sometimes used to improve the entrapment of sediment. Such ponds also can be places for precipitation of metals by adjustment of the acidity (pH) as discussed below.

Excess water delivered to a tailings pond is decanted through a system of internal drainage pipes and is either recycled or treated and discharged. Evaporation in an arid region may be so great that an excess rarely occurs, but handling excess water can be difficult at places subject to high seasonal runoff, such as the spring meltwater in high mountains. The decanting system, which typically includes a further treatment pond, can be designed to reduce suspended solids in the treated effluent to 10-30 milligrams per liter. Some water in tailings ponds can also escape by seepage, unless the pond is completely lined with impermeable material, but the actual amounts of seepage at most operations have only recently been subject to measurement (see, for example, Arizona Department of Health Services, 1976, page 4-6, Hansen 1978, and Section 5.2.7.2). Because of anticipated requirements under the Resource Conservation and Recovery Act and the Safe Drinking Water Act (Section 4.4.3, 4.4.1), considerable research on the potential hazards and magnitude of this problem is now underway (Pima Association of Governments 1978, Hansen 1978).

3.2.3.2 Thickeners

Thickeners are large tanks used as a stage in the disposal of processing waste to concentrate finely ground solids and to yield somewhat clarified water that can be recycled. Thus, they are primarily devices that facilitate economical use of water and more efficient further handling of solid and liquid wastes. Chemical flocculants often are used in thickeners to enhance their performance.

3.2.3.3 Flocculation

The settling of suspended sediment can be promoted by adding flocculants such as ferric compounds, lime, aluminum sulfate, and various polymers. These reagents are ordinarily used after larger particles have been removed. Their effectiveness varies with the specific characteristics of wastes to be treated.

3.2.3.4 Neutralization/Precipitation

Adjustment of pH to precipitate metallic compounds is the most common chemical treatment practiced in the mining industry, in that the addition of either acidic or alkaline reagents to waste water greatly influences the behavior of both suspended and dissolved components. For example, iron, manganese, copper, lead, and zinc are commonly removed from acidic solutions by adding lime, thus increasing the pH. The attainment of a pH of 7 (neutral) will theoretically reduce metallic ions to the following concentrations (U.S. Environmental Protection Agency 1975):

Metallic Ion	Concentration (milligrams/liter at pH7)
Copper	0.2 to 0.3
Zinc	1.0 to 2.5
Cadmium	1.0
Nickel	1.0
Chromium	0.4

However, the actual amounts of these metals that can be precipitated depends on numerous other chemical conditions, as well as temperature and other physical factors.

3.2.3.5 Oxidation/Reduction

A number of constituents that may be found in waste water from mining operations can be removed or made less harmful by oxidation--among them, cyanide, sulfides, ammonia, and various materials that otherwise would demand large amounts of dissolved oxygen. The simplest oxidation method is to aerate the waste water, and this also results in desirable cooling.

Reduction is particularly used in removing copper, selenium, and chromium from waste water. Much of the copper can be collected by passing the waste water over scrap iron such as tin cans, and residual amounts can then be precipitated by adding lime. Selenium is precipitated from acidic waste water by reduction with zinc powder and by then neutralizing the acidity with lime (Marchant 1978). Chromium is precipitated by adding sulfur dioxide.

3.2.3.6 Emerging Technologies

Several new technologies for water treatment have been tried experimentally at some mining operations in anticipation of stringent requirements under the Clean Water Act to prevent discharge of pollutants. The technologies that may be applicable to the mining industry include: ion exchange for removal of metals; adsorption on activated carbon, especially for removing color, taste, and odor, as well as most organic compounds; ultrafiltration and reverse osmosis, primarily for removal of salts; and biological treatment--that is, removal of contaminants through their uptake by aquatic plants and animals.

3.2.4 Special Problems of Water Pollution

3.2.4.1 Western Oil Shale

The oil shale industry is still immature, and its possible effect on water pollution is not yet known in detail. Early plans and experiments, however, indicate several unusual problems that can be anticipated from the magnitude of the proposed operations and the physical and chemical character of oil shale--namely, problems related to retort water, in situ leachates, and surface leachates. These problems are added to that of increased salinity of the Colorado River through consumptive use of surface water (see Working Paper VIII, Flug and others 1977).

3.2.4.1.1 Retort Water. Most effluents produced by an oil shale plant can be treated and reused. Technology exists to upgrade refinery effluents, cooling tower blowdown, boiler blowdown, backwash waters, and saline ground water. However, no control technology has been demonstrated for water produced during retorting, and much of the effort to purify this water has been discouraging. Retort water from the various surface retorting processes is not expected to be a major problem because it would be produced in comparatively small volumes and could be beneficially used to moisturize processed shale. Pollution from retort water produced by in situ processes, on the other hand, could be a potentially difficult problem to control because the quantities could be large.

Preliminary studies indicate that the cleaning of retort water will be technically difficult and costly (Harding and others 1978, Hubbard 1971). Inorganic carbon and ammonia can be reduced by conventional steam stripping (Mercer and others 1978), but technical problems with foaming and fouling from suspended solids and oils must be resolved. Packed beds of processed shale appear to be advantageous for reducing inorganic carbon and pH and could be beneficially used ahead of a steam stripper (Jackson and others 1978). Removal of organic compounds, however, appears to be a major stumbling block in efforts to further purify retort water. Most conventional processes investigated thus far, including use of activated sludge, anaerobic fermentation, trickling filters, electrolytic oxidation, rotating biodiscs, and activated carbon, have performed poorly (Ossio and others 1977, Wen and Yen 1977, Yen and others 1977). Biological processes are not yet feasible because of unresolved problems of toxicity, and processes that depend on physical and chemical reduction are limited by their very low efficiencies in reducing organic substances and by high costs.

In summary, no technology is yet available to upgrade retort water. Additional research on this subject, because of its complexity, could require many years.

3.2.4.1.2 In Situ Leachates. The prevention of degradation of ground water by in situ leachates will require novel control technology that may be very costly, and current industrial plans demonstrate that the technical feasibility of possible strategies for control is uncertain. The C-b Shale Oil Venture (1977) is investigating three approaches to prevent leaching of in situ spent shale: deliberate leaching with retrieval of the leachate, diversion of potential leachate by intercepting it at the perimeter of the mined area, and isolating the retort from potential leaching. The Rio Blanco Oil Shale Project (1977a, 1977b) proposes to backfill the abandoned retorts with processed shale from surface retorts and has outlined the research needed to evaluate this approach.

3.2.4.1.3 Surface Leachates. Present industrial plans for disposal of processed shale (Colony Development Operation 1974, Rio Blanco Oil Shale Project 1977b, Slawson 1978) will minimize the impact of runoff and leaching during the life of a project, but runoff may be discharged during large storms, and some seepage to ground water may take place at the toe of the pile. The risk of discharge during heavy rain obviously can be reduced by installing even larger catchment dams, but the present designs for impoundments represent a compromise between cost and acceptable risk and are believed to be generally adequate.

Abandonment of piles of processed shale poses special problems. The reservoir behind the catchment dam will fill with sediment and eventually overflow when withdrawals of water for plant use are no longer made. Evidently, provisions must be made for custodial care.

3.2.4.2 Uranium

Uranium mining and milling poses special problems in the control of water pollution by reason of residual radioactivity in the process water and certain constituents that are found in the ore. The water for milling is taken mostly from the mine itself and may contain radium-226 in amounts ranging from 100 to 400 picocuries per liter, as well as uranium, selenium, zinc, sodium sulfate, and nitrates--the nitrates being attributable to explosives used in mining (U.S. Environmental Protection Agency 1976b). For operations in the Rocky Mountain States, where evaporation is high, virtually all this water is used in the milling and disposal of tailings, and little if any is discharged. The levels of radium are controlled by ion exchange methods and by co-precipitation with barium, such that the amounts in mill water are mostly less than 3 picocuries per liter (International Atomic Energy Agency 1976).

Seepage of water from uranium tailings into ground water has received considerable attention (Martin 1978), and measurements at existing impoundments have shown some radioactive contamination of ground water. Current objectives for the design of such tailings ponds are to contain the waste water by lining the ponds with bentonite clay or a plastic sheet. Excess water could be decanted and either recycled or evaporated in a separate pond, depending on the process used. Ditches and drains around the tailings pond could also be installed to collect seepage at ground level. Still another method of control might be placement of the tailings in mined-out pits after they are dewatered on continuous conveyor-belt filters (Martin 1978).

3.2.5 Costs

Few generalities can be made about costs for controlling water pollution, in that the costs depend on the particular pollutants and the volumes that are to be discharged. These vary according to the character of the actual mineral deposits and the natural conditions of topography, hydrology, and climate. Also, some costs for drainage control and water treatment are an integral part of the mining operation and are not accounted for separately. Nonetheless, installation costs and the expense of operating treatment facilities of a given capacity are roughly comparable from place to place. Flocculants cost about $10,000 per year for treatment of a million gallons of waste water per day, in addition to an annual operating cost of $33,000. Installation costs for a facility to use activated carbon for absorption of pollutants were $200,000 in 1972 for treatment of a million gallons per day, and the annual operating costs were $190,000. Treatment by reverse osmosis is relatively expensive--costing $11,000,000 in 1972 for a plant only large enough to treat 15,000 gallons per day (Hyatt 1976). Treatment by ion exchange is also costly, $6.1 million having been spent in 1977 on a plant at Climax, Colorado, to treat 2,000 gallons per minute in order to reduce the content of dissolved metals, the acidity, and the turbidity. Some further estimates of costs and actual expenditures for control of water pollution are given in Table 3.1.

Aggregate yearly costs for segments of the mineral industry that will result from compliance with regulations for effluent limitations, as estimated by the Environmental Protection Agency, are given in Table 3.2.

3.3 AIR POLLUTION CONTROL

Particulates (dust) account for practically all the air emissions produced by a typical mining operation, but the processing of some non-coal minerals is further associated with other constituents that may be released to the air. These are discussed at the end of this section as special problems. The particulates come either from so-called fugitive dust that results from blasting, wind erosion of tailings, traffic on haul roads, and the like, or from a processing device such as a conveyor or crusher. Accordingly, our discussion of control practices deals both with stationary sources, as they are called, and with dispersed sources--that is, fugitive dust. The degree of control feasible, besides being dependent on the effectiveness of a suitable control technology, is influenced by the nature of the ore body and its overburden,

TABLE 3.1 Representative Costs for Control of Water Pollution from Mining and Processing

Operation	Location	Kind of Mine or Process	Waste-Control Activity	Cost (dollars)
Homestake Mine[1]	Lead, South Dakota	Underground gold mine (1,650,000 tons/yr)	Items for new tailings pond related to control and treatment of waste water, 1975-1978 (see also other construction costs in discussion of solid waste):	
				(1975-1978 dollars)
			Emergency disposal	168,000
			Recycle pumps and pipelines	254,100
			Carbon-in-pulp thickeners	1,100,000
			Sand dam enlargement	381,000
			Sand dam overflow	188,000
			Mill and sluice reservoir	690,000
			Char plant feed pumps	1,000
			Vat overflow thickener	50,000
			Washwater overflow	152,000
			Lab and equipment	52,500
			Carbon plant pipeline and other pipelines	22,800
				3,059,400
Coastal Plain Phosphate Industry[2]	Florida	Strip mine and milling	Comply with State requirements for disposal of slimes and tailings	
				(1978 dollars)
			Current operations	0.118/ton of product
			New Operations	0.078/ton of product

TABLE 3.1 (continued)

Operation	Location	Kind of Mine or Process	Waste-Control Activity	Cost (dollars)	
Oil Shale Industry[3]	Colorado	In situ retorting on tracts C-a and C-b	Possible techniques for control of leachate from underground retorts:	(per barrel) C-a	C-b
			Grout retorts completely with slurry of processed shale, assuming $6 per cubic yard for slurry	2.70	3.80
			Grout 30% of the retort volume	1.20	2.35
			Place grout curtain around retorts, assuming $13.50/sq ft of curtain	1.70	2.80
			Precipitate carbonates in spent retorts	1.80	
			Recover and treat leachate, assuming pumping cost of $1.20/ 1,000 gal	1.20	
			Absorb leachate on bentonite, assuming bentonite cost of $30/ ton	0.50	
Conceptual Uranium[4]		Open pit (308,000 tons/yr)	Treatment of 500,000 gal of waste water/day:	Installation	Annual operation
				(1972 dollars)	
			1. Flocculation	16,800	22,800
			2. 1 + clarification	86,000	26,700
			3. 2 + ion exchange	228,100	(33,700)*
			4. 3 + precipitation with barium chloride	240,500	(8,400)
			5. 4 + lime precipitation	282,600	11,500

* Ion exchange recovers $88,000 annually in uranium oxide.

TABLE 3.1 (continued)

Operation	Location	Kind of Mine or Process	Waste-Control Activity	Cost (dollars)	
				Installation	Annual operation
Conceptual Uranium[4]	Colorado	Mill (714,000 tons/yr)	Acid or combined acid/alkaline leach. Tailings basin of 230 acres, 10 miles from mill, operating at zero discharge	(1972 dollars) 1,101,800	78,900
Conceptual Bauxite[4]	Arkansas	Surface mine (950,000 tons/yr)	Treatment of 4,500,000 gal of waste water/day by lime precipitation (2 lbs lime/ 1,000 gal), with 2 days of settling	(1972 dollars) 383,200	174,000
Conceptual Iron Mine[4]	Minnesota	Open pit (9,400,000 tons/yr)	Treatment of 12,500,000 gal of waste water/day:		
			1. Flocculation, with 2 days settling	(1972 dollars) 192,500	87,900
			2. 1 + lime precipitation (2 lbs line/1,000 gal)	384,600	257,300
Conceptual Iron Mine[4]	Minnesota	Open pit (5,500,000 tons/yr)	Treatment of 3,550,000 gal of waste water/day:		
			1. Flocculation, with 2 days of settling	(1972 dollars) 65,000	81,400
			2. 1 + lime precipitation (2 lbs lime/1,000 gal)	181,000	152,600

TABLE 3.1 (continued)

Operation	Location	Kind of Mine or Process	Waste-Control Activity	Cost (dollars)	
				Installation	Annual operation
Conceptual Copper[4]	Montana	Open pit (18,250,000 tons/yr)	Treatment of 720,000 gal of waste water/day by lime precipitation and recarbonation, with 2 days of settling	(1972 dollars) 108,100	29,000

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[1] Jeffries and Tczap (1978).

[2] COSMAR (1979) Panel on Coastal Plain Deposits.

[3] Persoff (1979).

[4] U.S. EPA (1975).

TABLE 3.2 Estimated Annual Costs of Meeting Regulations for Control of Water Pollution, in 1972 Dollars

	Capital costs	Annual costs
Crushed stone	$13,531,000	$6,941,000
Construction sand and gravel	7,460,000	2,283,000
Industrial sand	644,000	169,000
Phosphate rock	3,340,000	1,056,000
Iron	274,200	204,100
Base and precious metals:[1]		
Copper	2,500	500
Lead and zinc	4,792,200	1,891,500
Gold	8,192,800	1,753,200
Silver	323,800	161,400
Aluminum	383,200	224,800
Ferroalloys	522,000	201,500
Uranium, radium, and vanadium	3,583,300[2]	805,900[2,3]
Titanium	96,200	39,900

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[1] Does not include mining and milling wastes that are treated with wastes from other operations.

[2] Partly estimated in 1976 dollars.

[3] Includes a credit for product recovery.

SOURCE: 42(133) Federal Register 35847; 43(133) Federal Register 29778.

the atmospheric conditions, the mining method, and the means of beneficiation or processing.

3.3.1 Control of Fugitive Dust

Fugitive dust is obviously hard to control in arid regions, because of silty soils and open landscapes, but is even more directly a function of the character of the mining operation (Table 3.3). The highest yields come from disposal areas for solid wastes. Tailings ponds, for example, which are composed largely of fine silt and which may cover extensive flat areas, are vulnerable to wind erosion.

Fugitive dust is commonly controlled by watering disturbed sites, roads, and disposal areas. In dry regions, where water is scarce and evaporation is high, chemical surface stabilizers have been found to be effective for periods of weeks or months, especially on tailings ponds.

Operational methods can also reduce fugitive dust. The shape or placement of stockpiles, for example, can lessen the impact of strong winds, as can timely rehabilitation of disturbed areas. Also, less dust is raised at dumps if the distance of fall is shortened. Dust from blasting can be reduced, although not entirely eliminated, by proper technique (Section 2.2.4).

3.3.2 Control of Particulates at Stationary Sources

Dust is produced at stationary sources by mining machinery (drills, shovels, conveyors, stackers), by handling operations at fixed locations (crushing, screening, transfer of material at conveyor stations), and by beneficiation or milling. Dust from mining is usually controlled by wetting, and dust from handling and processing is controlled by installing hoods, vents, and devices for entrapment and consolidation. Such control, besides serving air quality standards, is required by regulations for occupational health (30 CFR Subpart B). Nonetheless, some mining and processing does not meet air quality standards and continues under variances authorized under Section 110(a)(3)(A) and 110(f) of the Clean Air Act. For instance, copper mines in Arizona do not meet standards for particulates, and plants that process phosphate rock in southeast Idaho at times exceed standards for particulates, sulfur dioxide, and fluorides. The devices commonly used to trap dust are as follows:

Baghouses are chambers in which a high proportion of the particles in an air stream are captured on fabric filters. The trapped particles are normally recycled in the process

TABLE 3.3 Estimated Quantities of Fugitive Dust from Some Mining Operations

Operation	Number of Estimates	Quantity of Dust
Overburden removal	5	0.0008-0.45 lb/ton of ore 0.048-0.10 lb/ton of overburden
Shovels/truck loading	5	Up to 0.10 lb/ton of ore
Haul roads	4	0.8-2.2 lb/mile traveled
Truck dumping	3	0.00034-0.04 lb/ton of ore
Waste disposal	1	Up to 14.4 ton/acre/yr
Reclamation	1	Depends on climate and soil

SOURCE: PEDCo Environmental, Inc. (1976).

being used. Baghouses operate under a limited range of temperature and moisture and are relatively costly to maintain.

Dry collectors employ the principle of inertia to trap dust but are usually effective only for the medium-sized and larger particles. These devices are comparatively inexpensive and are easy to maintain.

Wet scrubbers are capable of trapping both particulates and some gases as a slurry, emitting a plume of steam, mist, and some unwetted fine particles. Their efficiencies vary with the power consumption and can extend over a wide range. The slurry is either recycled or disposed of as waste. In operation, the temperature and moisture at the inlet are virtually unlimited (although freezing conditions must be considered), the air stream is cooled and washed, and corrosive gases (sulfur dioxide, for example) can be neutralized by the scrubbing medium. The hazard of an explosive mixture of air and dust is small. Wet scrubbers are moderate in size and cost but are expensive to operate, in part because of the power needed to enhance their efficiency.

Electrostatic precipitators, although the most expensive of all collectors to install, are used to capture dust when the particles are small and dry, and when a baghouse is impractical (because of hot or corrosive gases), or when a wet scrubber would be too costly to operate.

3.3.3 Special Problems in Control of Air Pollution

3.3.3.1 Western Oil Shale

Particulates from oil-shale mining presumably can be controlled by the methods and devices described above, but the feasibility of controlling a number of other air emissions associated with processing of the oil shale is still uncertain. The nature and amounts of these emissions can best be determined by completing the large-scale demonstrations that began in 1978 on the Federal Prototype lease tracts which are being closely monitored (C-b Shale Oil Venture 1977; Rio Blanco Oil Shale Project 1977a, 1977b). The ability to control air emissions in these demonstrations, within the framework of requirements to prevent significant deterioration of the existing clean air, will largely determine the future size of an oil shale industry. Existing data to characterize the composition of the emissions comes from small-scale experiments that provide a basis for anticipating what controls will be needed, as discussed below.

Gaseous compounds of sulfur will be produced as hydrogen sulfide, mercaptans, sulfur oxides, and carbonyl sulfide. Their control is based on use of various amines, physical solvents, carbonates, and mixed solvents, and on management of the oxidation state of the sulfur (Cotter and others 1978). However, the procedures that depend on amine solvents are not selective between hydrogen sulfide and carbon dioxide and, thus, may be uneconomic on a large scale, especially in view of the large amounts of carbon dioxide produced during retorting of oil shale. No practical method has been identified to control the release of this carbon dioxide.

Current regulations require control of nitrogen oxides, non-methane hydrocarbons, ozone, and carbon monoxide, all of which are produced during processing. Some control of these constituents can be achieved by incinerating the retort gas. However, several gaseous products not now regulated may not be completely burned, including arsine, mercury compounds, carbonyl sulfide, uncondensed polycyclic aromatics, and possibly other organic constituents still to be identified. Some volatile compounds may be released to the air from piles of processed shale and from evaporation ponds. Also, particulates and aerosols will contain various trace metals that could be hazardous or toxic, including arsenic, selenium, nickel, zinc, and silicon.

3.3.3.2 Uranium

The special problems for air emissions associated with mining and milling of uranium ores concern chiefly the chemical characteristics of particulates and the hazards of radiation.

Fugitive dust produced by mining of uranium and by disposal of solid wastes is largely chemically inert, but may contain considerable amounts of calcium and magnesium, as well as traces of uranium, vanadium, copper, and phosphorous. This dust is effectively controlled by the procedures described in Section 3.3.1 (U.S. Environmental Protection Agency 1976b). Dust produced by crushing and grinding the ore, and by the drying of uranium oxide (yellow cake), is typically controlled by crushing while wet and by use of baghouses and wet scrubbers. Although this dust is toxic, its amount and concentration are thought to be sufficiently low so that its impacts are localized and minor (U.S. Environmental Protection Agency 1976b).

The radiation dosages and radionuclide concentrations at uranium mills are regulated under licenses issued by the U.S. Nuclear Regulatory Commmission. The existing annual limit of radiation exposure for workers in the plant is 5 rem. The present annual limit of 175 milli-rem (mrem) for the general public will be reduced to 25 mrem on December 1, 1980, by adoption of the Environmental Protection Agency's "Uranium Fuel Cycle Standard." This limit pertains to the dose received either by the whole body or by a single organ but excludes doses of alpha radiation from radon and its daughter products. This standard will be enforced by the NRC, and its achievement will depend on control of emissions, mainly at stationary sources, under comprehensive monitoring programs. Selective burial of materials of low radioactivity may be found to be necessary if doses from radon are also limited.

As reported by the Environmental Protection Agency (1976b), the chemicals used in processing uranium emit small quantities of gases, primarily kerosene and sulfur dioxide (the amounts of each being about a pound during the processing of 4 million pounds of ore), as well as some ammonia, amines, and vapors containing caustic soda. The small quantities are quickly dissipated and are thought to have no significant environmental impacts.

3.3.3.3 Lead

The atmospheric concentration of lead has recently been placed under regulations for ambient air quality, and its release to the atmosphere during mining has accordingly received considerable study (U.S. Environmental Protection Agency 1977). Lead is an ingredient in some particulates and customarily has been controlled by methods for reducing fugitive dust and the particulate emissions from stationary sources (Sections 3.3.1, 3.3.2). The new standard (U.S. Environmental Protection Agency 1978b), however (1.5 micrograms per cubic meter of air averaged over a calendar quarter), will require more stringent procedures for some mines, such as enclosed storage of ore and concentrates, covered haul trucks, increased ventilation, and more scrubbing capacity. Even with these further controls, it remains to be demonstrated whether lead mines can meet the standard.

3.3.3.4 Coastal Plain Phosphate

A special problem for air quality in producing phosphate--but to a much lesser degree than in mining uranium--is guarding against the possible hazards of radiation. The degree of danger from radiation in the mining of coastal plain phosphate has not yet been determined, and no control procedures are now being used. The radiation comes from radon that is produced from materials of low radioactivity, which are some distance below ground before mining. Control of radiation, if found to be necessary, is expected to consist of constructing buildings with ventilated foundations, burying material from the leached zone (a weakly radioactive layer above the phosphate ore), and burying processed waste (slimes).

3.3.4 Costs

Control of particulates accounts for nearly all the costs of meeting present standards for air quality at existing mines and is likely to be the major cost in future operations (except, perhaps, for control of certain emissions from oil shale processing and special handling of radioactive materials that may be found to be necessary at uranium and phosphate mines). Information on these costs is generally scarce. We give two examples of costs for control of dust at tailings ponds and discuss typical costs for dust collectors.

A proprietary chemical stabilizer called Coherex was used by the AMAX Corporation on 400 acres of tailings at Climax, Colorado in 1977 at a cost of $300 per acre, when the surface could not be stabilized with water at a time of excessive dryness. Some two or three applications were needed during the dry summer months (U.S. Environmental Protection Agency, in press). In 1969, the USBM applied an elastomeric polymer and a calcium lignosulfonate to tailings at Tuba City, Arizona, at a cost of $335 per acre. These chemicals were applied as aqueous solutions and dried to a crust that prevented wind erosion. The crust was then insoluble to water (Havens and others 1969, Western Interstate Nuclear Board 1977).

Costs for dust collectors vary considerably, depending on their type and size. Representative installation and operating costs for devices of the same capacity (except for the lesser capacity of the wet scrubber) are given in Table 3.4. These costs show that differences in requirements for power, water, and maintenance can be considerable, although not necessarily in proportion to efficiency. For a larger system, the American Industrial Clay Company reportedly spent $500,000 for a baghouse and wet scrubbers, but the true cost is hard to calculate in that dust from the baghouse is recycled at a profit, and sludge from the scrubbers requires the expense of treatment with water before being discarded (Guernsey and others 1978). The lime industry, which crushes, grinds, heats, hydrates, and dries its product, uses bag filters, dry collectors (cyclones), and scrubbers at successive stages of processing. Based on 1971 data for this industry, filters capable of an air flow of 5,000 to 10,000 cubic feet per minute (cfm) had an installed cost of $10,000 to $30,000; cyclones cost about $10,000; and a high-energy scrubber with a capacity of 50,000 cfm, coupled with a two-stage cyclone, costs $215,000 (Minnick 1971).

TABLE 3.4 Efficiency and Cost of Installing and Operating Typical Dust Collectors at an Air Flow of 60,000 Cubic Feet per Minute (CFM), Based on 1968 Prices

Collector Type	Efficiency on Standard Dust (%)	Average Pressure Drop (in)[3]	Installed Cost (dollars)	Power Cost (dollars/yr)	Water (gal/1,000 cubic ft)	Water Cost (dollars/yr)	Maintenance (dollars/yr)	Total Annual Cost (dollars/yr)	Total Annual Cost (cents/yr/CFM)
Dry									
1. Louver collector	58.6	1.7	34,500	1,560	-----	-----	300	5,310	8.9
2. Medium efficiency cyclone	65.3	3.7	25,000	3,380	-----	-----	200	6,080	10.1
3. High efficiency cyclone	84.2	4.9	42,500	4,520	-----	-----	200	9,570	16.0
4. Multiple cyclone	93.8	4.3	52,500	3,960	-----	-----	200	9,410	15.7
5. Electrostatic precipitator	99.0	0.9	233,000	2,000	-----	-----	1,300	26,600	44.4
6. Fabric filter, shaker[1]	99.7	2.5	165,000	3,740	-----	-----	10,000	30,240	50.4
7. Fabric filter, envelope[1]	99.2	2.0	152,000	3,380	-----	-----	9,500	28,080	47.0
8. Fabric filter, reverse jet	99.9	3.0	231,000	7,920	-----	-----	19,000	50,020	83.6
Wet									
9. Submerged nozzle	93.6	6.1	66,700	5,640	0.7	1,010	700	14,020	23.3
10. Spray chamber	94.5	1.4	139,000	4,760	21.7	31,250	1,000	50,910	84.2
11. Impingement scrubber	97.9	6.1	82,200	5,800	3.6	5,190	1,000	20,210	33.7
12. Wet dynamic scrubber[2]	98.5	---	136,000	45,400	6.0	8,640	700	63,340	141
13. Low return venturi	99.7	20.0	107,000	18,820	8.4	12,100	1,000	42,620	71.2
14. High energy venturi	99.9	31.5	117,000	29,740	8.4	12,100	1,000	54,540	91.0

[1] Maintenance charges include bag changes once per year for envelope-type and twice for shaker and reverse-jet filters.

[2] Air flow 48,500 cubic feet per minute.

[3] Inches of water relative to existing atmospheric pressure.

SOURCE: Sargent (1969).

3.4 SOLID WASTE MANAGEMENT

The mining industry is second only to agriculture in producing solid waste, accumulating 40 percent of the annual tonnage (2.3 billion tons in 1975), exclusive of waste from coal. Some 30 billion tons had accumulated by 1972, according to estimates based on production statistics (PEDCo Environmental, Inc. 1976). These wastes now cover more than 2 million acres (Mantell 1975) and account for 38 percent of the area disturbed by mining, according to data compiled by the USBM.

The solid wastes consist mostly of overburden and waste rock from mining, together with tailings, slurries, and slimes from processing (Andrews 1975), but include some waste from the treatment of air and water, ordinary garbage, and debris from construction and discarded equipment. About twice as much waste results from mining as from processing, most of the mining waste being overburden. (Quarries, of course, as compared with open-pit operations for metallic ores, sell most of the rock that is mined.)

The physical and chemical properties of this waste influence its stability and handling, as well as the potential for further beneficiation and for recovery of by-products. These properties further influence the procedures that are needed to protect public health and to control environmental effects. The physical properties also affect the appearance of the solid waste and may strongly influence its ultimate form on the land surface, as in the case of disposal of tailings as a slurry (Brawner and Campbell 1972). The chemical properties of this waste, besides being primarily responsible for any possible hazards to public health, are the factors that mainly determine its suitability for further processing and its effect on the physical and biological environment. We discuss typical control practices for solid wastes that are characteristic of most mining and processing, and then describe special problems connected with the extraction of oil shale, uranium, and phosphate.

A small part of the solid waste associated with mineral production is the slag formed at smelters. Slag heaps, along with many other wastes produced in refining mineral concentrates, are not a part of this study, but we mention them because they are conspicuous in places as unreclaimed disposal areas. Such smelter material now covers 1,700 acres, chiefly in Michigan (iron), Montana (copper), Arizona (copper), Idaho (phosphorus), and Utah (copper), with small amounts in Texas, New Mexico, Washington, Colorado, Pennsylvania, and a few other States. Slag is virtually inert and weathers very slowly. The slag produced 2,500 years ago at King Solomon's Mines north of Eliat, Israel, has not changed perceptibly over time. Thus, slag forms no noxious leachates, although the surface of a slag heap will remain barren unless covered with fertile material. Slag has some commercial value, 135 million tons of copper slag having been sold thus far for railroad ballast (see Working Paper VII).

3.4.1 Management of Overburden and Waste Rock

The solid wastes produced directly by mining obviously vary in nature and quantity according to the type of mineral deposit and its location, but the problems in their management pertain nearly exclusively to the amounts to be handled and the selection of a suitable site for their disposal. Commonly, the amounts are large relative to the quantity of ore, a circumstance that dictates a large area for dumping, and the choice of a disposal site is often restricted by ownership of the land. Also, the wastes usually must be segregated, in that some overburden (or topsoil) must be stockpiled for later use as a plant-growth medium, and some rock that is excavated may be saved as lean ore. In some instances, mining wastes can be placed in mined-out areas, but this ordinarily demands making careful plans beforehand, and may require permission from the surface owner. Finally, the placement of these wastes is strongly influenced by their cost of handling, which limits their practical distance of transport.

Within these restrictions, the choice of a disposal site is governed by topography (meeting objectives for confinement, compatibility with surrounding landscape, protection from erosion by wind and water, drainage control, and freedom from natural hazards); the chemical and mineral properties of the waste (for example, the content of pyrite can be a critical factor with respect to control of acid drainage); surface hydrology (characteristics of runoff and stream flow needed in designing drainage control); ground-water hydrology (depth and movement of ground water and properties of earth materials that could affect the migration of leachates); and, perhaps least considered in current practices, plans for postmining land use.

3.4.2 Management of Solid Wastes from Processing

Choosing a site for tailings and other processed waste is governed by the same considerations as those for mining wastes, but additional environmental and economic factors are relevant to their management and control.

Tailings areas range from small ponds to impoundments covering thousands of acres (Figure 3.1). Despite this range, their stability depends on similar engineering principles. Where coarse tailings ("sands") are available,

FIGURE 3.1 View of the Minntac taconite mines processing and waste disposal facility, Mountain Iron Minnesota, on the Mesabi Iron Ore Range. Wastes from ore processing are disposed of in the tailings basin (left center and background), which occupies an area of 16 square miles. The present disposal site is immediately behind the ore crushers and the concentrating plant in the left foreground. The narrow area extending across the top of the photograph is reserved for future tailings disposal.

these can be used to construct retaining structures, or rock waste or overburden can be used. Failures of such impoundments under current practices are rare, even in areas of seismic activity (Waller and others 1974). Erosion of tailings by runoff is controlled by proper design of embankments and spillways and by installing decanting systems of adequate capacity. Wind erosion is controlled by stabilizing the surface. However, the surface is an area of active accumulation during the life of a tailings pond and cannot ordinarily be stabilized until the close of operations. During this period, fugitive dust is a special problem. When the pond is no longer active, materials such as soil, overburden, rock waste, sewage sludge, and chemical stabilizers can be applied (Dean and others 1974). Revegetation is a preferred technique to control erosion (Dean and Shirts 1977, Dean and others 1973, Berg 1972) because vegetation provides a biological habitat and is aesthetically pleasing. Chemical stabilizers form a crust of comparatively short life.

Backfilling of underground workings with the sand fraction of milling wastes is an established technique at some mines, where this practice is used to improve stability, to maximize ore recovery, to control subsidence, and to reduce the size of disposal areas. However, the feasibility of backfilling, and the possible effect on later access to deactivated workings, depend on geologic and economic factors of the particular mine.

Disposal of tailings in lakes and oceans, although controversial, has certain economic advantages as well as both positive and negative environmental consequences. Costs are low, the disposal area can be virtually unlimited, especially in oceans, and the chances of structural failure are insignificant. Environmentally, this practice would eliminate piles of waste, and chemical reactions that lead to water pollution could be reduced (because of a lack of oxygen). The lack of disposal areas on land could also prevent the pollution of surface streams with sediment. However, disposal of mineral wastes in water, as in the former practice of dumping taconite tailings in Lake Superior, can cause concern about long-term biological damage and hazards to human health. Tailings dumped in this way generally cannot be recovered economically for further processing.

3.4.3 Management of Miscellaneous Solid Wastes

The miscellaneous wastes at a mine are usually discarded in designated areas of tailings ponds or in landfills constructed on the site. Such means of disposal are satisfactory for many substances (residuals from pollution control devices, leaching precipitates, construction wastes, general trash, and even the refinery slag produced at large integrated operations), but hazardous substances such as toxic or combustible wastes are generally shipped to special chemical landfills or treatment facilities.

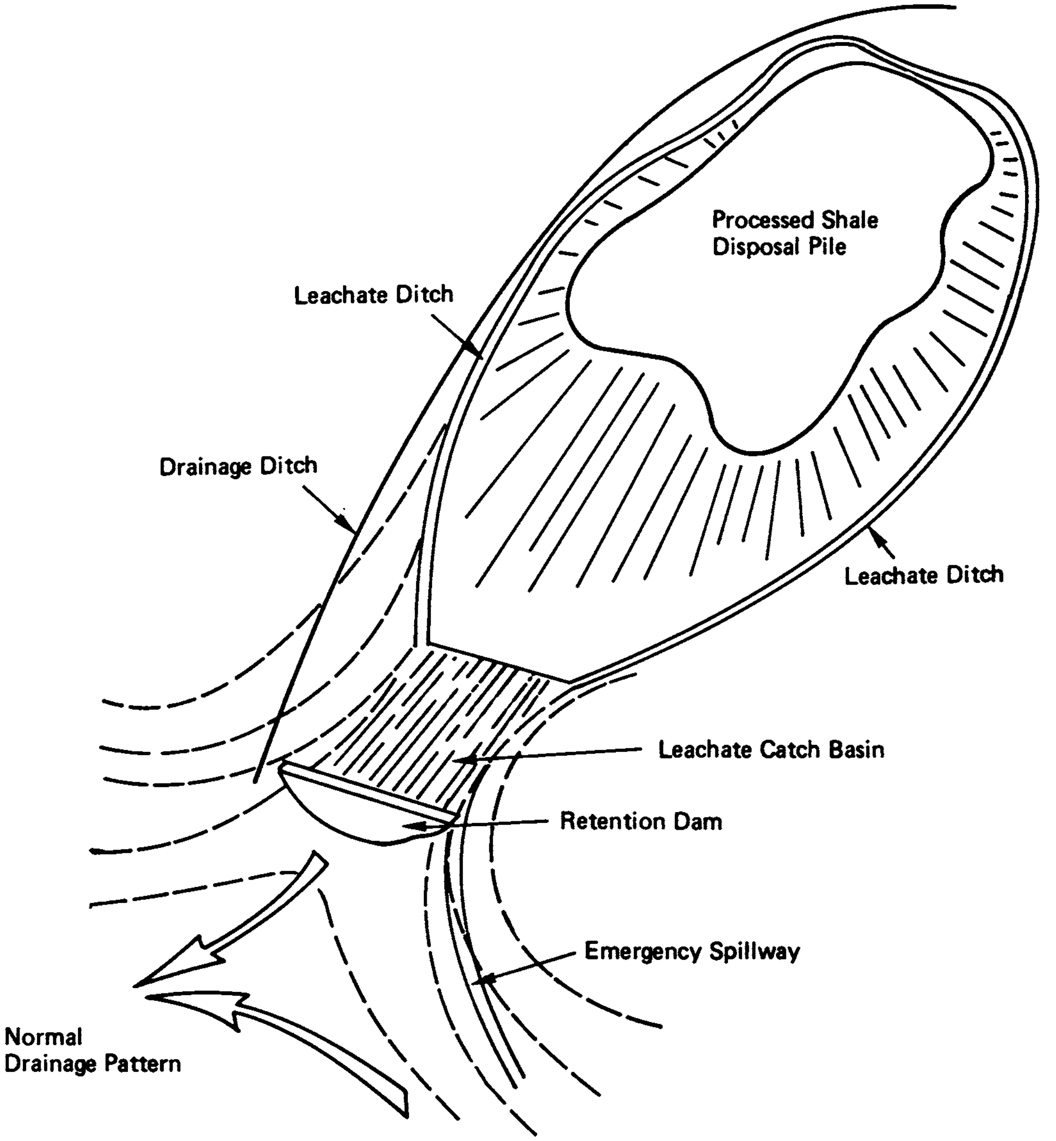
3.4.4 Special Problems in Managing Solid Wastes

3.4.4.1 Western Oil Shale

Plans for current oil-shale projects have given considerable attention to disposal of processed shale because of the enormous volumes that would be handled. For example, a plant producing 100,000 barrels of oil a day by surface retorting would accumulate 1.2 billion tons of processed shale in 30 years, or 950 million cubic yards at a moderate degree of compaction (White River Shale Project 1976:3.10-3, 7.10-8). This is 4 percent of the tonnage of all other solid waste from domestic mining that has accumulated thus far. The large areas required for such disposal will extensively change the original character of the land, and the disposal areas may require custodial care after the operations are closed.

Processed shale could be dumped either as a slurry or as a wetted (moisturized) aggregate. Because slurry transport requires excessive amounts of water, and would result in problems for disposal as well as for consumptive use in a region where water supplies are scarce, it is considered to be impractical. Current plans anticipate dumping the processed shale in nearby canyons after they are mixed with at least 14 percent water. The shale can then be compacted in stable piles (Figure 3.2). Dikes would be placed around a pile, and a catchment dam would be built to collect runoff and leachate. At final height, which would ordinarily be at least several hundred feet, salts would be leached from the top layer, soil or overburden would be laid down, and efforts to establish vegetation would begin. In the Uinta Basin, containerized plants would be transplanted into soil-filled trenches, and the surface of processed shale would be contoured to direct runoff toward the plants--a technique known as water harvesting (McKell and others 1979). The uncertainties about these methods concern matters of long-term stability, control of leachates, discharge of runoff from large storms, the adaptabilty of such disposal piles for postmining land uses, and custodial care of impoundments.

Subsurface disposal of processed shale in underground workings ordinarily could not accommodate all the processed shale because mining, crushing, and retorting expand the original volume substantially. Earnest and others (1977) estimate that about 80 percent can be returned underground. However, concurrent mining of nahcolite (sodium carbonate)



SOURCE: de Nevers and others (1978).

FIGURE 3.2 Conceptual diagram of a pile of processed shale before rehabilitation.

as a by-product could increase the space for underground disposal (Weichman 1974). Such disposal would be environmentally suitable only in mines without a flow of ground water because of the uncertain hazards of leachate from processed shale (Brown and Stewart 1978:223).

3.4.4.2 Uranium

Open-pit mining of uranium ore, which accounts for about half of current production, together with milling and processing of the ore, results in large amounts of solid wastes. The tailings alone currently total 9 million tons a year, and their accumulated amount has now reached about 150 million tons. Active tailing sites cover 3,000 acres, inactive sites 2,000 acres, and from 2,000 to 4,000 acres have been contaminated at mills and storage areas (Western Interstate Nuclear Board 1977). The problem with these wastes, however, is not especially their volume--although the amount of overburden from open-pit operations is nonetheless substantial--but derives from their chemical character and radioactivity. Some of the more troublesome aspects of uranium wastes are briefly described below, realizing that a thorough review is beyond the scope of this report.

Both the overburden and the tailings contain small amounts of selenium, a poisonous element that may be leached into streams and ground water or that may be concentrated at ground level by the growth of selenium-accumulator plants (Louderback 1975). The most effective means of control would be by selective burial of materials that contain selenium. Selenium can also be mobilized via wind-borne particulates. Hence, it is desirable to stabilize tailings, whether abandoned or active. Revegetation of inactive tailings, however, has been hampered by their high acidity or their alkalinity, depending on the methods of processing, and a cover of overburden or topsoil is necessary. In any case, a cover as much as 10-feet thick is now required for inactive tailings to control emissions of radon, and this cover could facilitate revegetation. Active tailings possibly could be selectively stabilized by segregating areas and by then applying suitable chemicals, but this practice has not yet been adopted (Martin 1978).

Radiation levels for uranium tailings, although typically low, are regulated under licensing by the Nuclear Regulatory Commission. Control procedures focus on the pathways of radiation exposure (Kennedy 1978), including: reducing the concentration of radon and its daughter products, limiting direct exposure to gamma radiation, controlling airborne dust, controlling water pollution, and physically removing and dispersing radioactive materials. Decommissioning plans for a mill now require burial of contaminated equipment; disposal of fuel and chemicals; dismantling, decontamination, and removal of buildings and structures; burial of foundations; and grading and revegetation after covering of buried materials. Requirements to bury tailings below grade are also contemplated, but it is uncertain what procedures would be environmentally appropriate where shallow ground water is present.

3.4.4.3 Coastal Plain Phosphate

Since the 1940s, about two-thirds of the area mined for phosphate in central Florida has been covered by waste clays (slimes) that are held in ponds as large as a square mile. The slimes pose a special problem for phosphate mining because they cannot be economically reduced in volume and they take decades to solidify. Current practice is to impound the slimes mostly above ground level where they have the best chance to be dewatered, although some slimes are placed in mined-out pits. Meanwhile, the dikes that hold the slime ponds carry some risk of failure. The slimes themselves eventually can become usable only for grazing, farming, or light construction, because they remain structurally weak at depth.

The slimes are produced by the phosphate beneficiation process in which one-third of the ore becomes waste clays, even though these also contain some 30 percent unrecovered phosphate. The initial slurry is highly liquid, consisting only of 3 to 5 percent solids, whose colloidal properties lead to extremely slow rates of thickening and settling. In 1972, the Florida phosphate industry embarked on a cooperative effort with the USBM to improve the handling of these slimes. The effort is aimed at minimizing above-ground disposal. The hundreds of schemes that have been investigated emphasize centrifuging, filtering, and flocculating. Four methods have evolved that hold promise:

1. A flocculant-thickener system using an organic polyelectrolyte flocculant and a mechanical thickener, which together dewater the slimes to a concentration of from 12 to 18 percent solids. When added to tailings (sand), the resulting mixture contains from 30 to 35 percent solids and can be deposited in mined-out pits. In 6 to 9 months, overburden can be gradually placed on the thickened waste, which leads to further consolidation and a surface approximately at the original grade. This procedure has been field tested but not yet on a commercial scale.

2. A sand-spray system involves successive applications of sand on layers of clay slimes to facilitate dewatering (Timberlake 1978). The slimes are allowed to settle about 3 months at one end of a mined-out area, while

water is decanted, and are then sprayed with a slurry of sand. The sand sinks, compressing the clay, and this process forms channels that facilitate further release of water. A concentration of 30 percent solids is obtained in about a year. The process is then repeated until the disposal area can be covered.

3. A dredge-mix method is one in which clay slimes are allowed to settle from 9 to 12 months in a pond before being dredged out and mixed with sand tailings for disposal in a mined area. Two ponds are used alternately; the slimes consolidate to 17 percent solids before becoming ready for mixing and are expected to reach a concentration of 30 percent solids within 1 to 3 years after being dumped.

4. A rotary trommel process that has been field tested by the USBM at its Tuscaloosa Research Laboratory involves a cylindrical sieve to dewater the slimes. Coupled with a polyethylene-oxide flocculant, this process increases the solids to 18 percent in a few minutes.

A lesser problem of solid waste associated with some phosphate processing is the management of impure gypsum produced in manufacturing phosphoric acid (see Section 5.2.7.2).

3.4.5 Costs

The costs for disposal of solid wastes are commonly included with the costs of overall operations, as part of the expense of handling and processing excavated material. By some accounting methods, such costs may also be calculated as part of the costs of grading and other rehabilitation. As with other costs for waste control, information on these amounts is scarce. Published estimates are given in Table 3.5, which emphasizes procedures designed to meet environmental requirements.

3.5 RECLAMATION

3.5.1. General Practices

Certain areas of agreement are found in the technical literature on what approaches and goals are appropriate for reclamation in mining, including the economic desire for maximum results from a given outlay of money (O'Neil 1977). These goals clearly influence current practices, in that most mining companies now reclaim or rehabilitate land and disposal areas to some degree.

Effective reclamation, of course, serves many purposes. For most sites, reclamation is understood as rehabilitating

TABLE 3.5 Representative Costs for Disposal of Solid Wastes from Mining and Processing

Operation	Location	Kind of Mine or Process	Tailings Storage and Stabilization	Cost (dollars)
Sherwood Project (Western Nuclear)[1]	Washington	Uranium mine under development	Install lining for tailings pond:	2-3 million
			Site preparation, 2,000 acres	4 million
			30-mil Hypolon lining	
Uranium Milling Industry[2]	Various	Milling and leaching	Increase storage volume of tailings to comply with Federal requirements	Range: 0.1-1.0/ton Average: 0.4-0.5/ton
Phillips-United Nuclear Mill[3]	Ambrosia Lake, New Mexico	Uranium mill	Stabilize 2,600,000 tons of tailings on 105 acres (depth 12 ft)	
			Option 1: construct stable perimeter, install fence, remove debris from open land, monitor and maintain	(1977 estimates)
			Engineering	74,000
			Construction	615,000
			Prepare impact statement	26,000
			Contingency	105,000
			Maintenance	100,000
				920,000
			Option 2: same as option 1 but cover and grade tailings to inhibit water erosion (no revegetation)	
			Engineering	152,000
			Construction	1,680,000
			Prepare impact statement	26,000
			Contingency	282,000
			Maintenance	90,000
				2,230,000

Star-Morning Mine (HECLA)[1]	Wallace, Idaho	Underground mine for lead, zinc, and silver (200,000 tons/year)	Disposal of tailings: slurry line, construction of pond, flocculation chemicals, operation and maintenance	1.00-1.50/ton
Oil Shale Industry[4]	Colorado	Underground mine with surface retorting	Backfill underground workings with processed shale (ore grade: 28 gallons per ton) assuming chamber and pillar mining	
				(1976 dollars)
			Conveyor transport	0.3101/ton
			Conveyor with pneumatic topfill	0.4221/ton
			Truck transport	0.5412/ton
			Hydraulic (slurry) transport	0.7640/ton
			Pneumatic transport	1.1855/ton
			Surface disposal only	0.2438/ton
Coastal Plain Phosphate Industry[5]	Florida	Strip mine and milling	Comply with State Requirements for disposal of slimes and tailings	
				(1978 dollars)
			Current operations	0.117/ton of product
			New operations	0.375/ton of product

TABLE 3.5 (continued)

Operation	Location	Kind of Mine or Process	Tailings Storage and Stabilization	Cost (dollars)
Homestake Mine[6]	Lead, South Dakota	Underground gold mine (1,650,000 tons/year)	Install and construct new tailings pond in compliance with State and Federal guidelines, 1975-1978 (see also control costs for waste water):	
				(1975-1978 dollars)
			Site preparation and engineering	1,051,250
			Mobilization	300,000
			Foundation and area preparation	678,800
			Embankment	3,940,500
			Interceptor canal	1,845,000
			Emergency pond	2,000
			Seepage collection ditch	125,000
			Electrical service	15,750
			Monitoring and stabilization	109,000
			Demobilization	100,000
			Slurry pipelines	1,989,600
			Slurry pump station	956,750
			Decant pump station	53,300
				11,166,950

[1] U.S. EPA (In press).

[2] COSMAR (1979) Panel on Discontinuous Sedimentary Ore Bodies in Bedded Rock.

[3] Ford, Bacon & Davis Utah, Inc. (1978).

[4] Earnest (1978).

[5] Zellars-Williams, Inc. (1978).

[6] Jeffries and Tczap (1978).

the disturbed area by grading in a manner compatible with the surrounding landscape, or with the intended postmining use, and establishing a self-sustaining vegetative cover. Reclamation is intended to control erosion, to restore the hydrologic balance, and to limit the off-site impacts, during and after mining. The ultimate purpose is to restore the mining site to productive use, for example, for agriculture, forestry, industry, housing, recreation, or fish and wildlife habitat. Desirably, this use should be at least as beneficial as the capability of the site before mining although not necessarily for the same purposes.

The need to integrate reclamation into the total mining operation is widely advocated, and planning for reclamation from the beginning of operations is generally accepted as being the only way to assure optimum results (Bradley 1977, Brammer 1978, Cook 1976a, Ellison 1976, Jonas 1973, Kesten 1977, Leathers 1976, Reilly 1975, Tuma 1976). According to these views, mining is an interim use of the land, although perhaps prolonged, directed in part toward some anticipated postmining land use, but recognizing that a return of the land to its premining status may be neither economically feasible nor desirable (Berg 1972, Dean and Shirts 1977, LaFevers 1977, Packer 1974).

In assessing the rehabilitation potential of a particular mining area, a number of factors are relevant. Some of these, according to O'Neil (1977) are: (a) the magnitude and topography of disturbed land, (b) chemical properties of the mining wastes, (c) physical properties of the waste, (d) an economic analysis of the mining and reclamation plan, and (e) climatic factors. In arid regions, the quantity and availability of water for irrigation is an especially important consideration, although for most commodities the predominant water use is for processing and waste disposal (Section 5.2.3). The possibility of reclaiming a mining area for social needs may also be pertinent.

A long-term ecological approach to land reclamation deemphasizes the agricultural aspects and places greater weight on successional processes so as to develop self-perpetuating plant and animal communities (Curry 1975, Ludeke 1977, Wahlquist 1976). This ecological approach stresses the concept of minimal impact and recommends that a "mining ecology" be developed, integrating mining and non-mining uses of the land under a system that reflects an understanding of the ecology of the area (Bonham 1976, Lane 1968, Wali and Kollman 1977). That is, the ecological approach attempts to limit long-term impacts that would reduce the plants and animals of an area or limit biological productivity.

Rebuilding the soil is thought to be the key to lasting reclamation success (Cryderman and Shetron 1976, Dean and others 1969, McCormack 1976). Soil development is greatly influenced by the available moisture, a factor that may severely inhibit reclamation success in arid regions (Berg 1972; R.W. Brown 1976; Hodder 1977, 1978). Large-scale contouring and grading, when used with small-scale surface treatment, is often beneficial in conserving moisture and reducing erosion (R.W. Brown 1976, Draskovic 1973, U.S. Environmental Protection Agency 1973, Ludeke 1977, Stephan 1977). Machines have been developed to meet these needs (Hodder 1976, 1977).

To plan for an ecological approach to reclamation, specific baseline data are needed, beginning with exploration and continuing through a mine's development (Clark 1974, Ellison 1976, U.S. Environmental Protection Agency 1973, O'Neil 1977, Rudio 19 ?, Wahlquist 1976). Such an inventory includes information on all the physical and biological features--for example, the ground-water hydrology and characteristics of the overburden (Schuman and others 1976, Dean and others 1973, Packer 1974).

Although aesthetic appeal is seldom a primary reclamation objective, it deserves consideration in most mining and reclamation plans (Beverly 1968, National Research Council 1974:55-57, Fenton 1973, Arthur and others 1977). Surfaces can be shaped and waste material from mining and processing can be placed such that a desired landscape design is achieved, thus helping to control erosion by wind and water and leaching of unwanted constitutents, as well as creating areas having new and productive uses. Recreational lakes are an example, particularly in places used for quarries. For this purpose, the services of landscape architects can be helpful (Chironis 1977, Down and Stocks 1977, Greenwalk 1976, Matter and others 1974, Mittmann 1974).

Revegetation is currently the preferred method of stabilizing disturbed sites (Dean and others 1973, 1974). Some of the recommended practices are listed below:

1. Burying materials poisonous to plants (Farmer and others 1976).

2. Leaching of tailings and other chemical methods of treatment to ensure success of plant growth (U.S. Environmental Protection Agency 1973, James 1966, Kenahan and Flint 1972, Nielson and Peterson 1973, and Watkin and Winch 1974). For example, allowing the land to lie fallow after its initial grading can increase leaching (Gemmell 1975, Ludeke 1977).

3. Combining chemical stabilizers with vegetation to enhance control of erosion (J.A. Brown 1974, Kay 1977).

4. Adding fertilizer in beneficial amounts, but avoiding continuous use that can hinder the development of self-perpetuating vegetation (R.W. Brown 1976, Gemmell 1975, Gordon 1969, Shetron and Duffek 1970).

5. Using sewage sludge as a soil amendment in order to control erosion and to stimulate plant growth (Dean and Shirts 1977, Dean and others 1973, U.S. Environmental Protection Agency 1973, Gordon 1969, Hodgson and Townsend 1973, Ludeke 1977, Peters 1974, Watkin and Winch 1974). Other organic soil additives such as mulches can hold seed in place and improve the water balance of the soil (Hodder 1977, Ludeke 1977).

6. Encouraging nutrient recycling (Peters 1974) and nitrogen-fixing plant growth as a means of increasing soil productivity (Berg 1976).

7. Using microbial soil inoculants from neighboring undisturbed soils to provide beneficial microorganisms that enhance vegetation growth (Aldon 1976a, Reid and Grossnickle 1978).

8. Adding topsoil, where feasible, to improve revegetation success (R.W. Brown 1976, U.S. Environmental Protection Agency 1973, Schuman and others 1976).

9. Increasing plant diversity and the number of native plants to improve the potential for plant survival (Aldon 1976a, R.W. Brown 1976, Chosa and Shetron 1976, Curry 1975, Ludeke 1977, Usai and Suzuki 1973).

10. Planting more easily grown, non-native plants as a nurse crop for native plants (Berg 1976, Dean and others 1969, Hodgson and Townsend 1973). Species capable of withstanding harsh site conditions, particularly high concentrations of metallic ions, may be advantageous for initial planting (Goodman and others 1973, Kenahan and Flint 1972, May 1967, Stephen 1977).

11. Collecting native seeds or plants in an area and then planting them on disturbed areas (Ludeke 1977).

Although revegetation is the most commonly accepted approach to reclamation, alternatives do exist. One procedure would be to use the mine waste as building or construction material (Kenahan and Flint 1972, Spendlove 1977). In some cases it might be better to plan a non-biological use--an area of solar or water collectors, for example--rather than simply to camouflage the disturbance caused by mining (May 1967, Aldon 1976b).

3.5.2. Reclamation of Waste Rock, Pits, and Tailings

The reclamation problems for large open-pit mines include the pit itself, the waste rock from removal of overburden, and tailings produced by milling the ore.

3.5.2.1 Waste Rock

Control of air and water pollution from piles of waste rock may be enhanced by suitable placement, construction of diversion ditches, and the like, but a stable cover on the waste pile can further reduce fugitive dust and impede the loss of surface moisture. The cover could consist of rocks, gunite, asphalt, concrete, smelter slag, bark, or replaced topsil. Among these materials, topsoil is the only cover that blends with the natural surroundings and that serves biological needs.

Chemical stabilizers, although not intended to be permanent, can effectively hold down dust in extreme situations and inhibit erosion by water. These chemicals are particularly useful in areas of harsh climates or where topsoil is not available.

3.5.2.2 Open Pits

It is axiomatic that a mineral can be mined only where it is found. Thus, if an ore deposit is mined by open-pit methods, the resulting pit may be more or less conspicuous, depending on geological circumstances. Active open pits, as compared with surface coal mines, provide little opportunity (if any) for simultaneous mining and reclamation because the pit continues to expand and deepen as long as the mine is producing. Also, the ultimate depth and shape of the pit, although roughly predictable, are dictated by the economics of mining and the geometry of the ore deposit rather than by particular reclamation goals. Indeed, the very size of a large open pit would make restoration by backfilling, or even by reshaping, an enormous economic burden of uncertain benefit (Section 5.2.2), and inactive open pits could be reactivated if economic conditions became favorable. Thus, in practical terms, reclamation of open pits is limited to planning for the placement of rock dumps and tailings ponds that will remain when the mining operation is closed. Principles of landscape design can be applied at little additional cost in placing these materials in a manner that achieves beneficial postmining land use (Matter and others 1974). The landscaping could be done by the mining company itself, or redevelopment rights could be leased or sold. The potential forms of redevelopment vary significantly from one mine setting to another, as do considerations of economic, social, and physical feasibility.

An example of redevelopment of mine wsates for a "higher or better use" is the construction of the Community Center of Morenci, Arizona, on an abandoned tailings pond. Imaginative designs of this kind can be easily expanded to include recreation activities, housing, or even facilities to collect solar energy (Matter and others 1974). Such redevelopment could be timely where mining sits are close to urban areas. Indeed, the increasing pressure for new housing and recreation, together with the need to preserve land that might otherwise be occupied by urban growth, calls for creative approaches to land reclamation (Figure 3.3).

In summary, where large volumes of material are handled in open-pit operations, redevelopment could be a legitimate postmining land use, in lieu of reclamation aimed only at establishing the original conditions. Such use can yield an economic return to offset the costs of reclamation and maintenance.

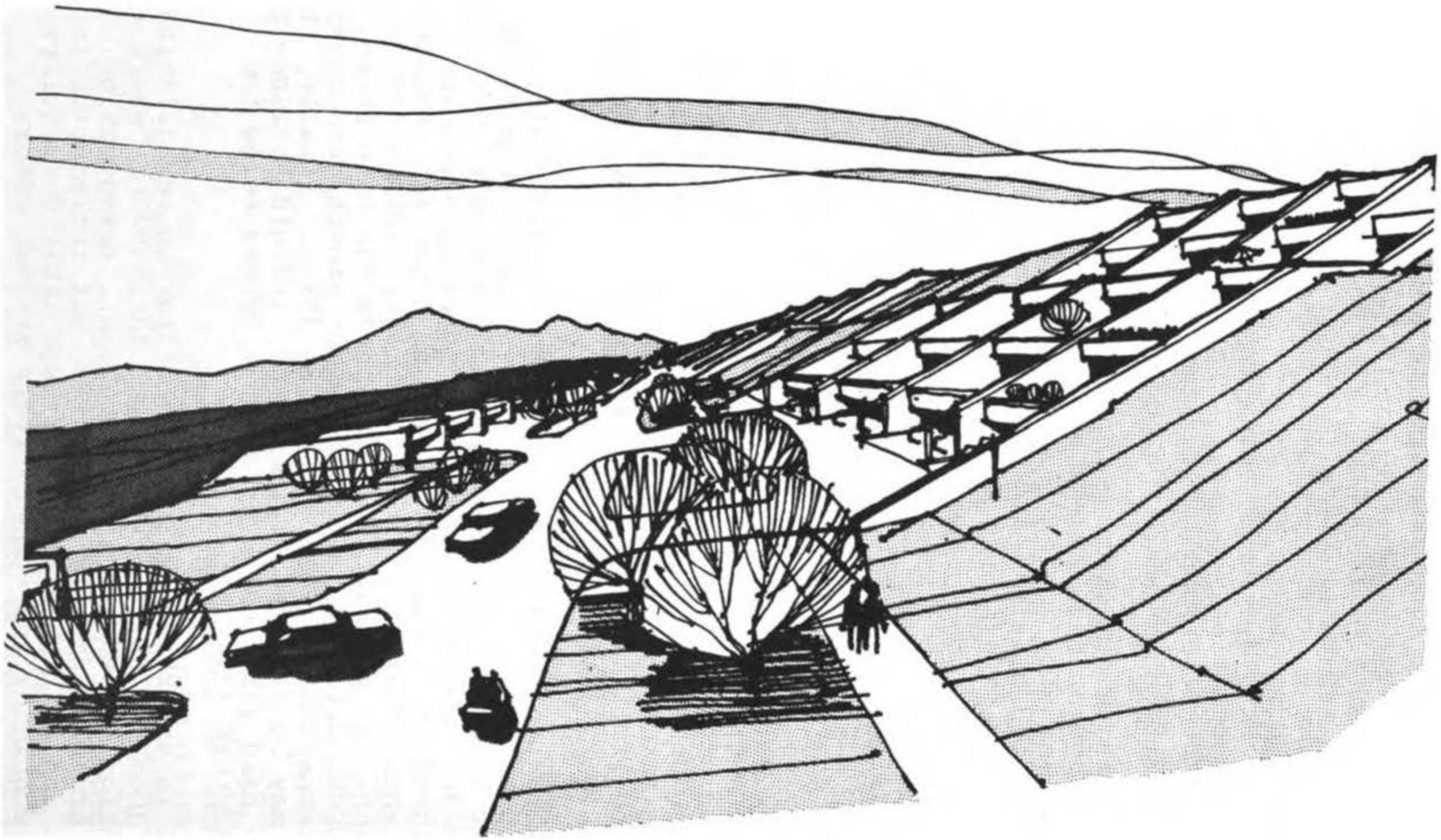
3.5.2.3 Tailings

Of all the mining wastes, mill tailings are the most intractable to reclamation, in part because their amounts can be very large, from 30,000 to 100,000 tons per day (Soderberg and Busch 1977). A complicating factor is that reclamation of waste rock and tailings could be premature if future technology or economic conditions makes them attractive as deposits of lean ore (Mantell 1975). However, the need to limit airborne dust may require that tailings be reclaimed in a timely manner.

Revegetation of tailings is inherently difficult, regardless of the ore mined, because tailings seem to be physically incapable of supporting higher plants (Dean and others 1969). Their fine-grained particles, which are easily picked up by wind when dry, and which are physically unstable when saturated, are also a major problem for reclamation. In addition, tailing ponds may have steep outer slopes, deficient water for plant growth, and severe surface temperatures (Down and Stocks 1976). Finally, the tailings may be cemented or compacted, and old tailings can develop a hard oxidized layer about 8 inches below the surface (Peters 1974).

Water is an extremely limiting factor in revegetating tailings (Cook 1976b, Ludeke 1977, Hodder 1977). Where the precipitation exceeds 20 inches (500 mm), revegetation problems are considerably simplified, but reclamation in the arid West and at high altitude or high latitude requires special techniques and comparatively greater effort.

Reclamation of tailings must start by building physically stable gradients and by then developing a medium



SOURCE: Matter and others (1974).

FIGURE 3.3 Sketch of possible housing on redeveloped mine wastes.

for plant growth on the tailings. This cover should resemble undisturbed soils near the mine in order to minimize long-term maintenance and to promote the growth of native plants (Curry 1975). Adverse characteristics of the tailings must be mitigated, namely: deficient nutrients; extreme alkalinity or acidity; excessive salts and heavy metals; deficient microbial populations; and frequent blowing dust (Dean and others 1974). Soil stability can be achieved through the use of mechanical surface manipulation, mulches, planting of annual species, and, finally, by establishing permanent vegetation (Hodder 1976). Soil moisture can be increased by impeding runoff, increasing infiltration, and reducing evaporation.

Soil neutralization, which enhances plant growth and reduces the mobility of heavy metals (Nielson and Peterson 1973), can be accomplished through either natural or induced leaching. Spraying an area with a fine mist until leaching progresses below the root zone has been successful in some cases (James 1966). Drip irrigation also has been used to leach the root zone, but its practicality in large revegetation projects is limited (Shoji 1977, DeReemer and Buch 1977). In humid areas, letting a site lie fallow for one or two years will allow natural leaching of salts (Gemmel 1975). Other neutralization procedures include adding sulfuric acid to saline and alkaline soils, and treating acidic soils with limestone or fly ash (Dean and Shirts 1977). If fly ash is used, the toxic elements that are commonly found in fly ash can be bound up as organic complexes by use of compost, manure, or barley straw. Placing the fine and coarse fractions of tailings in layers also helps to reduce the salinity (Dean and others 1973).

Tailings are poor in nutrients and use of commercial fertilizer is often recommended, even though the resulting plant cover may then require continued applications. Cook (1976b) says that commercial fertilizers should not be applied until the second year, if used at all. Inoculation of tailings waste with native soil or commercial mycorrhiza (a microorganism found in soils) has been shown to be particularly helpful in establishing vegetation (Aldon 1976a, Reid and Grossnickle 1978).

Applying sewage sludge to tailings appears to enhance revegetation (Peters 1974). Furthermore, Hodgson and Townsend (1973), from revegetation experiments on pulverized fuel ash, found that any bulky ameliorant such as sewage sludge, shale, or peat improved the growth medium. Spreading the sludge can alleviate blowing dust on tailings ponds (Peters 1974) and is more effective than topsoil in creating a growth medium where soils are poorly developed (Ludeke 1977). Sludge increases the water-holding capacity of the soil, moderates the pH, helps to dilute any phytotoxic materials that may be present, and is a good source of nutrients (Dean and Shirts 1977).

Legumes and other nitrogen-fixing plants should be encouraged to enrich the soil in nutrients (Hodgson and Townsend 1973), and early growth on tailings should be plowed back in to conserve nutrients and reduce the need for fertilizer (Peters 1974). For this reason, harvesting during the initial years is not recommended, and grazing by livestock and wildlife should be prevented.

Native species are often recommended (Aldon 1976a, Curry 1975, Ludeke 1977 and others), and transplanting them to disturbed areas has been found to be effective (Ludeke 1977). Whether or not native species are used initially, they may become established on the tailings after non-native plants have been growing for a few years.

Both broadcast seeding (Hodder 1976) and drilling (Cook 1976b) have been recommended as methods of planting. Also, most authors agree on the importance of some type of mulch to protect seeds, keeping them in place and providing some additional soil moisture (Hodder 1977, Kay 1977). Hydroseeding with a combination of mulch, seeds, and chemical stabilizers can provide a stable medium for germination (Day and Ludeke 1979); the most successful chemicals are elastomeric polymers such as Coherex (Kay 1977, Berg 1972).

3.5.3 Special Problems of Reclamation

3.5.3.1 Western Oil Shale

The principal land-related impacts of oil-shale development are expected to be changes resulting from disposal of solid wastes, construction of surface facilities, and possibly subsidence if in situ processing is used. Technical methods for controlling these impacts are uncertain because an oil-shale industry has not yet developed, and much additional research and industrial experience is needed before these uncertainties can be resolved. However, the solid wastes are known to differ both chemically and physically from those of other industries, and the volume of these wastes would exceed those of any comparable operation.

Environmental and aesthetic considerations will require that the disposal piles of processed shale be revegetated, and certain studies suggest that this may be possible. For the most arid areas, the use of containerized plants and water harvesting methods are briefly mentioned in Section 3.4.4.1. For less arid sites, it is generally agreed that the following minimum steps will be required:

1. Leaching salts from the top layer of the shale pile.

2. Applying a soil layer for plants with such additives as soil conditioners, native microorganisms, topsoil, and fertilizers. (Topsoil, however, may be available only where surface mining is done to recover oil shale, such as in open-pit operations.)

3. Selecting a mixture of native and imported plants compatible with local climate and soil conditions.

4. Protecting surfaces with mulches, and installing fences to ward off grazing animals.

5. Irrigating the planted area for two years or more to establish a viable root system.

3.5.3.2 Uranium

The reclamation of lands mined for uranium in the West is handicapped by low precipitation, high evaporation and transpiration, a short growing season, and poor soil.

Uranium tailings are usually extremely fine and very difficult to stabilize. A control procedure is to place the sands and slimes in layers and to adjust the acidity by adding lime (Kennedy 1978, Nielsen and Peterson 1973). The spoils from overburden, or interburden, can be acidic, but natural leaching over a period of years can remove most of the acid-forming ingredients at the surface. Also, the natural acidity can be reduced more quickly by treatment with lime (Watkin and Winch 1974), although the amount of lime required may be prohibitively expensive.

The characteristics of plants needed for successful revegetation at Western uranium mines are quite specific. The plants must be resistant to drought, acidic and alkaline soils, salt, and radioactivity. A simple and effective approach is to revegetate disturbed sites with plants that have actually invaded piles of overburden, such as sagebrush, rabbit brush, greasewood, and saltbush, as well as Russian thistle and many grasses and composites. Plants that accumulate selenium also thrive on areas disturbed by uranium mining in the West.

Reclamation of uranium tailings--that is, prevention of erosion--has special significance for long-term control of low-level radioactivity. To meet radiation standards, dust from tailings should be controlled (Kennedy 1978), and sites with identified radioactivity should be covered with country rock (Nielson and Peterson 1973). Uranium tailings can be graded and covered with sufficient overburden and topsoil to control emissions of radon. For this purpose, inactive tailings must now be covered to a depth of as much as 10 feet (Section 3.4.4.2). Seeding and fencing complete the initial reclamation. Underground disposal at significant depth would eliminate problems of erosion and radiation, but the possible effects on shallow ground water would need to be considered (Section 3.4.4.2). Also, uranium tailings should be regarded as potential ore bodies and should not be made too inaccessible (Kennedy 1978).

3.5.3.3 Coastal Plain Phosphate

Phosphate mines in Florida and North Carolina, operating in wetland ecosystems and using a hydraulic process to extract the phosphate, face a unique set of reclamation problems, most of which center on dewatering the slimes produced by processing. Reclamation efforts are divided between the slime pond and the mined-out pits (Moudgil 1976). A primary goal in reclaiming the slimes is to dewater them enough to make them able to support the agricultural machinery used for reclamation (Section 3.4.4.3). The land is otherwise favorable for reclamation, being flat and mantled with sand or clay that supports vegetation fairly well. Because of the prevailing shallow ground water, the mined-out pits become lakes that can be beneficial for wildlife and recreation.

In 1960 American Cyanamid devised a method of reclamation that could be carried on simultaneously with mining, at a cost 40 percent less than the conventional methods then being used. Small blocks within a large tract of mineable land are mined in sequence, thus making more efficient use of draglines and pipelines, as well as allowing some opportunity to backfill the mined-out pits. Consideration must be given to the mine depth, the thickness of overburden, the reach of the dragline, the contour of the adjacent property, and the distance from the processing plant. Since many of the pits become lakes, planning for their eventual use is desirable. Such planning involves consideration of the mine cuts and the grading of overburden.

3.5.3.4 Western Copper Mines

The main reclamation problems for western copper mines are in revegetating mill tailings. For example, as demonstrated by a study at Kennecott's copper mine at Ely, Nevada (Dean and others 1969), tailings do not support plant growth very well because of their deficient nutrients and their adverse textural, structural, and chemical properties. Plant growth is inhibited by poor aeration, lack of moisture, and by salts and heavy metals. Moreover, the light-colored tailings reflect sunlight onto plant surfaces, and dust picked up by wind causes the young plants to be sandblasted or buried.

Agricultural plants and introduced species generally are easier to establish on such tailings and grow more vigorously than wild varieties. Thus, nitrogen-fixing plants and winter wheat, the first crops to be grown on these tailings, are used to control erosion and increase the content of nitrogen. Growth is better in places where a granular, soil-like texture can be achieved, but even the simplest methods of making granular soil are expensive. Coherex, a proprietary chemical stabilizer, is economical and effective in controlling erosion and is compatible with plant growth.

The Cyprus Pima copper mine in Arizona has developed a number of effective reclamation procedures (Ludeke 1977), including: (a) grading to smooth gullies on the outer sides of tailing ponds, (b) building anti-erosion lips at the head of slopes, (c) constructing cross-dikes adjacent to a slope to collect water, (d) breaking up surface crusts to decrease compaction, (e) applying compost at a rate of 5 tons per acre, (f) spraying of sewage effluent at a rate of 1,000 gallons per acre, (g) irrigating before planting, (h) hydroseeding, (i) mulching, and (j) further irrigating with the addition of fertilizer to the water.

3.5.4 Costs

Reclamation costs, although not always reported separately, can be considered as including expenses for grading, contouring, stabilizing, topsoiling, seeding, irrigating, fertilizing, and maintaining tailings impoundments, waste dumps, and other land disturbed by mining. Thus, these costs in part overlap other costs for control of mining impacts, as discussed above in this chapter. The costs of typical reclamation activities are more or less comparable, regardless of location (Table 3.6), although the range represented by a few operations is quite large. The extremes range from $64,000 per acre at the Urad Mine in Colorado to establish trees on inactive tailings, to less than $200 per acre for simply hydro-seeding of commercial grasses under favorable conditions.

TABLE 3.6 Representative Costs for Reclamation of Areas Disturbed by Mining and Processing

Operation	Location	Kind of Mine or Process	Reclamation Activity	Costs (dollars)
Urad Mine (AMAX)[1]	Empire, Colorado	Underground Molybdenum (inactive)	Reclaim 2 tailings areas comprising 125 acres by covering tailings with 5 ft. of rock, spreading 20 tons/acre sewage sludge and 20 tons/acre wood chips, fertilizing with P_2O_5, and planting seedlings and transplants in first year In years 2 and 3, apply 10 tons/acre sewage sludge and replant failures, apply fertilizer annually until 1996	8,000,000 1974-1982
Climax Mine (AMAX)[2]	Climax, Colorado	Underground and open pit molybdenum (48,000 tons of ore/day)	Hydroseeding of construction site	400/acre (1977)
			Hydroseeding of steep slopes and install nylon erosion netting	1,600-1,800/acre (1977)
			Complete reclamation of mine (estimate)	27,000,000 (1977)
Star Morning Mine (HECLA)[2]	Wallace, Idaho	Underground lead, zinc, silver (280,000 tons of ore/year)	Revegetate tailings, using fertilizer, irrigation, straw, and seed	200/acre
Sacaton Mine (ASARCO)[3]	Casa Grande Arizona	Open pit copper (9,000 tons of ore/day (43,200 tons of waste/day)	Reclaim dam faces and construction sites by planting 335 gallon-size native shrubs per acre, supported with drip irrigation	1,900/acre of which 1,000/acre is for irrigation system

Cyprus Pima[8]	Tucson, Arizona	Open pit copper (inactive 1978)	Reclaim face of tailings ponds by hydroseeding, fertilizing, irrigating, planting of indigenous and introduced species of grasses, trees, and shrubs, including R&D (estimate)	1,600,000 6,000/acre
Erie Mining Co.[3]	Hoyt Lakes Minnesota	Open pit taconite (50,000,000 tons of ore/year) (20,000,000 tons of waste/year)	Reclaim face of tailings pond by hydromulching, applying 30-45 pounds of grass and legume seed and 250 pounds of fertilizer/acre; wood pulp, excelsior, straw, hay, or plastic emulsions are used for mulch	550-600/acre (1977)
			Temporarily stabilize tailings	150/acre (1977)
Klondyke Mine Englehard Minerals[2]	McIntyre Georgia	Scraper strip Kaolin	Reclaim 15 acres/year, including backfilling of overburden contouring, planting with grass and trees (Loblolly and slash pine) and maintenance. (Reclamation governed by 1968 State Surface Mining Act.)	400/acre
Thiele Kaolin[1]	Sandersville Georgia	Dragline strip Kaolin	Revegetate with grasses and trees; return to agriculture or recreation (lake)	500/acre

TABLE 3.6 (continued)

Operation	Location	Kind of Mine or Process	Reclamation Activity	Costs (dollars)
American Industrial Clay Co.[4]	Sandersville Georgia	Dragline and scraper strip Kaolin stripping ratio 6:1-8:1	Reclaim according to 1968 Georgia Surface Mining Act Greatest expense is regrading and preparation of spoils	Average 1973: 300/acre Typical 1976: 680/acre Many areas 1,000/acre 1976:
American Colloid Co.[5]	Bighorn County Wyoming	Bentonite surface mine	Reclamation procedures: contouring topsoiling seeding	200/acre 100/acre 50/acre 350/acre
Wyo-ben Products[5]	Wyoming	Bentonite surface mine (200,000 tons of ore and 700,000 cubic yards overburden per year)	Reclaim 65.6 acre/year: Replace overburden and topsoil Revegetation (unsuccessful)	16,000 2,500 18,600/year 283.54/acre
Federal Bentonite[5]	Crook County Wyoming	Bentonite surface mine	Regrade to original contour and bring land to use equal or greater than it was previous to mining	371/acre
Raycee Bentonite[5]	Washakie County Wyoming	Bentonite surface mine	Regrade, remove spoil piles, highwalls and pit bottoms	326/acre
Highland Exxon[5]	Douglas Wyoming	Open pit and underground uranium	Reclaim tailings at close of operations (1973 estimate), including covering with mixture of soil and lime 2 feet thick and seeding with grasses	1,000/acre

Agrico Chemical Co.[2]	Bartow Florida	Phosphate strip mine. Mine 1,200-1,600 acres/year	Reclaim clay slimes by planting 2 crops of annuals/year for 4 years and then plant grass	400-700/acre
			In 1977 reclaimed 2,444 acres	400-5,000/acre
			Seeding, dolomiting, and fertilization	120-150/acre
Florida Phosphate Industry[6]			Reclamation cost for current operations	.335/ton product
			Unreclaimed land fee for current operators	.200/ton product
			Reclamation cost for new operations	.418-.561/ton product
Uranium Industry[5]		Open pit 1,600 ton/day	Reclaim at rate of 100 acres/year	1,000-2,500/acre
Uranium Industry[5]		Underground	Cost of reclamation of surface plant	500-1,000/acre
Ideal Basic Industries[7]		Surface Quarries (Cement)	Estimated cost of restoring quarries to original contour:	
			Direct cost	76,761,000
			Cost of contouring pits	118,979,000
			Total estimate for Ideal Industries	195,740,000
Solvay[7]	Manlius New York	Surface operation	Reclaim 90 acres:	
			Tailings, haulage, grading, etc.	2,245/acre
			Tree planting, 90 acres	48/acre
			Grading and terracing of pit wall	1,500/acre

TABLE 3.6 (continued)

Operation	Location	Kind of Mine or Process	Reclamation Activity		Cost (dollars)
Phosphate Industry[8]	Southeast Idaho	Surface Operation	Waste dump shaping and grading		2,500/acre
			Seed bed preparation		55/acre
			Fertilizing and planting (1977 costs)		155/acre
Blackbird Mine Idaho Mining[8]	Blackbird Idaho	Undergroud (cobalt)	Reclaim sulfide-bearing overburden and waste dump (12 acres)		
			12 acres:		
			Grading and reshaping spoils		320/acre
			Liming, machine ripping	125/acre	
			lime (20 ton/acres)	640/acre	765/acre
			Topsoil (at $1.25/yd)		833/acre
			Fertilizer (includes application)		165/acre
			Planting (includes cost of seed)		155/acre
			Straw mulching (includes application)		150/acre
			Average for 12-acre project area		2,388/acre
			Reclaim tailings pond (300 acres):		
			Site preparation		210,000
			Topsoiling, $1.50/cu yd, 1 ft deep 484,000 cu yd		726,000
			Liming, $200/acre		60,000
			Fertilizer, 3 applications		36,000
					1,032,000
					3,440/acre

Uranium Industry[5]	(various)	Open pit	Backfill pit	55,000,000
Pinto Valley[8]	Miami, Arizona	Open pit (copper)	Backfill pit	330,000,000
Berkeley Pit[8]	Butte, Montana	Open pit (copper)	Backfill pit	550,000,000
Twin Buttes[8]	Tucson, Arizona	Open pit (copper)	Backfill pit	1,525,000,000
Bingham Canyon[8]	Bingham, Utah	Open pit (copper)	Backfill pit	3,230,000,000
Climax[8]	Climax, Colorado	Open pit (molybdenum)	Backfill pit	1,600,000,000
Pits and Quarries[7] of the cement industry	(various)	Quarry	Backfill pit	2,965,000,000

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[1] Hoppe (1978).

[2] U.S. EPA (1978).

[3] Argonne National Laboratory (1977a).

[4] Argonne National Laboratory (1978b).

[5] COSMAR (1979) Panel on Discontinuous Ore Bodies in Bedded Sedimentary Rocks, Appendix II-C.

[6] COSMAR (1979) Panel on Coastal Plain Deposits.

[7] Appendix A.

[8] Kenneth L. Ludeke, personal communication (1979).

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CHAPTER 4

EXISTING GOVERNMENTAL CONTROLS AND RECLAMATION REQUIREMENTS

4.1 DISPERSED RESPONSIBILITIES

The web of existing governmental controls constitutes a part of the environment within which provisions of the Surface Mining Control and Reclamation Act might be extended beyond the regime of coal mining. Some essential features of existing controls and powers are reviewed in the following sections. From our review, it appears that existing control powers are spread among local, State, and Federal governments; responsibilities are frequently not coordinated, a condition that appears to stem from past events more than from modern needs.

4.1.1 Three Streams of Legislation

Existing controls and requirements generally come from one of three historic streams of legislation. One stream deals with protection of the public safety and health, a second with land use planning and controls, and a third with conservation of natural resources and protection of natural environment. These three streams have evolved over several generations in related but separate movements. Their intellectual and organizational drives came from different academic disciplines and different parts of the nation's social fabric. For illustration of both the separateness and convergence of environmental laws see Kaiser and others (1974) and Dolgin and Guilbert (1974).

4.1.2 Different Levels of Government

The problem of bringing these three streams of legislation together in a coordinated way, for any particular parcel of land and its particular use, has been aggravated by a tendency to emphasize the different approaches in different degrees at different levels of government. In sections 4.2 through 4.5 existing controls and regulations of non-coal surface mining are viewed at the local, State, and Federal government levels. When one does that, one is also viewing, to some extent, the separation of naturally integrated decisions about location and purposes for any specific land use on any specific parcel of land. (See Almond 1975 for a good illustration of this point.)

4.1.3 The Management Coordination Problem

Given the divergent sources of motivation, the size and the diversity of the industry, and the massive detail of regulations, there is naturally a risk that planning and regulatory actions will lack full coordination (Bosselman and others 1976; Council on Environmental Quality 1978:185, 205, 210). The diversity of regulation is noted in the following sections of this chapter. There are many other cases. For example, one finds commonly that one agency issues a permit to withdraw water from a river, another issues a permit to discharge pollutants in the same place into the same river (Ramani and Clar 1978). One also finds that if a given mine operator is required to report the results of his water quality monitoring to two different Federal agencies the second agency learns the identity of the first from the mine operator rather than through interagency communication and cooperation (see Office of Surface Mining 1979).

4.2 LOCAL REGULATION

Counties or municipalities may regulate mining and reclamation of mined lands through zoning or other land use laws, in accord with powers granted them by State statutes. Although this type of local regulation is most likely to exist in densely populated areas, it may be applied under city and county zoning laws in many places. Several Supreme Court decisions have upheld the legal authority of local governments to regulate private mining near metropolitan areas. Zoning laws may not only require compliance with certain standards of performance if mining is to be conducted within an area, but may also require detailed end-use planning before mining is permitted at a site.

Local governments may vary considerably from one State to another in their control of mining. For example, all of the iron mines in Minnesota are subject to local municipal zoning, or county zoning if they lie outside an incorporated municipality (E. Rafn, Chief, Minerals Division, Minnesota Department of Natural Resources, personal communication, March 1979). In Colorado, compatibility with both local land use controls and zoning is required. But local zoning of surface mining operations covering more than 5 acres is prohibited in Arizona (see Working Paper VII), in effect insulating major enterprises with national impacts from local land use controls. Such variation results at least in part from differences in State enabling legislation.

Local controls also appear to reflect differences in local attitudes and circumstances from one type of environment to another. For example, attitudes toward zoning and performance standards on mining land are different for one municipality, isolated in northern forest or intermountain desert, than they are in other communities that are suburban to the metropolis, sensitive to its residential values, and economically independent of local business. Local controls and regulations naturally reflect concerns of local governments. For example, on the Mesabi Range in Minnesota, industrial zoning is applied to all currently active mining properties and virtually all inactive or abandoned ones; but major portions of the iron formation that are not yet under active mine development are not zoned and are not protected from an intervening, incompatible development that could result in eventual needless expense and strife if the decision is made to develop the ore (E. Rafn, Chief, Minerals Division, Minnesota Department of Natural Resources, personal communication, March 1979). On the other hand, in metropolitan suburban locations, local zoning may be invoked to prevent the development of major sand and gravel deposits which are necessary for efficient building and maintainance of the wider community (see Working Paper III). In both cases, there has been a lack of suitable procedure to satisfy the interest of both local citizens and other citizens of the wider, regional or national community.

In short, local controls are mainly land use controls, carried out primarily through zoning performance standards. The performance standards have not completely excluded but have not generally or systematically included such matters as dust control, sediment control, or quality of water and air moving across property lines and zone boundaries. Furthermore, local land use controls naturally tend to emphasize local priorities. Major known mineral deposits are not generally protected or reserved for future mining. Local communities may ignore national needs, and national corporations and public agencies may promote the national interest without due regard for expenses to local citizens.

4.3 STATE REGULATION

The reclamation of surface mining land in the United States began in the Midwest in the 1920s, when coal companies initiated a volunteer program attempting to establish, at minimum cost, quick-growth forest on ungraded spoil heaps. This venture was followed by the successful conversion of strip-mined land in Indiana to pasture and row-crops in the well-known Meadowlark Farms project. These demonstrations provided substantial impetus for the first State mined-land reclamation law, enacted in West Virginia in 1939. Others soon followed in Indiana, Illinois, Pennsylvania, and Ohio.

Early State reclamation laws addressed only coal mining. Rules were promulgated requiring revegetation and, in some cases, reduction of spoil pile slopes as a means of converting strip-mined land to a land cover that would be of economic value and reduce erosion.

In the 1950s and 1960s, revision of the early laws and newer laws passed in other States added requirements for soil conservation and water-quality control at the mine.

Near the close of the 1960s, States began to expand coverage of their laws to all mines and to both surface and underground mining, and the new State laws tended to address land use planning as part of reclamation. Detailed standards were developed relating to all the major activities that occur at a mine site--before, during and after mineral removal--and to the impact of the mining and reclamation activities on the surrounding environment. In the 1970s the emphasis of State regulation has been to integrate mined land reclamation with land use planning, treating mining as an interim land use.

As of May 1, 1977, 38 States had enacted statutes regulating mine reclamation. The scope of these laws varies. Seven of the States regulate coal mining only, while 28 regulate virtually all minerals. The types of operations covered also differ. Some States, including New Mexico, North Dakota, and many others in the Midwest, regulate only surface mining reclamation. But at least nine States--including Colorado, Montana, Utah, and Wyoming--have statutes regulating surface effects of both surface and underground mining.

Although these statutes differ, they provide for a similar administrative process. Basically, the laws direct an admininstrative body to issue permits and to enforce the statutes and performance conditions. The procedural requirements of the permit process are relatively uniform. Typically, an applicant will need to provide: (a) a statement or evidence of the applicant's right to mine, (b) technical and other information regarding the proposed mine site, (c) a mining plan, (d) a reclamation plan, (e) a bond securing compliance with approved plans, and (f) other applicable permits.

When the application file is completed, the agency will proceed pursuant to the statutes and adopted rules. Local notice, opportunity to file objections, hearings, and compliance with the requirements of surface owner and other agencies or advisory commmittees are frequently part of the procedure.

Approval of mining and reclamation plans by the State authority is the critical point in the permit process. During plan approval, the characteristics of the site (soil, vegetation, topography, climate) are considered and the mining and reclamation requirements are put in final form (Imhoff and others 1976). Since the required reclamation performance bond is contingent upon compliance with the approved plan, the plan is also important for enforcement.

Performance standards may require some degree of stabilization of slopes, grading to approximately original contour, revegetation, control of mine drainage and other water pollution sources, neutralization of toxic materials, erosion control, visual screening, proper disposal of waste, and such other action as may be necessary to restore the land to support premining or anticipated postmining uses.

While there are considerable similarities among the State requirements, there are also some differences (see Working Paper V). Such differences are illustrated by an analysis of surface mining and reclamation requirements in six iron-mining States. Among these States, most vest the review power in a single State agency, some do not. Not all provide these enforcement agencies with authority to issue orders to stop operations or assess penalties. Some do not include a permit system which gives practical power to the agency that receives and approves the reclamation plan. Still others do not provide for designation and preservation of areas defined as unsuitable for mining. In general, the State programs lack the detailed technical requirements that are applied to coal mining by the Federal government.

Some States have also adopted an environmental impact statement program patterned after the one mandated by the National Environmental Policy Act of 1969 (see Working Paper V). These programs normally would require an environmental impact statement (EIS) before State-required permits could be issued for any new mining operation. Review of that impact statement could well include consideration of reclamation plans; postmining land use; and special requirements for control of wind erosion, water erosion, air and water quality, or habitat protection.

Integration of environmental review with the planning process has been difficult (Council on Environmental Quality 1978:397, Pearlman 1977). A land use plan might well delineate each potential mining zone, based on the location of the resource, its accessibility, and its priority in the national economy. In turn, the legal zone established on the basis of the plan might well include performance requirements that would cover precisely the same topics as those considered by an EIS review. Those requirements would have to be met by any mining operation that uses land zoned for mining. Under the normal land use planning process, preparation of the plan, and its legal adoption, would be accompanied by extensive public participation and hearings. Thus, any proposal that would conform to the land use plan could automatically meet the environmental requirements for the area involved.

In summary, State controls and regulations affect (1) the locations and physical characteristics of structures, storage piles, waste piles, and excavations; (2) the quality, quantity, and location of discharges; and (3) plans for post-mining physical configuration and use of the land. Control is exercised through requirements for permits and performance bonds. These controls have tended to develop parallel to and separate from the location and performance requirements that are part of the local land use planning process.

Although not entirely up-to-date, three recent major publications provide detailed compilations of State regulations: NRC (1974), Imhoff and others (1976), and Thompson and Agnew (1977).

4.4 MANDATORY FEDERAL REQUIREMENTS AND THE STATES

4.4.1 Clean Water Act

Discharge of waste water from mining and processing is regulated under the Federal Water Pollution Control Act Amendments of 1972 and 1977. This "Clean Water Act" and its amendments established two major goals: (1) to achieve wherever possible by July 1, 1984, water that is clean enough for swimming and for propagation of fish, shellfish, and wildlife; and (2) to have no discharges of pollutants into the nation's waters by 1985. The focus of the Act is thus on the quality of receiving waters, but its mechanisms for reaching the intended goals depend on effluent standards. In this sense, the Clean Water Amendments correspond with requirements for ambient air quality (Section 4.4.2).

The approach taken by the U.S. Environmental Protection Agency in implementing the Clean Water Act was to establish an initial set of effluent limits at point sources, which were to be achieved by July 1, 1977, using the Best Practicable Technology currently available, or BPT, and a more stringent set of limits to be reached by 1984, using the Best Available Technology economically achievable, or BAT. The term "point source" refers to discharges from an identified opening, such as a drain pipe or a portal. Discharges at such points are regulated under the National

TABLE 4.1 Mineral Mining and Processing Point Sources for which Effluent Limitations Have Been Established or Promulgated

Mineral Mining and Processing Point Source	pH	Total Suspended Solids	Fluoride	Iron	General Requirements to Control Discharge of Pollutants
Crushed stone	X	X			
Construction sand and gravel	X	X			
Industrial sand	X	X	X		
Gypsum					X
Asphaltic minerals					X
Asbestos and wollastonite					X
Barite					X
Fluorspar					X
Salines from brine lakes					X
Borar					X
Potash					X
Sodium sulfate					X
Phosphate rock	X	X			
Frasch sulfur					X
Bentonite					X
Magnesite					X
Diatomite					X
Jade					X
Navaculite					X
Tripoli					X
Graphite	X	X		X	

SOURCE: 40 CFR 436; 40(201) Federal Register 48652-48668, October 16, 1975; 41(113) Federal Register 23551-23573, June 10, 1976; 42(133) Federal Register 35843-35852, July 12, 1977; U.S. EPA (1976a).

Pollutant Discharge Elimination System (NPDES), which is managed by Environmental Protection Agency and the States by issuing discharge permits--although some States have not yet submitted an acceptable plan under this program. Constituents regulated under BPT standards for several categories of minerals and ores were identified by Environmental Protection Agency between 1975 and 1978 (Tables 4.1 and 4.2). Permissible levels of effluents and the timetable to be followed until 1984 in reducing pollution vary between the States. Also, the limits to be reached are expected to be worked out on a case-by-case basis for particular segments of streams and, accordingly, could differ between regions. Thus, effluent limits for the mining industry could differ from place to place. Also, concentrations that could be achieved for some regulated constitutents might be reduced, at some operations, below the amounts found in the local water, by exercise of standard control technology for such pollutants. In addition, regulations for control of toxic pollutants under the Clean Water Act are being developed and are expected to be incorporated in NPDES permits to meet BAT standards.

The Clean Water Act also addresses non-point water pollution--for example, by runoff from a mining tract--by requiring "areawide plans" and "best management practices." Regulations under these provisions are still being developed, but relevant control techniques such as ditches to divert streams and to intercept runoff are sometimes incorporated in a NPDES permit.

Leachates that may percolate downward to ground water, such as by leakage from a tailings pond, are not embraced by the Clean Water Act, except as this water may contaminate surface water by emerging at springs and seeps. Under the Safe Drinking Water Act of 1974, however, the Environmental Protection Agency is developing regulations for injection or reinjection of any fluids. Also, control of leachate from hazardous wastes that may be identified at new mines is expected to be subject to special management practices under the Resource Conservation and Recovery Act of 1976 (Section 4.4.3). Also, the States have authority to regulate operations that could contaminate ground water, applying laws to safeguard public health, although the States have not frequently exercised this authority.

The regulatory approach described here for control of water pollution in streams and lakes apparently stems from the premise that the mechanisms of water pollution are well understood and "that control of water pollution to virtually any desired level can be all but guaranteed," as demonstrated by extensive engineering investigations and scientific research (de Nevers and others 1978:59). The pollution of ground water by leachates, however, if not controllable in the area of seepage, is influenced by

TABLE 4.2 Pollutants for which Effluent Limitation Guidelines Are Established for the Ore Mining and Dressing Point Source Category

Pollutant	Ore Mining and Dressing Point Source						
	Iron ore	Base and precious metals: copper, lead, zinc, gold, silver, tin, and platinum	Aluminum ore (bauxite)	Ferroalloy ores: chromium, cobalt, columbium, tantalum, manganese, molybdenum, nickel, tungsten, and vanadium (when recovered alone)	Uranium, radium, and vanadium ores	Mercury ore	Titanium ore: lode deposits and dredge mining of placer deposits
Acidity/alkalinity (pH)	X	X	X	X	X	X	X
Total suspended solids (TSS)	X	X	X	X	X	X	X
Chemical oxygen demand					X		
Cyanide		X		X			
Ammonia					X		
Aluminum			X				
Arsenic				X	X		
Cadmium		X		X			
Copper		X		X			
Iron	X		X				X
Lead		X		X			
Mercury		X				X	
Nickel						X	X
Zinc		X		X	X		X
Radium					X		
Uranium					X		

SOURCE: 40 CFR 440; 43(133) Federal Register 29771-29781, July 11, 1978; U.S. EPA (1978).

complex geologic, hydrologic, and geochemical properties that can be generally determined at a site only by testing and systematic monitoring.

4.4.2 Clean Air Act

The permissible concentrations of most atmospheric constituents associated with mining and processing are regulated by the Environmental Protection Agency under the Clean Air Act. The amounts are expressed as National Ambient Air Quality Standards, which apply nationwide. Further, where the air of a region is cleaner than the levels of pollution set by these standards, limits for significant deterioration have been established by the Clean Air Act Amendments of 1977. These limits are expressed as maximum allowable increases in particulates and sulfur dioxide over background conditions that existed on August 7, 1977. The limits for significant deterioration were established to allow some reasonable growth in regions of clean air and to protect certain pristine places such as national parks and wilderness areas.

The stumbling block in permitting this further growth is that the levels of significant deterioration, and hence the regional effect of emissions from a mining site, must be predicted from models of atmospheric dispersion. Predictions based on existing models are fairly reliable in flat terrain but are not reliable where the land is diversified by hills and valleys (de Nevers and others 1978:Appendix VII). Until more dependable models for rough terrain are established, permissible levels of emissions presumably will be limited by pessimistic forecasts--that is, by standards intended to cope with "worst case" atmospheric conditions. Thus, standards for air emissions, as applied to the mining industry, can be expected to be stringent.

The standards for ambient air quality currently regulate carbon monoxide, non-methane hydrocarbons, nitrogen dioxide, ozone, sulfur dioxide, particulates, and lead. Also, emissions of mercury, asbestos, and berrylium are regulated as hazardous air pollutants, and standards for cadmium and arsenic are expected in late 1979 or early 1980. A standard for protection of visibility under the "significant deterioration" provisions is also contemplated.

4.4.3 Resource Conservation and Recovery Act

The disposal of solid wastes from mining is expected to be regulated by the U.S. Environmental Protection Agency after completion of a study required by the Resource

Conservation and Recovery Act of 1976 (PL 94-580, Section 8002). Section 8002(A) of the law provides:

> (f) MINING WASTE - The Administrator, in consultation with the Secretary of the Interior, shall conduct a detailed and comprehensive study on the adverse effects of solid wastes from active and abandoned surface and underground mines on the environment, including, but not limited to, the effects of such wastes on humans, water, air, health, welfare, and natural resources, and on the adequacy of means and measures currently employed by the mining industry, government agencies, and others to dispose of and utilize such solid wastes and to prevent or substantially mitigate such adverse effects. Such study shall include an analysis of
>
> > (1) the sources and volume of discarded material generated per year from mining;
> >
> > (2) present disposal practices;
> >
> > (3) potential dangers to human health and the environment from surface runoff of leachate and air pollution by dust;
> >
> > (4) alternatives to current disposal methods;
> >
> > (5) the cost of those alternatives in terms of the impact on mine product costs; and
> >
> > (6) potential for use of discarded material as a secondary source of the mine product.
>
> In furtherance of this study, the Administrator shall, as he deems appropriate, review studies and other actions of other Federal agencies concerning such wastes with a view toward avoiding duplication of effort and the need to expedite such study. The Administrator shall publish a report of such study and shall include appropriate findings and recommendations for Federal and non-Federal actions concerning such effects.

The study will result in comprehensive analysis of the current practices in managing solid waste from mining and recommend appropriate additional measures.

Further, for toxic substances, the requirements for testing and for reporting their conditions of manufacturing and handling are currently being defined under authority of the Toxic Substances Control Act of 1976 (PL 94-469). Most, if not all, products of mining are expected to be excluded, but many of the chemicals used in processing minerals are likely to be listed as toxic. Hence, their use will soon be regulated.

Criteria for identifying hazardous wastes under PL 94-580 were proposed by the Environmental Protection Agency on December 18, 1978, as were standards for safe disposal of certain types of hazardous wastes. (40 CFR 250; Federal Register, v 43(243):58946-59028). Wastes found to be hazardous are expected to be subject to special management practices, including: standards for constructing landfills, procedures for security and emergencies, criteria for selecting disposal sites, stringent requirements for closure and rehabilitation, and procedures for inspection and monitoring.

4.4.4 Summary

In general, the Federal acts provide for uniform nationwide standards regulating new sources of pollution and substantial Federal control for new technology applied to existing sources of pollution. States implement water and air programs through permits pursuant to Federal delegation of authority or Federal approval of implementation plans. Particulate emissions are regulated by Federal standards to be enforced by States, but State standards are not universal. For regulation of water discharges from tailings basins and pits, State permits are required under the National Pollutant Discharge Elimination System (NPDES), where the effluents are collected at the point of discharge; but the permitted performances vary from one site to another. Non-point sources are not regulated at present (see Working Papers I, III, VI, and VII).

4.5 FEDERAL REGULATION AND CONTROLS ON FEDERAL LANDS

Federal controls are most direct on the land owned by the Federal government. Two agencies manage virtually all of the Federal lands where mineral development is possible. They are the Bureau of Land Management (BLM) and the U.S. Forest Service.

4.5.1 Bureau of Land Management

The BLM of the Department of the Interior has jurisdiction over 450 million acres of public land. The Bureau is also responsible for approximately 313 million acres where either surface administration is in another agency, including the 187 million acres in National Forests, or the land surface has been transferred to private ownership with a retention of mineral rights by the Federal government. The BLM is concerned with the identification, classification, use, and disposal of public lands and their development, conservation, and mining. It has responsibility for mineral leasing on the outer continental shelf and the administration of the mining laws on all public lands, as well as Acts, applications, and claims for the use, or title to, public lands.

Despite the extensive responsibilities of the BLM, until 1976 its mission and authority were based on the aggregation of many provisions of public land laws. With the passage of the Federal Land Policy and Management Act of 1976, commonly known as the Bureau of Land Management Organic Act, Congress defined the goals of the BLM and its authority for the management, protection, development, sale, and administration of natural resource lands.

The Act declares a national policy that these lands be managed under the principle of multiple use and sustained yield in a manner which will, using all practicable means, protect the quality of the environment. Appropriate land reclamation is a condition for use.

The Act directs the Secretary of the Interior to inventory the natural resource lands and to develop comprehensive land use plans for such lands, giving priority to "areas of critical environmental concern." Those areas are defined to include important natural systems and scenic or historic areas. Other guiding concerns include present and potential uses, long-term benefits, compliance with applicable pollution control laws, and coordination with State and local government planning activities. The Act also directs the Secretary to identify land suitable for wilderness study and to review and make recommendations to Congress for inclusion of eligible land within the Wilderness System.

For the locatable minerals, those mined under the 1872 General Mining Law on Federal lands, only limited authority has been exercised to control environmental impacts. Where other values are thought to be more important than minerals and claims to mining rights have not been established, the lands are often withdrawn entirely from mineral entry, a relatively inflexible action that fails to recognize degrees of control that could effectively protect surface resources. Regulations to mitigate damage to surface resources similar to those adopted by the Forest Service in 1974 (see Section 4.5.2) have been proposed, but not yet adopted, for land ministered by the BLM.

Under the Mineral Leasing Act of 1920, the BLM has promulgated regulations covering surface exploration, mining, and reclamation for the minerals classified as leasable--oil and gas, oil shale, coal, sodium, phosphate, potash and sulfur. These regulations apply to lands and minerals administered by BLM, including leasable minerals on the National Forests. In order to obtain a lease, an operator must agree to certain conditions of operation and post a performance bond. The amount of the bond must be sufficient to satisfy the reclamation requirements of an approved mining plan.

Prior to operation, a mining plan must be filed with the Mining Supervisor, U.S. Geological Survey--or with the Office of Surface Mining in the case of surface coal mining--outlining the mining operation and the measures to be taken to protect the environment and eliminate any hazard to health and safety. This plan must show the proposed methods and planning with regard to grading and backfilling the areas affected by the mining operation. The mining plan is subject to review and approval by the Department of the Interior. Mutual acceptance makes the mining plan binding on the part of the operator, but it may be amended as warranted by unforeseen events. If stipulated in the permit, lease, or contract, the mining plan must show methods of preparing and fertilizing the soil; the types and mixture of grasses, shrubs, or trees to be planted; and the amount per acre. Within 30 days of the end of each calendar year, or within 30 days of ceasing operations, the operator is required to file a description of operation including the area affected and the area reclaimed, the method of reclamation and results, and the reclamation yet to be done. These various requirements, apply only to leasable minerals.

4.5.2 Forest Service Regulations

The Forest Service has promulgated regulations to minimize adverse environmental impacts on national forest surface resources by mining under the General Mining Law of 1872. No permit is required, but individuals desiring to conduct operations that might disturb surface resources must file notice of intention with the District Ranger. If the District Ranger determines that such an operation is likely to cause significant disturbance of surface resources, the operator must submit a proposed plan of operations to the District Ranger detailing environmental protection and reclamation measures to be taken. A performance bond may be required.

Operators must ensure that all tailings, dumps, deleterious materials or substances, and other waste produced by the operations are disposed of, arranged for, or treated so as to minimize adverse impact. At the earliest feasible time, the operator is required, where practicable, to reclaim the surface disturbed by taking such measures as will prevent or control on-site and off-site damage to the environment. Such measures shall include: (a) control of erosion and landslides; (b) control of water runoff; (c) isolation, removal or control of toxic materials; (d) shaping and revegetation of disturbed areas, where reasonably practicable; and (e) rehabilitation of fisheries and wildlife habitat.

The Forest Service has been cautious in pressing its authority under these new regulations to assure that the miner's right of entry for mineral location is not infringed. In effect, this means that the process of controlling impacts of mining under the 1872 General Mining Law is one of negotiation between the Forest Service and the miner. The result is that there has been some improvement since 1974 in controlling the environmental impacts of mining on national forests, but there are still problems.

4.5.3 Mining Permitted on Other Federal Lands

There are certain categories of Federal lands where Federal mining laws apply only in a modified way. The legal status of valid existing mining claims and properties within national parks and monuments is not easy to characterize. Generally, existing claims can be developed if zoning allows it and there is access to the claims. Zoning, which can limit actions on the private property represented by valid mining claims, is determined under State law and exercised through counties. This is also true for mining claims in national parks that have been patented and are now fully in private ownership. In older parks, the National Park Service is in the process of gradually acquiring private properties that are in-holdings within the parks, and particularly those that might be utilized in a manner that would conflict with the purposes of the park (such as mining).

Mining claims could be filed within six units of the National Park System until 1976, when Congress ended that dispensation. However, active mining operations on old properties are expected to continue in certain parts of Death Valley National Monument under that law for quite some time. New mining claims cannot be filed within the 56 million acres of national monuments established by President Carter in Alaska in December of 1978, but there are many valid existing claims within those monuments that can still be developed if access problems can be worked out.

National recreation areas (NRA) are established by Congress and administered either by the National Park Service or the Forest Service. Mining is generally permitted where it does not conflict with a major purpose of NRAs. On those NRAs that have been created out of lands from the public domain, some parts are usually withdrawn from mining to minimize adverse impacts.

Wild and scenic rivers within the national forests and BLM lands are under restrictions with respect to mining.

All minerals on Federal lands within the beds and within one-quarter mile of the banks of such rivers are withdrawn from mineral entry and leasing. However, much of the mineralized land within such areas is already subject to valid existing mining claims. Title can be obtained only to the mineral rights, not to the full fee including surface rights.

National wildlife refuges and ranges that were created out of the public domain are generally open to mineral entry and mineral leasing unless specifically closed by a withdrawal order or by wilderness classification. Refuges composed of acquired lands that had been in private ownership are not open to mineral entry. Generally, portions of each refuge are designated as a strict nature sanctuary, while the balance may be subject to varying degrees of manipulation and commercial utilization. Generally such utilization is allowed to the degree that it is compatible with the primary purposes of wildlife production in the unit, or is related to established private rights. A number of wildlife ranges have been subject historically to signficiant mineral development, the most notable being the Kenai Moose Range in Alaska in which there is a major developed oil field. In connection with further reservations in Alaska, legislation now before Congress proposes to allow major oil and gas development in the North Slope National Wildlife Refuge; indeed leases for such development are mandated under that legislation.

Trails in the National Trails System are not closed per se to mining, though only those trails that pass through public domain lands in the West would be subject to the Mining Law of 1872. As a matter of public policy, it is unlikely that mineral leasing would occur in a way that would have substantial impact on a unit of the National Trails System. Generally, trails are supposed to be managed in a way that harmonizes with management plans of Federal land management agencies affected. Such plans could include provisions for mining, though this will not usually be the case. While mining claims within national trails can be condemned, no more than 25 acres per mile can be condemned. However, withdrawal authorities can be used to protect sensitive reaches of trail from having new claims filed.

Natural and historical landmarks and places that are usually privately owned are not closed to mining, although Federal actions that would cause adverse affects are to be avoided. Private owners of such places must decide if they wish to restrict management of them to meet Federal criteria to protect the recognized natural historical or cultural values.

4.5.4 General Environmental Legislation

Congress has enacted a wide range of laws that apply in varying degrees to the planning and operation of non-coal surface mines on non-Federal lands. Title 40 of the Code of Federal Regulations lists a wide range of concerns with air quality, water quality, solid waste management, noise abatement, and a variety of specialized controls of toxic and hazardous substances, as well as requirements for planning, standards of performance, monitoring and enforcement, and public participation. Additional regulations and executive orders deal with the same subjects and with related aspects of environmental quality such as flood plain management, off-road vehicle controls, wetlands protection, fish, and wildlife (see Working Paper III). The laws noted in Title 40 do not apply systematically to all types of mines in all locations. The Federal government generally delegates monitoring and enforcement to the States in conformance with Federal guidelines (Sections 5.1.1; 5.2.8; 6.1.1).

In summary, although Federal laws and regulations suggest virtually the full range of impacts on initial planning for mine development and operations, the laws do not cover the problems of (a) reclamation and planning for conversion to subsequent use following mining, (b) balancing mining against other uses of Federal lands, or (c) protecting non-mineral resources on land being mined under the 1872 law (U.S. General Accounting Office 1979). Also, like State laws, the Federal legislation tends not to relate systematically to the local land use planning process.

4.6 EXISTING REQUIREMENTS AND THE REGULATION OF LAND USE

All existing controls attempt to regulate operations in particular classes of land use in particular locations. Mines make up a distinct array of "zones" on the land use map of the nation. This array ranges from small, intermittently used gravel pits that occupy less than 5 or 10 acres, to operations that include large deep pits, processing plants, railroad yards, shops, tailings basins, waste-rock piles, reservoirs, and surrounding buffer zones. The latter operations may use several thousands of acres at one site alone.

4.6.1 Mining "Zones" on the Nation's Land Use Map

Each mining operation creates a special type of "heavy industrial" zone in terms of local public land use plans and zoning. Each operation involves large flows of energy and materials, and has a relatively high "nuisance level" because it generates, of necessity, large amounts of dust, noise, or other emissions. Some mining operations exist within planned and zoned areas. They may be given various labels in the multitude of county and municipal plans and zoning schemes throughout the United States. Many other mines, both large and small, are located in areas where land uses are not yet subject to any planning or zoning.

Surface mining operations are not always compatible with other present or future land uses, either with neighboring uses nearby or with those more remote from the mine down wind or down stream. But the mining operations are essential to the economy. Thus, there is a need to segregate them from incompatible neighboring uses while they are operating and to make plans to convert the land to other uses when operations have ended. This nationwide need applies in varying degrees to all surface mining.

4.6.2 Geological Constraints and Environmental Diversity

Geological conditions and demand for the commodities virtually dictate where mines are located, how extensive, dispersed or localized they are, whether the operations tend to be shifting or fixed, whether they disturb an extensive area or a small area, sweep over a large area in the course of several decades, or operate for many decades or even centuries within the same confined district. Meanwhile, the location of a deposit within the nation's comprehensive regional development pattern can influence profoundly the mining neighborhood today and the type and probable amount of postmining land use. Some deposits are obviously in the path of major development. Others are not. Some partially affect scenery or habitat which is commonplace over a large part of the country. Others affect unique natural areas.

The possible combinations of geological occurrence, commodity demand, and location in the nation's settlement geography are extremely varied and distributed without regularity across the map of the nation resulting in complex and varied environmental conditions.

These conditions dictate that there be a variety of plans for operation and for conversion of disturbed mined land. Each plan will have to be adapted to regional and local conditions of habitat, hydrology, and land market. While the goals of a clean, stable physical and biological environment are uniform nationwide, procedures to achieve them may vary from district to district and from mine to mine.

4.6.3 Controls as Local, State, and National Concerns

While conditions vary widely among localities, it does not follow that the related land use control questions are purely local.

At one extreme, each quarry among the thousands that exist is of purely local concern. It covers only a few acres and serves a market contained within one or two counties. Neighbors and users--who are concerned with any direct damage to the environment from the quarry, its benefits, and any costs of environmental reclamation--will all reside within the same local governmental jurisdiction.

At the other extreme are a few mining districts that are unique national resources because of their size, quality, or the kind of mineral they yield. The burden of direct environmental damages may be borne mostly or wholly by local neighbors. But the benefits flow more widely to the national community, including the local neighbors; and the costs of environmental control and reclamation are the responsibility of the national community, in whatever way it chooses to allocate and collect them. In those districts, land use controls that affect whether mining is done or not and controls that protect the mineral resource from conflicting uses are concerns of the national community.

While our concern here is with surface mining, clearly these findings and questions pertain to a wide spectrum of human modifications of the environment, of which mining is but one part.

4.6.4 Land Use Planning and Zoning

The existing regulatory machinery appears to be concerned basically with a variety of different aspects of land use planning although mining regulations themselves generally do not refer to planning.

Among the three historic streams of environmental legislation (Section 4.1.1), land use planning and control has had objectives that overlap those of the other two streams. These objectives also appear repeatedly in the body of existing controls that affect surface mining.

4.6.4.1 Patterns of Land Use

In large mining regions, surface-mine impact, control, and reclamation are measured to a major degree by changes in broad patterns of land use. Perhaps an overriding fact is the amount of material that has been moved and the even greater amount that will have to be moved to accomplish the objectives of reclamation. The term "planning," in its simple dictionary meaning, comes up repeatedly. Billions of tons of earth will be moved, and their movement should be compatible with the known geology, hydrology, settlement patterns and trends, land ownership, long-term capital requirements, and long-term importance of the region as a wildlife habitat, watershed, recreation area, or source of other resources and potential land uses.

One traditional aim of land use control has been to protect the wider community from land use under one ownership that is potentially damaging to other land owners or users. Examples of the pursuit of that goal in the Coal Mining Act include designation of urban areas as "unsuitable for mining," regulation of blasting and of discharges of gas and water, and control of off-site effects of mining.

A second traditional aim has been to promote efficiency in the location and layout of major land uses, including mining. Efficiency is one consideration in the placement of roads, dams, reservoirs, tailings, and waste dumps, that are controlled under some existing mining regulations. Efficiency must also recognize the cost of providing government services.

But efficiency is also a consideration in a larger sense. For some minerals, virtually the entire national reserve is concentrated in one or a few localities and can be produced only in those places (Section 2.1). Hence efficiency from a national point of view may well require that in those localities planning must assure that there will be enough land in reserve to meet anticipated needs, not only to recover the ore but to accommmodate tailings, reservoirs, and other necessary developments. Thus, if the goal of protection implies designation of areas "unsuitable for mining," the goal of efficiency implies that there should be "designation of areas reserved for mining."

A third traditional aim of land use control has been to promote design standards in physical structures, for reasons of both stability and aesthetics. Requirements for contour restoration or shaping of dumps are examples of that objective in existing mining regulations. Publications of the Urban Land Institute, Washington, D.C. provides numerous examples of uses of planning and accompanying regulations to control drainage effluents, or placement and design of structures in large-scale developments (see Community Builder's Handbook).

A fourth aim has been to assure that there will be enough land in reserve to meet anticipated needs. Effective land use planning must involve all land-based activities of man, not solely that of mining.

Virtually all precedents and experience in the pursuit of these goals directly through land use planning have been at the local level. Planning has been accompanied by zoning, subdivision controls, and performance standards. The plans are subject to modification as circumstances change--for example, the discovery of a potentially important new mineral deposit or an unanticipated need to control a toxic discharge. Land use plans are developed increasingly with open participation of land owners, officials, and all the various publics whose interests are affected.

4.6.4.2 The Planning Process

Mutual understanding about and agreement on the problems and purposes of the plan are essential to starting the planning process. Some major long-range questions are where to locate the tailings basins; how large and how deep to make them; which existing settlements could be barriers to efficient long-term recovery of ore; where those settlements might be re-established; how much additional water storage capacity is needed and where it will be. Then there are performance standards to be specified within each of these locations, such as how to control discharge of noxious or hazardous materials, or how to accomplish revegetation.

It is impossible to set policies for the location of these major long-term mining developments without placing them specifically on a map. Hence, it is necessary to consider systematically the resources, ownership, value, and accessibility of every parcel of land in the area and to consider its relative suitability for the major developments whose location must be planned.

As the map of suitability is developed, experience indicates that most sites will be highly suitable for one type of development but not for others. In other words, there will be no potential conflict over their future use.

But some sites will be highly suitable for more than one use. Examples are urban settlements on the mineral deposit, or tailings basins near highways or settlements. For those sites that are potential conflict zones, their planned future use will have to be mediated as part of the planning process. Again, the mediation process in some locations is constrained by the fact that there may be no alternative source of a particular mineral. In those cases, an alternative location will not be one of the possible solutions, and the conflict must be resolved in other ways.

Finally, in the process of planning the map of land development suitability and priorities for development and preservation (e.g., zero development) must be laid out. With this step, the plan will be complete.

4.6.4.3 Zoning and Performance Standards

In order to put the plan into action, it is necessary first to constitute legally zones that reflect the locational suitabilities and development priorities in the plan. When that is done, there will be zones established for future tailings basins, pits, reservoirs, and transportation lines as well as for future residential, commercial, and wilderness areas. There will also be non-conforming uses within those zones in the immediate future and perhaps for a long time; but they will reflect the assumptions of all concerned about resources, environmental protection, long-term goals, and trends. Second, it is necessary to spell out the performance standards that affect each zone. In the case of mining, these standards will pertain to dust control, quantity and quality of water discharges, reclamation, and the other practices whose effects are to be confined within a designated land use zone or within a designated period of time. Performance standards could include requirements for buffer zones around certain types of land use. Actions needed to enforce the zoning and performance standards are already commonly used: they include permits to build or to use the land, effluent standards and withdrawal or discharge permits, and reclamation requirements.

In those regions where mining is prevalent and widespread, the definition of the industrial-use category can be extended to include mining. This implies that mining is allowed, without proscription, in those zones that the local community designates as industrial. Exceptions can be provided by zone-map amendments or for non-conforming and pre-existing uses. Where mining is more localized, the community can generally proscribe its presence but provide for a system of special exceptions that is tailored to mining. Applications for special exceptions would resemble those for a permit and could include provisions for both mining and reclamation plans.

Zoning is carried out as an exercise of the State's police power. Local governments do not inherently possess police power, but have received that authority in every State in the country through some form of State enabling act that delegates police power from the State to the local level. The police power of the State is the power that must be exercised in order to discharge effectively the State's paramount obligation to promote and protect the health, safety, morals, comfort, and general welfare of its people. Because mining can present a safety problem to surrounding residents, it may be subject to reasonable regulation under police power (see Working Paper VI).

4.6.4.4 Implementing Planning and Zoning

Participants in implementating the planning process must include the mining companies; the local land owners, residents and businesses directly affected by mine development, operations, and reclamation; the wider public dependent on the products of the mine; and the wider public directly dependent on alternative and competing uses of the area affected by the mining operation.

The companies together with local, State, and Federal governments are, in fact, agents of all the participating parties. There is an obvious need and desire to monitor the planning process for the constituents of all four agents--constituents of the companies and constituents of the three levels of government. If planning is to work, it has to be carried out by responsible agents of the great mass of concerned parties--the companies and the governments.

A key to success of the planning process is the maximum possible amount of information and understanding. Planning is not an adversary process although there are inevitably conflicts and adversary relationships in its first stages. But development and execution of a plan depends essentially on study, exchange of information, understanding, and commitment. Regulation is essentially an adversary process. Hence it does not provide either a substitute or a framework for planning. Once a plan is developed, it provides performance standards within a zoning framework, and it is within that framework that monitoring and regulation are necessary, and can be rational, and better understood.

In many instances, the necessary government organizations are already in place and operating; local planning bodies; regional planning bodies; State planning agencies; planning and analysis sections of State Departments of Natural Resources and Transportation; Federal agencies including the Geological Survey, Bureau of Mines, Corps of Engineers, Forest Service, Department of Transportation, and Soil Conservation Service. These agencies have data collection networks, planning staffs, planning responsibilities, and experience. Many counties and municipalities have continuing local data collection responsibilities on land use, land value, and land ownership; companies have plans; local businesses have plans. And there are growing, computerized land management information systems in several States and Federal agencies.

4.6.4.5 Looking Ahead

Large mining districts are entering a new epoch in their evolution in terms of scale and intensity of production and, consequently, of the generation of waste materials, disturbance of the terrain, and competition for land. The major problems emerging in these mining areas, however, will be controllable by planning, zoning, and performance standards, particularly the problems of waste from mining and processing. The machinery for planning and implementing plans is already in place, and the cost of adapting it to the needs of mining should be only marginal. In fact, in 1973 the National Commission on Materials Policy made a number of specific recommendations for coordinated national, State, and local policies on zoning, operational performance, and reclamation on mineral lands, as well as zoning for very large industrial developments (National Commission on Materials Policy 1973).

If mining regulation were to lead to a new dimension of the land use planning and regulation process, attention would be intensified and turned on some continuing and important questions. Which types of mines concern only local constituencies? Which mining districts concern State or national constituencies? Answers to these questions will make it possible to structure the planning process to assure participation of the appropriate constituencies, to assure just treatment of the various interests, and to assure that responsible commitments are made.

In addition, through this process, it will be possible to decide which public agencies are to monitor the environment to observe the changes that take place--for better or worse--in land use, water, air, and aesthetic quality in response to laws, regulations, and the actions of mining operators.

While our concern here is with surface mining, clearly these findings and questions pertain to a wide spectrum of human modifications of the environment, of which mining is but one.

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CHAPTER 5

APPLICABILITY OF THE SURFACE MINING CONTROL AND RECLAMATION ACT OF 1977 (PL 95-87) TO NON-COAL MINERALS

5.1 OBJECTIVES OF THE ACT AS A REFLECTION OF CONGRESSIONAL GOALS FOR CONTROL AND RECLAMATION OF SURFACE MINING FOR NON-COAL MINERALS

The objectives of the Surface Mining Control and Reclamation Act are found explicitly in its statement of purposes (Sec. 102) and implicitly in its findings (Sec. 101), but they are also inherent in the Act's conceptual approach to the control of surface mining. Whether explicit, implicit, or conceptual, the objectives address the environmental, economic, and social problems recognized during the history of the Act, as outlined in the introduction to this report. In the sense that the objectives for coal mining can be largely paraphrased as objectives for non-coal mining, remembering that the Act began as an all-minerals bill, they seem to imply the Congressional concerns about the surface effects of all mining. Thus, our analysis of the applicability of the Act to non-coal minerals begins by considering the objectives of the Act and general public goals for control and reclamation of surface mining, even though a few of the Act's objectives focus only on institutional or procedural matters that are not otherwise discussed in this report.

5.1.1 Objectives Explicitly Listed in the Act in Its Statement of Purposes (Sec. 102)

(a) Establish a nationwide program to protect society and the environment from the adverse effects of surface coal mining operations.

Relevant Provisions. The Act establishes minimal national standards for the regulation of surface coal mining. A program to implement these standards is established by the opportunity given to the States to assume exclusive authority over regulation of surface coal mining--except for certain matters reserved to the Secretary of the Interior--under an approved program that meets the minimum requirements of the Act (Sec. 503), and by the backup of a

Federal program (Sec. 504). A State may elect to regulate surface coal mining and reclamation on Federal lands within its borders (Sec. 523), although the Secretary retains authority for some aspects. Regulation of such operations on Indian lands rest with the Secretary, supplementary to whatever authority has been previously reserved to a tribe, but the Act calls for a study of legislation by which Indian tribes may elect to assume full regulatory authority, and a tribe may impose conditions on new leases more stringent than those required by the Act (Sec. 710). The Act does not address offshore mining of coal. Other elements of a national program are provided by authorization for the Office of Surface Mining Reclamation and Enforcement (Title II), State mining and mineral resources and research institutes (Title III), the Abandoned Mine Reclamation Fund (Title IV), and for university coal research laboratories (Title VIII).

> (b) Assure that the rights of surface landowners and other persons with a legal interest in the land or appurtenances thereto are fully protected from such operations.

Relevant Provisions. The surface owner is protected from uprooting by surface mining, where the mineral rights are separately owned, by a requirement for his written consent (Sec. 510(b)(6); Sec. 714(c)). Where the coal is owned by the United States, the Secretary of the Interior is directed by the Act to consult with surface owners before proposing a leasing tract asking for statements of preference for or against offering the underlying coal for lease (Sec. 714). If a significant number of owners are opposed, the Secretary shall, in his discretion, but to the maximum extent practicable, refrain from leasing the coal for purposes other than underground mining (Sec. 714(d)). The surface owner may also comment on plans for postmining land use (Sec. 508(a)(3)). Water rights are protected by the need to describe measures to be taken to protect the rights of present users of surface and ground water (Sec. 508(a)(13); Sec. 515(b)(8)) and by a requirement to replace a water supply that has been contaminated, diminished, or interrupted by a nearby surface coal mining operation (Sec. 717). Any person with a valid legal interest that may be adversely affected can file written objections to a proposed release from bond (Sec. 519(f)) and can petition for designation of lands as being unsuitable for surface coal mining, or for termination of such a designation (Sec. 522(c)). Many provisions in the Act deal with protection of public and private property from offsite impacts.

> (c) Assure that surface mining operations are not conducted where reclamation as required by this Act is not feasible.

Relevant Provisions. A determination that reclamation of an area, regardless of ownership, is not technologically and economically feasible is a mandatory basis for designating the area as unsuitable for surface mining (Sec. 522(a)(2)). For areas where surface mining is permitted, detailed requirements are specified in planning for reclamation (Sec.508), and the permit process requires the applicant to demonstrate, and the regulatory authority to certify, that reclamation required by the Act can be accomplished under the plan (Sec. 510(b)(2); Sec. 511(a)(2)). For prime farm land, the regulatory authority must certify that the operator has the technological capacity to restore the mined land to a level of agricultural yield at least equal to that of non-mined prime farm land in the surrounding area, within a reasonable time (Sec. 510(d)(1)).

> (d) Assure that surface coal mining operations are so conducted as to protect the environment.

Relevant Provisions. Title V of the Act is concerned with the control of environmental impacts of surface coal mining. Notable in these provisions are the environmental protection performance standards (Sec. 515) and requirements for surface effects of underground mines, which are to operate in accordance with the standards established for surface mines (Sec. 516). Several other sections of Title V deal with information needed and requirements for permits, reclamation plans, performance bonds, coal exploration, termination (release from bond), and--perhaps most important for overall environmental protection--the procedures and criteria for designating lands as being unsuitable for surface coal mining. The Act also requires that repeated disturbances of the environment be minimized by maximizing recovery of the coal during a mining operation (Sec. 508(a)(6); Sec. 515(b)(1)).

> (e) Assure that adequate procedures are undertaken to reclaim surface areas as contemporaneously as possible with the surface coal mining operations.

Relevant Provisions. This purpose is repeated as a requirement in the environmental protection performance standards (Sec. 515(b)(16)) but can be understood as being forced by provisions for release from bond, whereby the release of a minimum obligation of $10,000 is conditional on satisfactory achievement of reclamation (Sec. 509(a); Sec. 519). Such a release requires a hands-off demonstration of successful revegetation for 5 years after the last year of reclamation efforts, or for 10 years where the average precipitation is 26 inches or less (Sec. 515(b)(20)). Because the evaluation of a request for release from bond must consider compliance with laws on pollution of surface and subsurface water (Sec. 508(a)(9); Sec. 519(b)), the attainment of control over water quality can be understood as one test of the success of revegetation.

> (f) Assure that the coal supply essential to the Nation's energy requirements, and to its economic and social well-being, is provided, and strike a balance between protection of the environment and agricultural productivity and the Nation's need for coal as an essential source of energy.

Relevant Provisions. Two provisions are intended to insure that administration of the Act will not delay the search for and recovery of coal. Mineral exploration, subject to reclamation standards, is not inhibited by a State's designation of an area as unsuitable for surface coal mining (522(a)(1)), and mining can be permitted on Federal lands under review for such designation (522(b)). Variances in timeliness of reclamation are provided in order to combine surface mining with underground mining to assure maximum practical recovery of the mineral resources (Sec. 515(b)(16)). Small operators are relieved of the expense of obtaining some geologic and hydrologic data required by the Act (Sec. 507(c)), presumably so that these costs will not interfere with their production. The Congress evidently considered the Act's protective requirements as not imposing undue restraint on the production of coal.

> (g) Assist the States in developing and implementing a program to achieve the purposes of this Act.

Relevant Provisions. Annual grants to any State are authorized to assist such a State in developing, administering, and enforcing State programs under the Act, starting at 80 percent of the costs during the first year, 60 percent the second year, and 50 percent thereafter (Sec. 705). Cooperation with a State in developing, administering, and enforcing its program must include technical assistance and training as well as assistance in preparing and maintaining an inventory of information on surface coal mining and reclamation for the State. The duties of the Office of Surface Mining Reclamation and Enforcement include administering the grant-in-aid program, maintaining a data center for use by the States, among others, assisting the States in developing criteria and procedures for designation of lands unsuitable for surface coal mining, and cooperating with State regulatory authorities and others to minimize duplication of inspections, enforcement, and administration (Sec. 201).

> (h) Promote the reclamation of mined areas left without adequate reclamation prior to the enactment of this Act and which continue, in their unreclaimed condition, to substantially degrade the

> quality of the environment, prevent or damage the beneficial use of land or water resources, or endanger the health or safety of the public.

Relevant Provisions. Title IV establishes the Abandoned Mine Reclamation Fund for this purpose, consisting of amounts derived from reclamation fees levied on mined coal, user charges for reclaimed land, donations, and other recovered money. Lands and water that were mined for coal, or that were affected by such mining, are eligible for reclamation under this title. Also, as much as one-fifth of the funds allocated to a State can be used to reclaim surface impacts of any other previous mining operations that may degrade the environment.

> (i) Assure that appropriate procedures are provided for the public participation in the development, revision, and enforcement of regulations, standards, reclamation plans, or programs established by the Secretary or any State under this Act.

Relevant Provisions. The Act requires public notices and public hearings for adoption of State and Federal programs, approval of permit applications and reclamation plans, or revisions, actions on applications for release from performance bonds, and for review and appeal of actions taken by the regulatory authority. Many opportunities are also provided for filing written objections. A unique provision allows any person to supply the Secretary of the Interior information concerning a suspected violation at a mining operation. Such information may result in a Federal inspection, and the person providing the information then shall be allowed to accompany the Inspector (Sec. 521(a)(1)). Persons having an interest which is or may be adversely affected may file written objections to a permit application and may gain access to the proposed mining area for the purpose of gathering information (Sec. 513(b)). Another novel provision allows any person with an interest which is or may be adversely affected to petition the regulatory authority to initiate review of lands for designation as unsuitable for surface coal mining, or for termination of such a designation (Sec. 522(c)). Thereafter, anyone can intervene in the administrative process. Owners of property within half a mile of surface coal mines are to be notified daily about schedules for blasting and may require a pre-blasting survey of buildings (Sec. 515(b)(15)). Owners of property proposed for mining must be given opportunity to comment on plans for its postmining land use, together with comments by State and local governments and agencies (Sec. 508(a)(3)). Copies of information pertaining to a mining operation are to be made conveniently available to residents in the area (Sec. 517(f)). In addition, persons may be awarded costs and expenses (including legal fees) connected with participation in administrative proceedings (Sec. 525(e)).

> (j) Provide a means for development of the data and analyses necessary to establish effective and reasonable regulation of surface mining operations for other minerals.

Relevant Provisions. Most directly, the Act authorizes this report to assist in establishing regulation of surface and open pit mining and reclamation for minerals other than coal (Sec. 709). Less directly, data of various kinds are required during the planning, permitting, and reclamation stages of surface coal mining. To the extent that this information provides knowledge of local and regional conditions, including observations on the success of reclamation efforts, it could be useful in considering the regulation of surface mining for other minerals. Such information is to be made available at a data center (Sec. 201(c)(8)) and within each State that implements a State program (Sec. 705(b)(2)). Information of local interest is to be collected at locations convenient to residents in an area (Sec. 517(f)). This procedure does not provide for collection of data in States without coal. The kinds of data include factors of hydrology; climatology; logs of drill holes, test borings, and core samplings; and various chemical analyses (Sec 507(b)). The operator is required to install, use, and maintain monitoring equipment, keeping appropriate records and evaluating the results (Sec. 517(b)(1)). Operations that disturb aquifers require observations of the quantity and quality of water above and below the mine site (Sec. 517(b)(2)). Information of this kind, coupled with knowledge from many other sources, could provide the data base and inventory system required by the Act to evaluate the capacity of different land areas for reclamation of surface coal mining operations (Sec. 522(a)(4)) and for other surface mining.

> (k) Encourage the full utilization of coal resources through the development and application of underground extraction technologies.

Relevant Provisions. The Act requires consideration of the distinct difference between surface and underground coal mining (Sec. 516(a)). This provision allows for modifications in performance standards, after the Secretary of the Interior has promulgated applicable rules, to accommodate to the difference that distinguishes underground mining from surface mining (Sec. 516(b)(10); Sec. 516(d)). One difference specifically recognized in the Act is that subsidence need not be prevented if the underground coal mining technology requires planned subsidence in a predictable and controlled manner (Sec. 516(b)(1)). A variance also may be allowed in the timeliness of reclamation to combine surface mining with underground mining for maximum recovery of the mineral resources (Sec. 515(b)(16)). In management of coal resources owned by the United States, where the surface is privately owned, the Secretary is given discretion to lease the coal for underground mining. Underground coal mining is also encouraged by the reclamation fee, which is 35 cents per ton for surface mined coal (although 10 cents per ton of lignite) but only 15 cents per ton for coal produced by underground mining (Sec. 402(a)). Investigations of underground mining technology are not mentioned in provisions authorizing State mining and mineral resources and research institutes (Title III), although such research is not ruled out in the broad latitude of duties assigned to these institutes (Sec. 301(b)).

> (l) Stimulate, sponsor, provide for and/or supplement present programs for the conduct of research investigations, experiments, and demonstrations, in the exploration, extraction, processing, development, and production of mineral(s) and the training of mineral engineers and scientists in the field of mining, mineral resources, and technology, and the establishment of an appropriate research and training center in various States.

Relevant Provisions. This purpose is repeated in the provisions that authorize State mining and mineral resources and research institutes (Sec. 301(b)). The Act also provides for establishment of 10 university coal research laboratories with facilities and specialists for research on coal energy resources, coal conversion, and coal characterization, as well as for research on related environmental problems (Sec. 801(d)).

> (m) Wherever necessary, exercise the full reach of Federal constitutional powers to insure the protection of the public interest through effective control of surface coal mining operations.

Relevant Provisions. Constitutional powers are the basis of enforcement provisions in the Act, which deal with inspections, notices of violations, orders of cessation, and penalties. Inspections are required for a permit application or hearing (Sec. 514). When a permittee has filed a request for release of all or part of a performance bond, the regulatory authority must conduct an inspection and evaluate the reclamation work involved (Sec. 519). Frequent, but random and unannounced, inspections are also required during mining and reclamation (Sec. 517) and are immediately mandatory by Federal inspectors if imminent danger of significant environmental harm is indicated and if the State has failed to take appropriate action (Sec.

521(a)(1)). In some circumstances, private citizens have the right to accompany an inspector during an inspection (Sec.(521(a)(1)) or to enter a proposed mining area to gather information. An operation that creates an imminent danger to public health or safety, or that can be expected to cause significant environmental harm, must be given a cessation order (Sec. 521(a)(2)). Violations are to be abated in 90 days (Sec. 521(a)(3)). A violation of the Act, whether for coal exploration or for mining and reclamation, is subject to a maximum civil penalty of $5,000, after an opportunity for a public hearing (Sec. 512(c); Sec. 518), and conviction of willfully and knowingly violating a condition of a permit, refusing to comply with certain orders issued under the Act, making a false statement, or failure to file or maintain documents required by the Act carries a mandatory penalty of as much as $10,000 or imprisonment for one year, or both (Sec. 518(e);Sec. 518(g)). An operator failing to correct a violation must be penalized $750 for each day that the violation continues beyond the period allowed for its correction (Sec. 518(h)). Lastly, the Secretary of the Interior is empowered to suspend or revoke a permit if he finds a pattern of violations exists or has existed, and that such violations are caused by the unwarranted failure of the permittee to comply (Sec. 521(a)(4)).

5.1.2 Objectives of the Act Implicit in Its Statement of Findings (Sec. 101)

A number of the findings that the Congress cites in introducing the Act simply express aspects of surface mining that are also stated as purposes, as reviewed in the foregoing section. However, some of these findings are applied to all surface mining, whether for coal or other minerals, and they therefore imply the Congressional concerns that motivated the call for this report. Thus, a brief review of these general findings is germane to non-coal minerals. Also, certain of the findings disclose objectives that are not otherwise stated in the Act.

The findings not exclusive to coal point out that: the extraction of minerals can be accomplished by surface mining (Sec. 101(a)); many surface operations result in disturbances that adversely affect commerce and public welfare in numerous ways (Sec. 101(c)); because of the diversity in terrain, climate, biology, and other conditions in areas subject to mining, the primary responsibilities under the Act--hence, for coal mining--should rest with the States (Sec. 101(f)); and there is a need to regulate surface mining for minerals other than coal, but such regulation depends on further data and analyses (Sec. 101(i)).

Certain provisions of the Act, or its general nature, seem to spring from concepts revealed in the findings but not spelled out as articulated goals. The effect of surface mining in degrading the quality of life in local communities is mentioned (Sec. 101(c)), and this problem is addressed in the Act, although indirectly, in terms of the incompatibility of surface mining with local land use plans (Sec. 522(a)(3)). Such incompatibility is a basis for excluding surface coal mining. Efforts to conserve soil, water, and other natural resources, which are cited as being adversely affected by surface mining (Sec. 101(c)), are presumably to be encouraged under the Act by requirements for coordination with other Federal or State permit processes or local law (Sec. 503(a)(6); Sec. 504(h); Sec. 515(b)(2)), by provisions for reclamation of prime farm lands (Sec. 510(d)(1); Sec. 515(b)(7)), and by Presidential oversight of enforcement actions under laws pertaining to clean air and water (Sec. 713), as well as by explicit performance standards (Sec. 515; Sec. 516) explained above. A finding that recalls the unevenness among State requirements for reclamation is that equal standards are essential to insure that competition between sellers of coal produced under differing State requirements--hence, at disparate costs--will not weaken a State's ability to improve its environmental standards for mining (Sec. 101(g)). The Act faces this problem by establishing a national program. Where mined land has not been reclaimed, the findings further point out that deferred social and economic costs and continued impairment of environmental quality are imposed on nearby residents (Sec. 101(h)). These costs of former mining are made a part of current mining operations under the Act by establishing reclamation fees to pay for reclamation of abandoned mined land (Title IV).

5.1.3 Concepts of the Act in the Context of General Goals for Development and Reclamation of Non-Coal Mining

From the foregoing review, the Act can be seen as facing the environmental problems recognized in surface coal mining along a broad front, but dealing with these problems in an exact and explicit manner. Standards and procedures are established by which the objectives of implementing control are intended to be achieved. Provisions for management of mineral development (Sec. 512), or non-development (Sec. 522; Sec. 601), are given, but such matters are not the central purpose of the Act. It is aimed almost exclusively at correcting disturbances of the environment, which have long troubled large regions of the country. In the next section, we examine in some detail the adequacy of provisions in the Act for the mining of non-coal minerals. Here, we summarize concepts inherent in the Act and raise some questions that are pertinent in considering the suitability of the Act's provisions to non-coal minerals.

These questions also underlie the discussion of institutional approaches in the following chapter. We do not suggest answers to these questions, but we believe that asking them may clarify important issues about the control of surface mining.

The concepts underlying the Surface Mining Control and Reclamation Act, and the questions these raise for the mining of non-coal minerals, can be classified as follows:

1. The Act establishes a national program for control of surface coal mining. Are the impacts caused by extraction of a mineral commodity, or by a method of extraction, such that further control is needed? If so, is Federal control appropriate; or is State control, or even more local control, preferable?

2. The Act regulates by a permit program and by a system of performance standards, that is, by specifying the practices to be used. Is direct regulation of non-coal minerals, or of some aspects of their mining, the best procedure; or can public goals be achieved more effectively, or more economically, by other means of control, for example, by technical assistance, by economic incentives, or by public ownership?

3. The Act considers surface coal mining to be a temporary use of the land, reclaimable to equal or higher use; non-reclaimable areas are to be placed off limits. Is mining for a particular non-coal mineral truly temporary in human terms, ending with the close of operations; or is the outcome so far in the future as to be relatively infinite and uncertain? Should the mining be permitted, even if not reclaimable, because the mineral is geologically concentrated and important to the national economy? The answers to these questions, which deal with the need for planning and custodial care, with acceptance or rejection of local sacrifices in the national interest, and with the question of who pays, could determine whether Federal or local control is indicated.

4. The Act specifies explicit standards for environmental protection, implying that remedies for recognized environmental problems are accurately known. Assuming a particular method of extracting a non-coal mineral, at a place dictated by its geologic occurrence, are the impacts known and predictable? If any are not, the optimum means for their control may differ from the procedures for those that are.

5. The Act provides abundant opportunity for citizen involvement and for protection of rights. When is a mining activity so local that the interests of nearby residents assume overwhelming precedence; and when is the activity, or

its effects, so dispersed that citizens from a wide region--even the nation as a whole--have a need to be heard? The answers could determine choices for control.

6. The Act addresses deferred costs by establishing a means to reduce them, through reclamation of abandoned mines. Is the legacy of non-coal mining such that extensive remedies are desirable? More directly, what problems will continue if reclamation is not practiced more intensively? In other words, how can the external costs be made a part of the cost of mining?

7. The Act requires maximum recovery and conservation of the mineral resource, although only in terms of the need to minimize repeated disturbance of the environment. Is such a requirement germane to particular non-coal minerals? If so, what balance between conservation and cost of recovery is appropriate; and who is to be given the authority to decide?

5.2 ANALYSIS OF TECHNICAL PROVISIONS OF THE ACT WITH RESPECT TO NON-COAL MINERALS

The technical provisions of the Surface Mining Control and Reclamation Act largely deal with requirements and standards for environmental protection. For ease of comparison with subjects discussed elsewhere in this report, we have grouped the provisions in equivalent general categories: mining technology; effects on land (prime farm land and other provisions); impacts on water availability; effects on biological systems; economic matters (recovery of resources, non-coal mining, and other provisions); social impacts (property rights and community services); control of wastes and reclamation practices (pollution of air and water, solid wastes, revegetation, and other aspects of reclamation); jurisdictional controls; and existing land use plans. A following section discusses the relevance of provisions for collection of data, planning, and enforcement.

In listing the provisions of the Act, we follow its wording closely, although condensing the provisions that appear in similar form in more than one place. Language that pertains to administrative and procedural matters is omitted, but enough of the wording is retained to give new readers a knowledge of the Act's phrases, without further need to read the Act in its entirety. Our synopsis can thus be considered a concise statement of the Act's environmental and technical requirements, serving as an index to a substantial part of its contents.

For purposes of discussing the adequacy of provisions in the Act for the mining of non-coal minerals, we have grouped the minerals in several mining categories, according to the effect of their extraction on the surface, or on ground water that can be expected to reach the surface. In keeping with the classification of mining activities that is discussed in Section 2.1, these categories are as follows: quarries (open excavations that remove much more material than can be returned); open pits (excavations associated with large dumps of rock waste, which result from removal of thick sections of overburden to reach local mineralized zones); strip mines (sequential excavations by which some material removed at one place is backfilled in an adjacent or nearby pit or trench); underground mines (subsurface excavations reached by shafts or tunnels); and in situ and solution mining (subsurface extraction by chemical, thermal, or other processes, including leaching of surface dumps). Effects of mineral exploration and of on-site processing are discussed in the context of these mining activities, as appropriate, although on-site processing is necessarily emphasized in the discussion of provisions for waste control. A few minerals, because they can be extracted in several ways, are discussed here in more than one category of mining activity.

Our discussion of the applicability of the Act's technical provisions to non-coal minerals draws on numerous examples identified in the course of our study, as well as information compiled in preceding chapters of this report. Accordingly, some aspects of non-coal mining that are described elsewhere are also mentioned here, especially matters of waste control and costs, so that this chapter can be directly responsive in analyzing the Act's environmental requirements. Information on costs is often incomplete, uncertain, or unavailable, but we give examples of costs for waste control and reclamation, as experienced in some operations. These examples represent real costs of present practices, but these practices are not immutable. The cost of backfilling, for instance, is calculated in terms of returning excavated material to the pit, rather than as a sequential operation that fills old pits with the waste from new workings.

5.2.1 Provisions that Concern Mining Technology

5.2.1.1 Synopsis of Provisions

507(b)(7), 508(a)(5)

The permit application and the reclamation plan shall contain a description of the type and method of the coal mining and reclamation operation, the engineering techniques, and the equipment used, as well as a descripton of how each of the requirements set out in Section 515 will be met.

515(b)(9)

Seal all auger holes (from auger mining) to prevent drainage. Augering may be prohibited by the regulatory authority under specified circumstances.

515(b)(15), 719

Plan, announce, record, and limit the types of explosives to prevent injury to persons, damage to public and private property outside the permit area, adverse impacts on any underground mine, and change in the course, channel, or availability of ground or surface water outside the permit area. Explosives are to be used only by trained personnel.

515(b)(25)

An undisturbed natural barrier beginning at the elevation of the lowest coal seam to be mined shall be retained in place as a barrier to slides and erosion.

516(b)(1)

For underground coal mining, the operator is exempted from the requirement to prevent subsidence, where the mining technology used requires planned subsidence in a predictable and controlled manner.

516(b)(2); 516(b)(3)

For underground coal mining, seal all openings and exploratory holes no longer needed for the mining operation, and maximize to the extent technologically and economically feasible the return of wastes to mine excavations.

516(b)(10); 516(d)

Provides for modifications by the Secretary of the Interior to performance standards and other requirements for control of environmental impacts as necessary to accommodate the distinct difference between surface and underground coal mining.

522(a)(1)

Designation of an area by a State as unsuitable for surface coal mining shall not prevent mineral exploration pursuant to the Act.

5.2.1.2 Discussion

The Surface Mining Control and Reclamation Act, by being restricted to coal mining, is predicated on a limited range of mining technology. When non-coal mining is considered, many more techniques of mining obviously become pertinent in seeking to understand aspects of mineral extraction. Such an understanding is the first step in contemplating what further control over the effects of mining, if any, may be desirable (see Chapter 2). The mining provisions of the Act, to the limited extent that they address technical aspects of excavation, concern only mining of stratified deposits in multiple seams. Even so, these requirements are largely applicable to the circumstances of non-coal minerals. Only the provisions for auger mining (Sec. 515(b)(9)) and for retaining a barrier at the toe of the lowest seam (Sec. 515(b)(25)) are unique to coal. Considerations of mining for non-coal minerals, however, would need to deal with many more methods of extraction and with a broader range of conditions related to the places where these minerals are produced and processed. Most important would be differences in scale of operations as compared with surface mining of coal. In Florida, for example, 6,000 acres are strip mined each year for phosphate as compared with the current annual disturbance of about 5,000 acres for all Western coal mining. Also, open pit mining for copper in the Sahuarita district of Arizona handles material at a rate greater than 680,000 tons per day when in full production (USBM Minerals Yearbook 1974), and an underground mine producing 50,000 barrels of oil per day from rich zones of oil shale would process 85,000 tons of oil shale (Hoskins and others, 1976)--an amount much greater than any underground coal mine.

The variable nature of the geologic occurrences of non-coal minerals also influences the choice of mining techniques that are most efficient. The discontinuous distribution of uranium ore in sedimentary basins, for example, and variation in the size, depth, configuration, and grade of the ore bodies, impose physical and economic constraints on the sequence of mining and on handling and placement of overburden and interburden.

The requirements for blasting under the Act are considered to be needlessly detailed for certain kinds of non-coal mining, although the general provision to prevent damage to public and private property is clearly mandatory, and any operator should be required to investigate and rectify any damage from blasting. The Act does not specify a standard by which potentially damaging effects of blasting could be limited, but there are technical arguments for basing such a standard on a combination of particle velocity and frequency (Medearis 1976). Also, for some mining operations, the requirement for a blasting schedule could be replaced by the common practice of firing at a fixed time of day, although most operations adjust their schedules for blasting in accord with local climatic conditions such as atmospheric inversions and lightning storms. Inversions reflect the noise of blasting, and lightning can accidentally ignite explosives.

The provisions for sealing openings and exploratory holes are discussed with other requirements for control of water pollution (Section 5.2.7). Backfilling of underground workings is discussed in Chapter 3 on waste management (Sections 3.4.2, 3.4.4.1).

5.2.2 Provisions that Concern Effects on Land

5.2.2.1 Synopsis of Provisions Given in the Act

Prime Farm Land

507(b)(16) - 701(20).

The permit application shall contain a soil survey to confirm the location of prime farm lands, when a reconnaissance suggests that such lands may be present.

508(a)(2) - 701(20).

The reclamation plan shall include a statement of the condition of the land, including appropriate classification as prime farm lands.

510(d)(1) - 701(20).

If the area to be mined contains prime farm land, the regulatory authority, in order to issue a permit, shall find in writing that the operator has the technological capability to restore such mined area to equivalent or higher levels of yield as non-mined prime farm land in the surrounding area and can meet the soil reconstruction standards of the Act.

515(b)(7).

For prime farm land: segregate the A horizon of the natural soil (except where other soil materials have a greater productive capacity), stockpile this material separately and protect it from wind and water erosion and from acid or toxic contamination; segregate and protect the B or C horizons in a similar manner, in order to create a final root zone comparable to that of the natural soil; replace the B or C horizons over the regraded spoil material; and redistribute the A horizon.

Other Provisions

507(b)(14).

The permit application shall contain comprehensive cross-section maps of the area prior to mining and profiles at appropriate cross sections of the anticipated final surface configuration.

515(b)(3) - 515(b)(17) - 701(2).

Backfill, compact, and grade in order to restore the approximate original contour, with high walls, spoil piles, and depressions eliminated (exceptions are allowed for thickness of coal in relation to overburden). The reclaimed area may include terraces, access roads, and water impoundments, but shall closely resemble the general surface configuration prior to mining and shall blend into and complement the surrounding drainage pattern. (For requirements on configuration of excess spoil material, see Sec. 515(b)(22) under provisions for waste control.)

515(b)(12).

Refrain from surface coal mining within 500 feet of an underground mine, except as permitted by the regulatory authority.

515(d).

Surface coal mining on slopes steeper than 20 degrees, or on lesser slopes defined by the regulatory authority, may be allowed provided that no debris, disabled equipment, spoil material, or waste is placed downslope, that backfilling is done to completely cover the highwall, and that land above the highwall is disturbed (if permitted at all) only in amount to facilitate compliance with the Act.

516(b)(1).

For underground coal mining, prevent subsidence to the extent technologically and economically feasible (an exception is allowed where the mining technology used requires planned subsidence in a predictable and controlled manner).

711.

Provides for departures from environmental protection standards for limited experimental mining and reclamation practices if these practices are approved for a particular postmining land use and are not larger or more numerous than necessary to determine their effectiveness and economic feasibility. (For other conditions for such departures, see provisions for waste control and for social impacts.)

5.2.2.2 Discussion

Exploration, although scarcely mentioned in the Act (Sec. 512), is an essential part of the recovery of all minerals. Depending on the nature of the mineral commodity and its geologic occurrence, the effects of exploration on the land surface, and on ground water if exploratory holes are deep (Section 5.2.3.2), are more or less widespread, even though confined to the drilling sites, test pits, and access roads. For coal mining, the Act recognizes that disturbances caused by exploration are to be reclaimed in a manner comparable to other disturbed sites (see reclamation provisions, Section 5.2.7.4). A similar provision is applicable to exploration for non-coal minerals. However, because of the wide differences in the geology and hydrologic conditions of these minerals, and because of the geographic and climatic variability of their occurrence, requirements for the conduct of exploration necessarily should recognize such diversity. For example, the requirements might recognize differences in vulnerability of the land, or in its potential for reclamation, as reflected in the nature of ground cover, surface conditions that vary with the season, character of land use, and land management designations (special use areas, roadless areas, wetlands, alpine tundra, and many others). Other considerations pertinent to the effect of exploration are the possible effects on historical features and outdoor recreation.

Quarries necessarily result in an excavated pit, and reclamation of the land surface by regrading to the approximate original contour, as envisaged in the Act, is not practical, because virtually all the excavated material is consumed. However, backfilling might be possible if fill material could be obtained from nearby sources. In some cases limited terracing may be feasible. Also, the detailed requirements for permits and reclamation plans (Sec. 507; Sec. 508) are generally inappropriate for these kinds of mines, which ordinarily occupy only small areas but are exploited for very long periods of time. Even so, some of the Act's provisions could be applied to operations that extract certain kinds of clay and sand and gravel. In particular, the restrictions for steep-slope mining (Sec. 515(d)) and for operating near an underground mine (Sec. 515(b)(12)) are applicable, the latter especially so if a quarry is opened for aggregate or dimension stone and requires use of explosives. The requirements for reclaiming prime farm land are generally not applicable, because the land surface is lowered, perhaps even below the water table. However, certain parts of a sand and gravel operation in some terrain, notably in areas of terrace deposits, could be reclaimed for farming under a suitable reclamation plan (see Working Paper III). For clay mining, requirements for reconstructing soils in areas of prime farm land could be met, provided that it is recognized that materials such as kaolin and bauxite do not normally occur in such areas. Complete backfilling of quarries with on-site material is ruled out, in that the excavated material is consumed. For example, to backfill a typical stone quarry in Indiana using available overburden and waste, which would fill only four-fifths of the quarry, would cost 10.3 percent of the sales price of the stone (letter from Indiana Limestone Institute of America, Inc., January 15, 1979). Also, if backfilling of existing quarries mined by the cement industry were to be required, the total cost would approach $3 billion (Table 3.6). Even without backfilling, some areas mined for brick clay can be beneficially modified by eliminating steep slopes. Similarly, a quarry can be reclaimed for various desirable postmining uses other than exclusively for farming, such as for wildlife habitat and for recreation. Such uses have been widely promoted by trade associations (Schellie 1977) and could be compatible with recognized public needs.

Quarrying operations for construction materials also differ from surface coal mining in that they are mostly as close as possible to the places where the excavated materials will be used. Accordingly, operators often hear complaints about noise from blasting, truck traffic, and unsightliness while the operations are under way. These problems for the operators, and for the residents in the affected area, do not have obvious solutions, but the future of the construction materials industry depends on a resolution of these issues.

Open pits involve excavation and dumping of large masses of earth and rock, a process that completely changes the character of the land surface. Pits dug for phosphate rock in southeast Idaho, for example, are in mountainous terrain where the excavated overburden is ordinarily dumped downhill on steep slopes. Open pits for low grade deposits are also associated with large volumes of tailings that are generated by milling the ore. Rock waste and lean ore at the Bingham pit in Utah, the world's largest, covers 6.8 square miles, and the tailings cover another 8.4 square miles. Tailings and rock waste associated with taconite production in Minnesota now cover about 40 square miles. Controlling the effect of these wastes on land is chiefly a matter of selecting suitable areas for disposal. With planning, it should be possible to construct waste piles in the taconite district with reasonable conformity to the local topography, terracing the slopes to minimize erosion. Provisions for dealing with the rock waste and tailings are discussed below under control of waste (Section 5.2.7.2). Here, we are concerned with the practicality of backfilling such pits and with other options for reclamation.

Backfilling, provided that depletion of the mineral deposit makes it at all possible, is a costly requirement of the Act if applied to some open pit operations (Sec. 515(b)(3)), as discussed below. Even if an adjacent pit is available for dumping, or if the nature of the mineral deposit is such that the pit can be advantageously dug in an elongate form, thus allowing for backfilling on one face while the pit advances on the opposite face (Banks and Franciscotti 1976), backfilling nonetheless requires rehandling of the material initially excavated. For this material, the cost of handling is at least doubled. In the case of mineral deposits that are reached only at depths of several hundred feet, this cost would be very large. For example, in 1977, 110 million cubic yards was excavated from open pits mined for uranium. Counting a 30 percent expansion factor and some use of excavated material to fill contiguous pits, a requirement for backfilling would have resulted in double-handling of half the overburden at an approximate cost of $55 million (see Working Paper IV). The cost to backfill an iron mine in the Lake Superior district would also be large, increasing the cost per ton of taconite pellets 19 percent for a large mine in Minnesota having a life of 50 years (a backfilling cost of $3.5 billion for a remaining tonnage of 900 million) and 59 percent for a medium-sized mine in Michigan having a life of 10 years ($415 million for a remaining tonnage of 35 million) (see Working Paper VII). The cost of backfilling would thus be from 20 to 100 times the cost of grading and revegetation (Section 3.5.4). The costs to backfill other large pits would be in the same range (Table 3.6).

Rather than backfill large open pits, placement of the rock waste and tailings conceivably can be managed in ways that would build a new landscape suitable for anticipated postmining uses. Such a concept has been presented for handling rock waste and tailings in the Sahuarita copper district (Matter and others 1974) and is consistent with certain provisions in the Act that provide flexibility in planning for postmining land use, for example, the requirements for mountain-top mining (Sec. 515(c)). Surface disposal of some solid waste is usually necessary in any case because the mined material expands during mining and processing, thus filling a volume greater than the original pit.

With regard to the other provisions, existing open pits for the extraction of iron, copper, molybdenum, uranium, and other low-grade ores are not found in areas of prime farm land, and the Act's reclamation requirements for such lands do not apply. The other provisions for effects on land are generally applicable to open-pit mining.

A requirement to backfill to the original contour is inconsistent with some reclamation aspects of strip mining for phosphate in Florida, even though backfilling could be accomplished with solid wastes produced during mining and processing. That is, the space previously occupied by the ore, which is about a third of the original volume, could be approximately compensated by a 30 percent expansion factor for the excavated material. The problems for backfilling arise from considerations of cost and from characteristics of slimes from processing (Section 3.4.4.3), which have limited potential for reclamation. The slimes can be reclaimed only for light agricultural use after many years of drying. In current practice, the slimes are mostly backfilled into excavated areas enlarged by use of peripheral dikes. But when pits are unavailable, slimes are also placed in ponds that are constructed outside the pit on unmined lands. The ponds rise to a height of 40 to 60 feet above grade and use sand for embankments that came originally from the mined-out pit. The cost of handling is currently the guiding principle in selecting the disposal area and the size and depth of ponds, whether these are in the pit or above grade, but such economic factors can also reduce the area ultimately covered by slimes. That is, a balance is struck between the height of the dike--a factor that obviously influences the pond area--and the availability and cost of land. The resulting landscape, although differing from the surrounding flatter terrain, is reclaimable for postmining land uses under appropriate reclamation plans. Such uses include agriculture, wildlife habitat, and recreation (U.S. Environmental Protection Agency 1978).

The other provisions of the Act that deal with effects on land are compatible with phosphate mining in the Coastal Plain, although no areas of prime farm land are identified in Florida. Also, for this region, adequate drainage of the soil is more significant for plant growth than the soil's intrinsic physical and chemical properties (Swift Agricultural Chemical Corporation 1978). The provisions for experimental practices (Sec. 711) are especially appropriate and would be applicable as the high-grade land-pebble deposits become exhausted (only a few years hence) and as other sources of phosphate in the region come to be correspondingly of economic interest. Because some of the phosphate deposits not now exploited occur along streams and in wetlands, requirements for future mining should consider appropriate reclamation practices and land use policies for such areas. Wetlands of the Coastal Plain are rapidly being reduced by man's activities but are essential habitats for maintaining certain economically valuable fishery resources, as well as for wildlife habitat (U.S. Fish and Wildlife Service 1977).

In the event that radiation from decay products of uranium, which is associated with the Coastal Plain phosphate deposits, is identified as being hazardous to public health, although it is not now so recognized (Roessler and others 1978), material from the uranium-bearing leached zone could be buried, and slime ponds could be covered to a safe depth.

Requirements of the Act for the effects of underground mines on the land surface are applicable but mostly pertain to disposal of solid wastes and to reclamation of sites disturbed by surface facilities and roads. These matters are discussed under the provisions for waste control and reclamation practices (Section 5.2.7).

Solution mining of sulfur by the Frasch process, which is practiced on the Gulf coast of Louisiana and Texas, is nearly always accompanied by subsidence of the surface. Such subsidence is advantageous for further production because it forces hot water used in the process into bodies of sulfur not yet melted and, hence, improves recovery (Cummins and Given 1973). Solution mining of salt in shallow deposits of the Eastern States also induces some subsidence, but pumping of the brine is stopped when subsidence is detected because further subsidence would damage the well. The well is then closed and plugged. Thus, if solution mining is done for sulfur or salt in built-up areas, subsidence could damage surface structures. The only feasible control is to limit areas of such solution mining.

Some of the effects on land that are associated with in situ processes and solution mining are recognized in the Act by provisions for reclaiming sites used for surface facilities. These requirements are discussed below under reclamation practices (Section 5.2.7.4). The surface effects associated with what is called "modified in situ" mining of oil shale, however, would result in such large and permanent changes to the land surface that these effects are appropriately summarized here. The modified in situ method requires excavation of 20-30 percent of the oil shale in an underground chamber. The remaining oil shale is broken into small pieces by blasting and is then heated by burning some of it, thus expanding the shale and filling the chamber more or less completely. Accordingly, virtually none of the excavated shale can be returned underground. One operator plans to retort the excavated shale by a surface process, but another contemplates simply storing it in surface dumps. In either case, the amounts of shale placed on the surface would be large. For a project that is designed to produce 57,000 barrels of oil per day from the richest interval of oil shale, thus excavating comparatively small amounts of shale in contrast with the same production from leaner zones, the excavated shale would total 14 million tons per year (C-b Shale Oil Venture 1977). Placed in a canyon, but rising from 100 to 200 feet above the surrounding terrain, this dump would cover 1,100 acres in 30 years. Plans for land use at the close of such an operation would need to consider how such a disposal area could be used, and these plans could influence its design and reclamation.

5.2.3 Provisions that Concern Impacts on Water Availability

5.2.3.1 Synopsis of Provisions

507(b)(10).

The permit application shall contain the name of the watershed and location of the stream into which the surface and pit drainage will be discharged.

507(b)(11) - 510(b)(3).

The permit application, or revision of an existing permit, shall contain a determination of the probable hydrologic consequences of the mining and reclamation operations, both on and off the mine site, with respect to the hydrologic regime, quantity and quality of water in surface and ground water systems, including the dissolved and suspended solids under seasonal flow conditions, and sufficient data for assessment of the cumulative impacts of all anticipated mining in the area upon the hydrology of the area and particularly upon water availability -- when hydrologic information on the general area prior to mining is made available from an appropriate Federal or State agency -- but the permit shall not be approved until such information is available and the regulatory authority has made this assessment and determined that the operation has been designed to prevent material damage to the hydrologic balance outside the permit area.

507(b)(14) - 507(b)(15) - 508(a)(12).

The permit application and the reclamation plan shall contain cross-section maps or plans showing the location of subsurface water, if encountered, and its quality, the location of aquifers, the estimated elevation of the water table, the location of impoundments, any water facility, constructed or natural drainways, and locations of discharges to any surface water on or adjacent to the affected land. This information shall also contain results of analysis of the chemical properties of the coal and overburden, including potentially acid and toxic forming properties, and of the stratum immediately under the coal.

508(a)(5).

The reclamation plan shall include a plan for control of surface water drainage and of water accumulation.

508(a)(13) - 717.

The reclamation plan shall describe measures to be taken to protect: quality of surface and ground water, both on-site and off-site; rights of present water users; and quantity of surface and ground water, both on-site and off-site -- or to provide alternative sources of water.

510(b)(5) - 701(1).
No permit application, or revision of an existing permit, shall be approved if the proposed area is an alluvial valley floor west of the 100th meridian and would interrupt, discontinue, or preclude farming, or would materially damage the quantity and quality of water in surface or underground water systems that supply such a valley floor. (For protection of the hydrologic functions of alluvial valley floors during mining and reclamation, see Sec. 515(b)(10).)

515(b)(8).
Construct any authorized impoundments so that water quality will be suitable on a permanent basis for its intended use, so that the level of water will be reasonably stable, and so that such impoundments will not diminish the quality or quantity of water used by adjacent or surrounding land owners.

515(b)(10 - 516(b)(9).
Minimize disturbances to the hydrologic balance at the mine site and in associated off-site areas by avoiding acid or other toxic mine drainage, preventing contributions of suspended solids to stream flow or runoff, and by avoiding channel deepening or enlargement. For surface coal mining, further minimize such disturbances by constructing siltation structures, removing temporary settling ponds after disturbed areas are revegetated and stabilized, restoring recharge capacity, and by preserving the essential hydrologic functions of alluvial valley floors in arid and semiarid areas.

5.2.3.2 Discussion

Exploratory drilling, especially exploration for uranium, is now commonly taken to such depths that several aquifers may be breached. Such holes, if not completely plugged, may cause some mixing between the aquifers, but the possible effects in changing the availability of water are unknown. Presumably, the effects are mainly to alter the water quality (Section 5.2.7.1), but drill holes left open could also cause a loss or gain of accessible water, depending on possible changes in artesian conditions. Exploration drilling for coastal plain phosphate does not breach the main artesian aquifer, but drainage wells (which are also known locally as connector wells) are drilled into the artesian aquifer in order to dewater the ore zone. This practice is endorsed by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency 1978).

Quarries do not significantly affect the availability of water in most regions of the country, although some use water in substantial quantities. Water used in sand and gravel operations is ordinarily recycled, and little make-up water is needed (Evans 1978). Kaolin producers in the principal part of the kaolin belt in Georgia are permitted to withdraw up to 64 million gallons per day (Husted and others 1978), which is a phenomenal consumption by Western standards (72,000 acre-feet per year). This withdrawal has not had serious consequences, because the ground water is abundant and because other users withdraw only small amounts. On the other hand, quarries in humid regions of the country normally receive an inflow of ground water that is pumped out during quarrying operations. The surrounding water table is then lowered, perhaps to the detriment of nearby users. Such pumping at Hershey, Pennsylvania, caused wells, springs, and streams to go dry or to suffer lower water levels to a distance of a mile and a half from the mine (Foose 1969). Commonly, it is possible to augment the water by deepening the wells. However, in the Eastern States, where the right to use ground water and surface water customarily goes with ownership of the land, the requirement to provide alternative sources of water to off-site users (Sec. 508(a)(13); Sec. 717) could be viewed as discriminating against surface miners, who also have rights to the available water. In the West, where surface water is apportioned and rights for its beneficial use are adjudicated by the States, use of surface water by a mining operation would be limited by such rights, irrespective of these provisions of the Act. Substantial withdrawals of ground water in the West are also regulated by the States. Lowered water levels adjacent to mining sites could be monitored with observation wells, as required by the Act (see provisions for collection of data, Section 5.3.1).

Quarry operators could comply with the requirements to determine the location of subsurface water (Sec. 507(b)(14)), to control drainage (Sec. 508(a)(5)), to remove settling ponds (Sec. 515(b)(10)), and to minimize disturbances to the hydrologic balance (Sec. 515(b)(10)). Inactive quarries, and quarries that do not pump large quantities of water for operation, have minor effect on the hydrologic balance. Some water is lost by evaporation, thus lowering the contiguous water table, but ground water is also intermittently recharged by storms. Quarries in arid lands are commonly above the water table and in these circumstances there is no effect on ground-water reservoirs. If bodies of water created by excavating quarries below the water table are considered to be impoundments (Sec. 508(b)(8)), the requirements of the Act could be satisfied. However, the alluvial valley floor prohibition (Sec. 510(b)(5)), if applied to construction materials, might exclude some new operations from Western valleys, perhaps to the detriment of users who depend on these valley deposits for sand and gravel. We know of no clay mine that occupies an alluvial valley floor. The provision to make a permit conditional on a determination of the cumulative hydrologic consequences of mining (Sec. 507(b)(11)) would place a considerable burden on operators in that such information is not generally available. This requirement seems inappropriate for quarries, which are typically small and scattered.

Open-pit mines could not generally comply with the provisions on maintaining the availability of water, especially in arid and semiarid regions. Any use of water in such places inevitably depletes the water available to others. Large pits in low-grade deposits necessarily consume considerable quantities of water for milling the ore and for disposal of tailings, even though much of the water may be recycled (Section 3.2.2). The amounts consumed per ton for typical mineral deposits are 240 to 480 gallons for copper, about 240 gallons for uranium, and 150 to 250 gallons for iron ore. For copper mining in the West, this water may be taken from surface impoundments, but it is more usually pumped from ground water, perhaps from aquifers in alluvial basins that are also being pumped for irrigation water. Thus, the mine competes with other users, and the ground water supply is progressively depleted. Such "ground-water mining," as it is called, has long been one of the most serious resource problems in the West (Arizona State Water Commission 1975, Harshbarger 1966). In some instances, depletion of ground water leads to land subsidence, to opening of cracks in the ground surface, and to degradation of water quality. To the extent that milling of ores may contribute to the problem of ground water depletion, consideration of water resources as an aspect of mineral policy must recognize the consumptive demands of such operations. For example, increased production of taconite in Minnesota during the years ahead, coupled with commensurate growth in population, is expected to provoke some problems in water supply early in the next century (U.S. Army Corps of Engineers 1976).

If alluvial valley floors are identified in an area of non-coal mining, and if the provisions of the Act were to be applied to such mining, the places in which solid waste could be dumped would be limited. Aspects of the possible effects of such solid waste on the water quality of alluvial valley floors are discussed in Section 5.2.7.1.

Strip mining for Florida phosphate also consumes water. This water is mostly entrained in slimes and tailings, but some is used for slurry transport. These uses of water have caused a regional lowering in the Floridan aquifer of 40 feet in the past 25 years (Mills and Laughlin 1976), even though central Florida receives rainfall at least equal to that of other Eastern States. The further hydrologic consequences of cumulative phosphate mining, as required by the Act (Sec. 507(b)(11)), are predictable (Mills and Laughlin 1976) but probably cannot be mitigated as long as mining and processing of the phosphate continue. The Floridan aquifer could be partially replenished by connecting the near-surface ground water to the artesian system with injection wells, a practice that is now followed at most processing plants. This drawdown of the Floridan aquifer is considered to be reversible when the mining stops. However, water withdrawals for mining that result in encroachment of salt water, a danger only in North Carolina, would not be quickly reversed.

Underground mining poses no particular difficulty for maintaining the availability of water, except where operations consume water for processing the ore and are done in a locality with limited supplies. In this sense, the water demands for underground mining are comparable to those for surface mining.

Most in situ processes consume water and could not meet the requirements of the Act for maintaining the availability of water. Recovery of oil from tar sands by in situ steam injection consumes more than 9 barrels of water per barrel of oil (Cameron Engineers, Inc. 1978:365), and recovery of potash from salt-laden solutions at Moab, Utah, evaporates 1,200 gallons per ton of potash. Curiously, the modified in situ process for oil shale also consumes water, even though excess water is produced by retorting (Rio Blanco Oil Shale Project 1977, V. 2; Cotter and others 1978). The retort water is highly contaminated, and the feasability of recycling it is uncertain because effective and economical treatment methods have not been developed (Section 3.2.4.1). Dewatering during in situ processing of oil shale also affects the availability of ground water, hence its discharge to nearby springs and streams; and the water collected as runoff from processed shale is so contaminated with salts that it must be prevented from being discharged, virtually in perpetuity. Thus, for oil shale mining, making water available at impoundments (Sec. 515(b)(8)) and removing settling ponds (Sec. 515(b)(10)) would be ill-advised.

On the other hand, in situ mining of uranium depletes the local ground water very little because most of the water brought to the surface is reinjected after being stripped of uranium. Still, some ground water is lost (Section 5.2.7.1). A requirement to replace any water that has been diminished in quantity by this extraction process (Sec. 508(a)(13)) would simply mean that the water would be made unavailable to some other user from whom a water right has been purchased. The same comment applies to water consumed by oil shale processing, as indeed it applies to all industrial water used in regions where the available water is fully appropriated.

The provisions in the Act that deal with hydrologic regime (Sec. 507(b)(11)), location of subsurface water (Sec. 507(b)(14)), control of surface drainage (Sec. 508(a)(5)), impoundments (Sec. 515(b)(8)), and minimizing disturbances (Sec. 515(b)(10)) all have some applicability to in situ processes and solution mining. Nonetheless, their actual suitability depends on the nature of the activities, the severity of the impacts on quantity of water, and the character of the region in which the processes are used. The provision for protecting alluvial valley floors is not widely applicable to in situ mining (Sec. 510(b)(5)), but this requirement has local significance in the region of Western oil shale and tar sands.

5.2.4 Provisions that Concern Effects on Biological Systems

5.2.4.1 Synopsis of Provisions

515(b)(17).
Construct and maintain roads to control or prevent damage to fish or wildlife or their habitat.

515(b)(24) - 516(b)(11).
Minimize disturbances and adverse impacts to fish and wildlife, and enhance such resources where practicable.

522(e).
Prohibits surface coal mining in National parks, wildlife refuges, wilderness areas, wild and scenic rivers, recreation areas, and national trails. Surface mining is restricted, but not necessarily prohibited, in national forests and public parks.

5.2.4.2 Discussion

Protection of fish and wildlife, as required by the Act, is obviously applicable to all mining operations and is without question an important aspect of national policy. Such a requirement is duplicated in many other State and Federal programs. The Act's provisions, however, lack the teeth of specific detail and fail to recognize that virtually all mining disturbs or displaces biological systems during the life of an operation. For example, displaced animals ordinarily have no place to go because the surrounding habitat is usually filled to capacity, and fish that live in small populations, if reduced in numbers by spillage of toxic effluents, may not be capable of regeneration. Effects of these kinds may extend far beyond the limits of a mining operation and raise the question of what responsibilities for protection and for restoration of habitats should be placed with the operator (Gammon 1970, Bardarik and others 1971).

The Federal Prototype Oil Shale Program (Office of Technology Assessment 1978), because it embraces biological systems of substantial size and complexity, provides guidance for considering the protective role of the operator and the functions of governmental institutions for mining supervision and for wildlife management. The program depends on baseline data collected by the operator, on subsequent monitoring under supervision of the management authority, and on research efforts by wildlife specialists (Dietz and others 1978, Rio Blanco Oil Shale Company 1979, C-b Shale Oil Venture 1979). Such a program may be inappropriate where the operations are small or scattered, but even small mines may have adverse or irreversible effects if located in critical habitats.

5.2.5 Provisions that Concern Economic Matters

5.2.5.1 Synopsis of Provisions

Recovery Of Resources

508(a)(6) - 515(b)(1).

Maximize the utilization and conservation of the solid fuel resource so as to minimize reaffecting the land in the future.

512(d).

Coal removed pursuant to an exploration permit shall be not more than 250 tons, without written approval.

515(b)(9).

Conduct any augering operation (auger mining) to maximize recoverability of mineral reserves, except that augering may be prohibited to maximize utilization, recoverability, or conservation of the solid fuel resources or to protect against adverse water quality impacts.

515(b)(16).

Provides for variances in timeliness of reclamation to combine surface mining with underground mining to assure maximum practical recovery of the mineral resources.

Non-coal Mining

601(c).

Federal land, while under review by the Secretary of the Interior for designation as unsuitable for non-coal mining, may be temporarily withdrawn from mineral entry or leasing for not more than two years.

601(e) - 601(f).
Prior to designating any area of Federal land as unsuitable for non-coal mining, the Secretary of the Interior shall prepare a statement on: the potential mineral resources; demand for these resources; and the impact of such designation on the environment, the economy, and the supply of such mineral resources. The area may be withdrawn from mineral entry and leasing if the Secretary determines from this analysis that benefits from such designation would be greater than benefits to the regional or national economy which could result from mineral development.

Other Provisions

507(c).
Exempts operations not exceeding 100,000 tons per year from the cost of determining the probable hydrologic consequences and of providing results of test borings or core samplings as part of a permit application, and provides in these circumstances that the cost is to be paid by the regulatory authority.

507(f). The permit application shall contain evidence that the applicant has satisfied requirements for public liability insurance.

509(a) - 509(b).
A performance bond not less than $10,000 shall be filed with the regulatory authority before a permit is issued, covering the area to be mined and reclaimed, and covering the duration of the operation and a period coincident with the operator's responsibility for revegetation.

522(d).
Prior to designating any area as unsuitable for surface coal mining, the regulatory authority shall prepare a statement on: the potential coal resources; demand for these resources; and the impact of such designation on the environment, the economy, and the supply of coal.

523(d).
No class of purchasers shall be unreasonably denied purchase of mined coal owned by the United States.

5.2.5.2 Discussion

The provisons in the Act that concern economic matters are a miscellaneous lot. Their rationale varies according to the purposes they are intended to serve. To the extent that these purposes pertain to non-coal minerals--namely: maximizing recovery of resources (Sec. 515(b)(1); Sec. 515(b)(16)), permissible size of test pits (Sec. 512(d)), exemptions of certain costs for small operators (Sec. 507(c)), assurance of public liability (Sec. 507(f)), some form of surety for completion of required reclamation (Sec. 509(a)), and evaluation of mineral resources in the context of land use policy (Sec. 522(d))--they are surely applicable. However, the particular suitability of these provisions for non-coal minerals is doubtful in the light of the diverse mining operations and conditions considered in this report. Several modifications would be appropriate, as discussed below.

Maximizing recovery at quarries is commonly hindered by zoning and other local restrictions, although timely knowledge of location of mineral deposits in built-up areas can help to relieve such conflicts (Section 4.2) (Weaver and Cleaves 1970). Also, a performance bond is inappropriate for many quarry operators and for some uranium miners because such operations commonly have a long lifetime. Other forms of surety could be more economically sound. For example, if a kaolin mining company in Georgia can demonstrate financial responsibility and compliance with its mining plan, requirements for posting a performance bond are waived (Sanford Darby, Georgia Environmental Protection Division, personal communication, 1978). The provision to satisfy requirements for public liability is, of course, universally enforced for quarry operators under local laws and ordinances.

Recovery of resources at an open-pit mine is a matter of achieving balance between the ore grade and the tonnage of material to be handled. Thus, the degree of recovery is influenced by plans for placement of rock waste and tailings. Quite obviously, the grade of ore that can be profitably recovered is also influenced by its selling price, and this factor further determines the quantities of rock waste and tailings that can be moved. Within these restraints, Matter and his co-workers (1974) have suggested aesthetically pleasing and livable designs for placement of the solid wastes. The resulting landforms, however, would differ markedly from the rigid geometric shapes associated with current operations. Future consideration of control of open-pit mining should recognize the economic concepts that underlie these landscape designs.

Considerations of resource recovery are also pertinent in selecting the optimum mining method, in that both open-pit mining and strip mining can result in comparatively high recovery. An open-pit mine in thick sections of Western oil shale would have a waste-to-ore ratio of about one-to-one and would recover even the relatively lean ore from the total thickness of the oil shale deposit (Banks and

Franciscotti 1976). Other methods of extracting oil from oil shale are much less efficient, especially the in situ process as discussed below.

Because of its low cost, strip mining is the preferred method for extracting Coastal Plain phosphate, but the phosphorite that is disseminated in the underlying limestone is not now mined. Experimental approaches for mining and processing the phosphoritic limestone are being tested by the U.S. Bureau of Mines. Future mining of this limestone would disturb land previously mined and reclaimed for land-pebble phosphate in contradiction to provisions in the Act to maximize recovery during the initial operation (Sec. 515(b)(1)).

The degree of recovery of mineral resources by underground mining, like the economic conditions for open-pit mining, depends on mining costs and the selling price. If an underground mine had to be closed indefinitely because of market conditions, some means of reclaiming surface disturbances--at least to the extent of controlling effluent discharges and dust--would be environmentally desirable.

A further complicating factor that influences resource recovery, and that could argue for disturbance of previously reclaimed sites, is the value of tailings and rock waste from old mines and of lean deposits not yet worked out. Improvements in technology and advantageous market conditions have sometimes made such materials economically mineable. Indeed, tailings have been reworked several times at some mines.

In situ operations that are planned for Western oil shale would require several exceptions to these provisions of the Act. These operations are designed to exploit the richest interval of oil shale, retorting only 60 percent of it and recovering only half the potential oil in the part that is retorted. The yield of oil is thus 30 percent of the interval mined (see Working Paper VIII). Thick sections of oil shale above and below would be left untouched, and one operation contemplates no recovery of oil from shale that is excavated in constructing the underground retorts (C-b Shale Oil Venture 1977). Such operations are discordant to the spirit of the Act (Sec. 515(b)(1)) and suggest the need for a policy decision on how far this technology can be carried without causing undue harm to the public interest. Environmental considerations for in situ processing of oil shale also argue against large-scale use of this extraction method (Section 5.2.7.1). With regard to other provisions, because of the experimental character of oil shale mining by in situ methods, and because of the uncertain--but surely prolonged--nature of the environmental impacts, provisions in the Act that give relief to small operators (Sec. 507(c)) and that establish a performance bond (Sec. 509(a)) are inappropriate. Such operations require large investments, and means of surety other than bonding should be found to provide for the anticipated custodial care. However, the provisions for withdrawing Federal lands from mineral entry (Sec. 601) seem to have been designed with the Federal oil shale lands in mind. The baffling legacy of mineral claims for oil shale under the 1872 mining law--a privilege that was replaced under the Mineral Leasing Act of 1920--has been a subject of prolonged adjudication.

5.2.6 Provisions that Concern Social Impacts (Property Rights and Community Services)

5.2.6.1 Synopsis of Provisions

507(b)(2).
The permit application shall contain the names and addresses of owners of all adjacent surface and subsurface areas.

507(b)(13).
The permit application shall contain a map showing significant known archeological sites, boundary lines and owners of abutting surface areas, and buildings within 1,000 feet of the permit area.

507(g) - 515(b)(15) - 719.
The permit application shall contain a blasting plan, and a pre-blasting survey of man-made structures in an area determined by the regulatory authority shall be made when requested by the resident or owner of such a structure within one-half mile of the permit area.

508(a)(9).
The reclamation plan shall include the steps to be taken to comply with applicable health and safety standards.

508(a)(13) - 515(b)(8) - 717.
The reclamation plan shall describe measures to be taken to protect the rights of present users of surface and ground water, or to provide alternative sources of water. A water supply shall be replaced that has been contaminated, diminished, or interrupted by a nearby surface coal mining operation.

510(b)(6) - 714(c) - 714(d).
No permit application, or revision of an existing permit, shall be approved without written consent of the surface owner. The Secretary of the Interior shall consult with surface owners of land underlain by Federal coal deposits before these deposits are offered for lease and shall, in his discretion but to the maximum extent possible,

refrain from leasing such coal for development by methods other than underground mining.

514(d)(3) - 525(c) - 526(c) - 701(8).

When a permit application is approved or disapproved or a notice of violation or cessation order has been issued and a hearing on the determination is requested, the regulatory authority (or court) may grant temporary relief as appropriate, pending final determination, if such relief will not adversely affect public health or safety. (For other conditions, see Sec. 514(d)(3) under provisions for waste control.)

515(b)(17).

Construct and maintain roads to control or prevent damage to public or private property.

516(c).

The regulatory authority shall suspend underground coal mining where there is imminent danger to inhabitants of urbanized areas, cities, towns, and communities.

522(a) - 522(c).

Any person having an interest which is or may be adversely affected may petition the regulatory authority to have an area designated as unsuitable for surface coal mining or to have a designation terminated. Thereafter, any person may intervene by filing allegations supported by evidence.

711 - 701(8).

Provides for departures from environmental protection standards for limited experimental mining and reclamation practices if these practices do not reduce the protection to public health and safety. (For other conditions for such departures, see provisions for waste control and for effects on land.)

5.2.6.2 Discussion

Many of the provisions in the Act that are intended to protect residents and to prevent social injustice were derived from concerns about social impacts of coal mining in the East and West (Section 1.4). Despite the specialized purposes of these provisions, several of them pertain to mining of non-coal minerals, although others would be needlessly burdensome if so applied.

For quarries, the requirements to construct roads without damage to property (Sec. 515(b)(17)) and to protect water rights (Sec. 717) are applicable. The blasting provisions, however, would be economically burdensome to the construction materials industry and can be considered to be an inefficient mechanism to relieve a recognized social problem, namely, harrassment and possible property loss from blasting. Quarries for crushed stone are commonly in densely populated areas, which are subject to frequent changes in ownership of property. Accordingly, the requirement to list the names and addresses of all neighboring property owners (Sec. 507(b)(2); Sec. 507(b)(13)) is inappropriate. A description of land uses surrounding the quarry should be sufficient. Also, a general requirement for inspection of buildings before blasting (Sec. 515(b)(15)) could be costly. For example, one quarry in Illinois has 4,425 residences within half a mile. Figuring $50 per inspection, the total cost for a pre-blasting survey would be about $220,000, and the mailing of blasting notices to these residents on a monthly basis would cost $8,000 annually for postage (see Working Paper III: 78-80). Quarries that use no explosives, such as those for clay, obviously would be excluded from blasting requirements. Water rights, as they might be affected by quarries, are discussed in Section 5.2.3.

Open-pit mining, except at a few places such as Butte, Montana, is done at locations fairly remote from population centers, and the social benefits to be derived from detailed requirements for blasting would be doubtful. Such blasting now conforms with local laws and ordinances intended to protect public health and safety. Open-pit mines could comply with the other provisions for mitigating social impacts, even the requirement for protection of water rights, provided that such provisions are suitably modified for existing climatic, hydrologic, and demographic conditions.

Strip mines for Coastal Plain phosphate could generally comply with these provisions, although the blasting requirements and provisions for the surface owner are not relevant, because explosives are not used. The extensive strip mines for bentonite in Wyoming could also comply and would have no difficulty in meeting requirements for protection of water rights. Clays that underlie the bentonite are impermeable and do not promote a loss in runoff by infiltration.

The requirement that pertains particularly to underground mines is the provision to suspend such mining that endangers urban areas (Sec. 516(c)). Such a requirement would be generally obviated by currently recommended procedures used in planning underground mines (Cummins and Given 1973), but the possible hazard should be recognized nonetheless. A surface owner who is damaged by failure of old underground workings should be compensated under indemnity laws if the mine operator can be found. If not, equity demands that the owner be compensated in some other way.

In situ processing of oil shale has some social implications not recognized in the Act apart from the community impacts that are discussed in Section 2.5. In particular, the health and safety standards referred to in the Act (Sec. 508(a)(9)) presumably pertain to matters such as the safety of drinking water, not the hazard of organic residuals, catalysts, arsenic, and other toxic or hazardous wastes associated with oil shale processing. The surface owner provisions (Sec. 714) also should be modified for Western oil shale to cope with conflicts that may arise from the mingling of Federal and private lands. Perhaps also pertinent in this regard would be resolution of conflicts with grazing permits and leases, which can now be cancelled for oil shale development. The adversary procedure under the Act for considering unsuitable lands (Sec. 522(a)) is intrinsically sound as part of a planning process for regional decisions on oil shale, although many other considerations are necessarily involved in seeking to manage this resource in the public interest (Chapter 6).

As explained earlier (Section 5.1), an important objective of the Act is to protect surface owners and provide opportunities for public participation, some of which are integral to the provisions listed here. The benefits to be derived in making equitable decisions under the Act and the possible threats to industrial growth incurred by too liberal use of these opportunities are still to be determined, but there can be no doubt that a doorway for interventions--by concerned citizens and by affected commercial interests--is desirable in a democratic society.

5.2.7 Provisions that Concern Control of Wastes and Reclamation Practices

5.2.7.1 Provisions for Controlling Pollution of Air and Water

508(a)(9) - 508(a)(13).
The reclamation plan shall describe steps to be taken to comply with applicable air and water quality laws and regulations, and measures to be taken to protect the quality of surface and ground water, both on-site and off-site.

510(c).
The applicant for a permit shall list violations of any Federal law, rule, or regulation pertaining to air or water environmental protection during the previous three years, and how such violations were resolved. If the applicant is currently in violation of the Act, or other laws of the United States pertaining to air and water environmental protection, no permit shall be issued until the violation is corrected or is being satisfactorily corrected.

514(d)(3) - 525(c) - 526(c).

When a permit application is approved or disapproved or a notice of violation or cessation order has been issued and a hearing on the determination is requested, the regulatory authority (or court) may grant temporary relief as appropriate, pending final determination, if such relief will not cause significant imminent environmental harm to land, air, or water resources. (For other conditions, see Sec. 514(d)(3) under provisions for social impacts.)

515(b)(4).

Stabilize and protect all surface areas to control erosion and attendant air and water pollution.

515(b)(10).

Minimize disturbances to the quality of water in surface and ground water systems at the mine site and in associated off-site areas by avoiding acid or other toxic mine drainage (prevent contact with water, treat drainage, case or seal boreholes), by preventing contributions of suspended solids to stream flow and runoff, by constructing siltation structures, and by removing temporary settling ponds after disturbed areas are revegetated and stabilized.

515(b)(14).

Dispose of debris, acid-forming materials, toxic materials, or materials constituting a fire hazard in a manner to prevent contamination of ground or surface water and to prevent sustained combustion.

515(b)(17) - 515(b)(18).

Construct and maintain roads to control or prevent erosion, pollution of water, damage to fish or wildlife or their habitat, or public or private property, and do not construct roads in or near streams.

516(b)(12).

Locate new openings for drift mines working acid-producing or iron-producing coal seams so as to prevent gravity discharges of water from the mine.

519(b).

The evaluation of a request for release from bond shall consider whether pollution of surface and subsurface water is occurring, the probability of continuance or future occurrence of such pollution, and the estimated cost of abating such pollution.

5.2.7.1.1 Discussion. The control of fugitive dust from mining activities, from wind erosion of tailings and rock waste, and from traffic on haul roads is a continual problem at mines, especially in arid regions (Table 3.3). For instance, the amount of dust generated by mining phosphate rock in Idaho is estimated to be 5,250 tons per year (unpublished estimate by U.S. Geological Survey field personnel). Indeed, existing standards for particulates are occasionally exceeded in nearly all mining sites of the country, even in humid areas such as the kaolin district of Georgia. The dust is typically controlled by watering disturbed sites, but chemical stabilizers can be effective for longer periods and where water is scarce. Chemicals cost at least $300 per acre to apply and must be renewed from time to time. Grading and rehabilitation of disturbed sites is the ultimate means for control of fugitive dust and can involve an initial cost of from $400 per acre (Englehard Minerals kaolin mine at McIntyre, Georgia) to as much as $64,000 per acre (125 acres of molybdenum tailings at the Urad Mine, Empire, Colorado) (Section 3.5.4).

Limestone quarried for the manufacture of lime is handled and processed in a manner that requires control of dust from stationary sources, as they are called. Control is by the use of bag filters, dry collectors, and wet scrubbers (Section 3.3.2). These devices cost from $10,000 for a filter system with a capacity of 5,000 cubic feet per minute (cfm) to $215,000 for a scrubber capable of cleaning 50,000 cfm (Minnick 1971).

Air quality standards for lead (Section 3.3.3.3) could be hard to meet at lead mines in that some lead in the atmosphere seems to be inevitable with such mining activity (Wixson 1977). The ore is lead sulfide (galena), a mineral that is insoluble in the natural environment, although it may be converted to a slightly soluble form, lead chloride, in the stomach (U.S. Environmental Protection Agency 1977). Control of lead at lead mines may require covered haul trucks, enclosed storage of ore and concentrates, and improved facilities for handling and ventilation.

For the mining industry at large, the choice of dust collectors--within the limits of operating conditions for temperature and moisture, as well as within possible constraints related to corrosive properties of the air stream--is governed by a balance between installation and operating costs and the efficiency of entrapment that can be achieved. For an air flow of 60,000 cubic feet per minute, the installed costs in 1969 ranged from $25,000 (a dry collector of 65 percent efficiency) to $233,000 (an electrostatic precipitator of 99 percent efficiency), and annual operating costs ranged from $0.09 to $1.41 relative to a flow of a cubic foot per minute (Table 3.4). Such collectors are commonly used where excavated materials are handled and processed, particularly the dry collectors. Thus, these costs are thought to be generally applicable to control of dust at stationary sources in the mining industry--updated, of course, to current prices.

Exploratory drill holes that penetrate water-bearing zones can have an adverse effect on the quality of ground water because they provide a conduit for mixing of water between aquifers of differing quality. In this way, deep ground water heavily laden with dissolved salts could mingle with potable water at lesser depth. Although the influence of drilling on water quality is poorly known, the potential for contamination suggests that such holes should be completely plugged immediately after they have been logged and sampled. Such a requirement would be particularly necessary where drilling is carried to considerable depth on closely spaced centers. This potential problem is especially relevant to the exploration for uranium, which is commonly done in sedimentary basins that hold large quantities of ground water under artesian conditions. Exploratory drilling (including development drilling) for uranium had produced about 1.2 million holes by 1977, totaling nearly 340 million feet, and continued drilling adds 45 million feet annually (Chenoweth 1978). The cost of plugging a diamond-drill hole in 1978 averaged $659, according to information from one company (letter from Omer R. Humble, Exxon Minerals, February 26, 1979), but was only $140 for a rotary-drill hole.

Quarries for the minerals and products listed in Table 5.1 rarely produce acidic, toxic, or flammable materials (Sec. 515(b)(14)) and in general have no adverse effects on the quality of surface water under current methods of operations (Sec. 508(a)(9); Sec. 508(a)(13)). Also, water used at most quarries is recycled where feasible. Operators could easily bury any hazardous debris in a manner that would prevent contamination of water. Like other point sources of potential pollution, discharges to streams and lakes from quarries are regulated under the National Pollutant Discharge Elimination System, that is, by compliance with effluent standards under NPDES permits (see Section 4.4.1). Provisions of the Act for constructing roads at quarries (Sec. 515(b)(17); Sec. 515(b)(18) are consistent with current practices.

Quarries typically disturb very little area beyond the excavation (Sec. 515(b)(4)), and most sediment derived from such operations comes to rest in the bottom of the pit (Oleszkiewica and Krenkel 1972). Where dredging is done in water-filled excavations, any turbid water is routinely retained in ponds. If such excavations are considered as impoundments, it would not be technically feasible to certify the quality of the contained water (Sec. 515(b)(8)) despite designs to insure control of discharge of sediment (see provisions on water availability, Section 5.2.3). This water would ordinarily reach the quarry by inflow of ground water whose quality cannot be controlled by the operator.

Quarries excavated for clay and bauxite commonly produce large quantities of sediment, but the sediment is currently retained in settling ponds of suitable capacity. Such ponds in Georgia are designed to standards of the Soil Conservation Service (see Manual for Erosion and Sedimentation Control in Georgia, published by the Georgia State Soil and Water Conservation Commission) and have been reclaimed by covering with earth and then revegetating the site (S. Darby, Environmental Protection Division, Georgia Department of Natural Resources, personal communication, 1978). These impoundments may also be left in place if they meet specifications of the regulatory authority (Georgia Surface Mine Land Use Board, Rule 645-5-15). On the other hand, the Aluminum Company of America has designed a facility in Arkansas to hold the runoff from a 25-year storm. This operation treats 21 million gallons a day with lime in order to neutralize the acidity from sulfate (pH of 2 to 4) that remains after processing bauxite. Data as recent as 1970 indicate that not all the residual sulfate is removed. The sulfate can exceed 800 milligrams per liter (mg/l) at times of low flow but is diluted to as little at 30 mg/l at times of high flow (USGS 1964). More recent data were not available to show current loading of dissolved sulfate.

If a pond constructed to hold tailings produced by a bauxite mine can be considered a facility for water treatment as well as a receptacle for solid wastes (Section 5.2.7.2), its operation can be counted as being the cost of controlling water pollution. For a mine in Arkansas producing about a million tons per year, this operating cost is $174,000 in 1972 dollars (Table 3.1).

These provisions of the Act could be applied more or less without change to open-pit mines, except that the wording would need to recognize the existing hydrologic factors and the peculiarities of such operations. For instance, the requirement to prevent contact of wastes with water (Sec. 515(b)(10)) does not recognize the role of water in the milling process and the fact that tailings are inevitably exposed to rain. Similarly, even if the pit walls are comparatively vulnerable to erosion, they do not necessarily need to be stabilized (Sec. 515(b)(4)) in that any products of erosion would travel no farther than the pit floor, provided that the pit has no exterior drainage. Piles of rock waste produced by excavating overburden, however, should be protected from erosion, and any derived sediment should be trapped in settling ponds.

Open-pit mines are normally associated with tailings ponds that are in part designed as water treatment facilities. Indeed, under the requirement of the Federal Water Pollution Control Act that the mining industry attain zero discharge of water used in processing (Hyatt 1976), treatment of water cycled through a tailings pond can be considered as a cost of meeting effluent standards. However, on this basis, the cost of treatment can also be considered as a routine business expense in producing water clean enough for further use in the plant. Whatever method of accounting is used, the costs for tailings ponds are very large in that they involve the design and construction of interceptor ditches, pond sealants, underdrains, flow baffles, aeration chambers, riffles, and staged ponding, as well as facilities for treatment of the inflow and the outflow. These features and their costs are discussed in Chapter 3. For example, for treatment of the inflow alone, facilities to handle 12.5 million gallons of water per day at an iron mine in the Mesabi Range, mainly by flocculation and lime precipitation, represent a capital investment of $385,000 and an annual operating cost of $257,000 in 1972 dollars (Table 3.1).

For a copper mine in Montana having an inflow of 720,000 gallons per day, the cost of treatment by lime precipitation is numerically less, although proportionately as much as 3 times larger for the amount of water treated: $108,000 for installation and $29,000 for annual operation (Table 3.1). Because of the complexities of treatment of water used in processing uranium ore (flocculation, clarification, ion exchange, addition of barium chloride, and lime precipitation), the capital investment to treat 500,000 gallons per day is calculated to be $283,000, and the annual operating cost is $11,500, after counting a profit of $88,000 for uranium oxide recovered in the treatment process. These costs are the highest in the industry if figured on the basis of annual tonnage and flow of water. To comply with zero discharge, the costs for water treatment of uranium tailings could be from 3 to 4 times higher.

Strip mining for Coastal Plain phosphate involves very few actions not embraced by these provisions, apart from certain matters of waste disposal that are mentioned later (Section 5.2.7.2). The phosphate itself has no acidic or toxic properties (Sec. 515(b)(14)) but is associated with small amounts of radioactive materials, one of which is the gas, radon-222. Houses on areas that leak radon can be constructed with ventilated foundations, and wastes having low radioactivity could be buried if proved to be hazardous (Section 3.3.3.4). Some ore and waste is transported by pipelines that may occasionally break, thus contaminating surface water. The means of guarding against such ruptures, besides inspection of the pipe, include selection of the alignment and use of double-walled pipe and an alarm system (Zellars-Williams, Inc. 1977). To comply with regulations for control of water pollution in Florida costs $0.118 per ton of product for current operations (Table 3.1).

Some underground mines that extract sulfide ores can produce acidic water if these sulfide minerals become oxidized. Present practice requires treatment of water drained from such mines before it is discharged under a NPDES permit. This can be done at a pond beyond the portal. In this way, such operations comply with the provisions of the Act (Sec. 515(b)(10)), except for their possible effect on the quality of ground water. However, the provision to locate mine openings so as to prevent gravity discharge of water (Sec. 516(b)(12)) is impractical and inconsistent with current practices. Underground mines need efficient haulage, ventilation, and drainage, which means that a tunnel is driven so as to slope slightly downward to its portal. Such openings, in many cases, can be effectively sealed at the close of operations, as required by the Act (Sec. 516(b)(2)). For block caving operations, however, the collapsed area can act as a collecting point for surface water, thus leading to potential contamination of ground water when the mine is closed. No technology is known to prevent this seepage into ground water. Water treatment of tailings from underground mining is comparable to treatment of those from open-pit operations and involves similar costs.

An unsolved problem is the water pollution caused by discharge of acid, metals, and sediment from inactive underground mines (Martin and Mills 1976). More than 1,200 kilometers of streams and 100 locations are affected, 80 percent of them being in Colorado (486 km), Montana (161 km), Missouri (135 km), Idaho (133 km), and California (89 km). Discharge of acid and metals contributes 70 percent of the pollution, the remainder being sediment. An estimated 30,000 metric tons of acid and 10,000 metric tons of metals are discharged annually, not counting low-level sources. Leachates from tailings account for half the pollution, but discharge from openings to underground workings makes up more than 30 percent. Programs to abate this pollution have not gotten underway because of questions of ownership, the possibility of reopening inactive mines, the cost of treatment, and the lack of funding. Technology exists to control discharge of these pollutants to surface water, although the cost would be high (Section 3.2.5). Effects on ground water may be severe, but they are unknown and are probably not controllable.

Solution mining of uranium involves the possible risk of contaminating the ground water, both during and after mining (Thompson and others 1978, Cox and Roushey 1979). Leaching of uranium is currently done with an alkaline liquor of ammonium bicarbonate and hydrogen peroxide; sulfuric acid solutions are also being considered for leaching some deposits. The former reagent is generally preferred because it selectively dissolves uranium and because it facilitates subsequent processing. Whichever solution is used, more is pumped out than is injected in order to insure recovery of the active ingredients and to help in restoring the quality of the ground water. The imbalance causes some depletion of the ground water. Also, despite precautions, leakage from the leach field is possible, and observation wells are needed to monitor the operation. When leakage is detected, the control procedure is to relocate the injection and production wells. Such leaks are known in the industry as excursions. The effects on quality of ground water after mining reflect the inherent difficulty of pumping out all the leaching solution, and, indeed, no such project has yet demonstrated that the water quality has been restored. Moreover, where ammonium bicarbonate is used, the ammonium ion tends to combine with clay in such a way that it cannot be quickly pumped to the surface. Hence, it may remain as a long lasting contaminant.

Water used in mining sulfur by the Frasch process is continuously removed at wells spaced around the periphery of the mine. After treatment and cooling, the water is discharged in a manner to comply with the Clean Water Act, usually into estuaries.

Leaching of copper from worked-out pits in the Globe-Miami district of Arizona began in the 1920s and is now planned on a more intensive scale by the Occidental Minerals Corporation. Sulfuric acid is used to dissolve the oxidized copper. Leaching of waste dumps for recovery of additional copper is also practiced at Bingham Canyon, Utah, and at some mines in Arizona. The effect of such operations on water quality has not been evaluated (Section 5.2.7).

In situ processes for oil shale produce unusual air emissions and liquid effluents that are not embraced by the Act in its provisions for quality of air and water, although the limited requirements of the Act generally apply. Some of these wastes are regulated under the laws for clean air and water, but most of them--including all those potentially most toxic--are not controlled, and technical procedures for reducing them are either uncertain or unavailable (see Working Paper VIII). These same emissions and effluents are produced during surface processing and represent a similar hazard, but the amounts of some of them are then reduced, and opportunities for containment are seemingly more manageable (Crawford and others 1977).

The fate of these emissions and effluents from oil-shale processing is expected to be observable under the current Federal Prototype Program, and such monitoring could lead to some understanding of tolerances for levels of pollution. A large-scale industry, however, should be predicated on a much higher level of knowledge and on more certainty about the feasibility of effective technical controls.

One of the gaseous products from oil shale processing that has no known control, but which has global significance, is carbon dioxide, a gas that is innocuous in small quantities. In situ retorting of oil shale, however, is done at a high temperature that results in breakdown of carbonate minerals and in voluminous quantities of carbon dioxide. Results of simulated in situ retorting indicate a yield of 3.5 pounds of carbon dioxide per pound of oil, apart from the carbon dioxide produced by burning the oil itself (J.H. Campbell, Lawrence Livermore Laboratory, personal communication, 1979). On this basis, production of 300,000 barrels per day--a rate equal to 1.5 percent of the nation's present demand for oil, which may be reached by 1990 according to current industrial plans--would yield 0.3 percent of the 1974 global output of carbon dioxide from fossil fuels (Rotty 1977). On the other hand, about half the 1990 production is expected to be by surface retorting, and this process would yield only one-third as much carbon dioxide as in situ methods (see Working Paper VIII). Considerable concern has been expressed by part of the scientific community about adding to the world's burden of atmospheric carbon dioxide, in that the "greenhouse effect" attributed to this gas may be causing a progressive rise in global temperature (Baes and others 1977). However, the reality of this effect is still in doubt (National Research Council 1977).

An unsolved problem pertinent to the control of air emissions from oil shale processing is that models for atmospheric dispersion in the oil-shale region are very poorly understood. Reliable models and better information on meteorologic conditions are needed before efforts to exercise control over atmospheric concentrations can be effective (Section 4.4.2).

In situ processing of oil shale also involves the risk of massive contamination of ground water if the underground retorts are backflooded. If the backflooding takes place, the contamination would surely last a very long time, perhaps several hundred years (see Working Paper VIII). The contaminated water, because of the dynamics of the hydrologic system, would eventually discharge as surface water with consequent impacts on streams and aquatic habitats. Controls to prevent or limit this contamination of ground water are uncertain and undeveloped. Grouting of in situ retorts as a possible means of control would cost from $1.20 to $3.80 per barrel of oil, if found to be technically feasible, and other means that have been considered for isolating the retorts from ground water would involve costs in the same range (Table 3.1).

5.2.7.2 Provisions for Controlling Solid Wastes

515(b)(11) - 516(b)(14)

Stabilize mine wastes, tailings, coal processing wastes, and other wastes through construction in compacted layers, including use of incombustible and impervious materials, with the final contour compatible with natural surroundings, and revegetate the disposal site in accord with the Act. For surface disposal of wastes from underground coal mining, assure that leachate will not degrade water quality below applicable Federal and State standards.

515(b)(13) - 515(f) - 516(b)(5)
Control according to standards and criteria used by the Chief of Engineers use of existing and new coal mine wastes, tailings, coal processing wastes, or other liquid or solid wastes in dams or embankments.

515(b)(21) - 516(b)(7)
Protect off-site areas from damages that may result from mining or reclamation operation and do not deposit soil or waste outside the permit area.

515(b)(22) - 515(b)(25)
Place excess spoil material in a manner to assure stability, with appropriate drainage, avoiding springs and water courses, on the most moderate slope using a buttress or barrier at the toe, and in a configuration compatible with the surrounding drainage pattern and suitable for intended uses.

516(b)(8) - 701(8)
For underground coal mining, eliminate fire hazards and conditions hazardous to public health and safety.

5.2.7.2.1 Discussion. The previous comments have dealt with solid wastes in the context of their relation to mining technology, changes in the land, water availability, economic considerations, health and safety, and pollution of air and water. Here we are concerned with provisions of the Act with respect to the stability of such wastes and their role in degrading water quality by contributing leachate.

The provisions for stabilizing solid wastes can be met for most quarries, which are regulated in this respect by the various States. For instance, waste rock produced at quarries for crushed stone does not ordinarily need to be compacted to achieve stability. Scraps from stone quarries have value and eventually can be sold. The prohibition against off-site dumping of solid wastes (Sec. 515(b)(21)) is troublesome, however, if this requirement is meant to exclude use of this material to backfill other sites. Waste from stone quarries is chemically inert and is not harmful for off-site uses (see Working Paper III, and Section 5.2.4). In considering how solid wastes are to be placed and contoured, the meaning of grading, as mentioned in the Act (Sec. 515(b)(3)), should be explained, and the long life of typical quarries should be recognized. That is, the provisions do not describe how a compatible contour is to be designed, although a configuration compatible with the natural surroundings and drainage is specified (Sec. 515(b)(11); Sec. 515(b)(22)).

Waste from bauxite processing, colloquially referred to as "red mud," is a special case for quarry operations because it is so voluminous with respect to the quantity of ore. Some 12 million cubic yards are generated each year, enough to cover 300 acres to a depth of 25 feet (U.S. Environmental Protection Agency 1974). Only 10 percent of the bauxite, however, is refined from domestic ore. The red mud is currently held indefinitely behind embankments that are placed on the land surface. These impoundments cost $0.50 to $4.00 per ton of dry solids (U.S. Environmental Protection Agency 1976). Like the slimes from processing of phosphate, the red mud is oversaturated with water and is extremely slow to dry (U.S. Environmental Protection Agency 1974:40). Its stability is entirely contingent on the integrity of the impounding structure and on the adequacy of provisions to divert runoff. Even so, ponds of red mud under existing designs have withstood the onslaught of several hurricanes and are considered to be stable (U.S. Environmental Protection Agency 1974:23). The principal environmental problem caused by red muds is that the wastes occupy substantial areas and are not known to be reclaimable. Also, the water entrained in the red muds is highly alkaline and presumably percolates downward into ground water on some sites, although data on such possible pollution are not available. A mitigating factor is that trace metals found in red mud are in the form of hydroxides that are chemically insoluble under the prevailing conditions. Even so, care must be taken to make impoundments for red mud as impermeable as possible (U.S. Environmental Protection Agency 1974:57).

Open-pit mining involves vastly greater quantities of solid waste than were envisaged in the Act, but the requirements for stability are thought to be satisfied by present practices. However, spoils from pits dug for phosphate rock in Idaho, which are commonly placed on steep slopes, are vulnerable to slumping and erosion. Another consideration is that the volume of solid waste from some operations is so large that springs and water courses cannot always be avoided as required by the Act (Sec. 515 (b)(22)). The volume of solid wastes is, in places, partly reduced by marketing these wastes for road fill, concrete aggregate, and other uses. Some perspective on the quantity of these wastes is provided by the example of oil shale processing. The amounts of processed shale that would be produced from oil shale retorting are so enormous that deep canyons in the oil shale region usually have been considered to be the most suitable places for disposal, the only problems for stability then being the design of a stable configuration for the toe. Some 60 of these canyon sites, providing a volume greater than 5 billion cubic meters, exist in the Piceance Creek Basin of Colorado, enough to accommodate production of nearly 2 million barrels of oil per day if no more than 5 percent of the canyon space is used for processed shale in any year (Ericsson and Morgan 1978). Clearly, at the end of 20 years, the Piceance Creek Basin under this schedule would have little resemblance to its former topography. The amount of processed shale (8.2 billion tons) would represent 27 percent of all other solid waste from mining that has accumulated thus far (Section 3.4). By one calculation, processed shale can be transported and dumped at a cost of about $0.25 per ton (Earnest and others 1977).

Tailings ponds associated with open-pit mining grow from the face backward and normally achieve stability without the need for prior embankments constructed of other material. The tailings are necessarily saturated when initially deposited and stay wet for many years, probably decades (Cummins and Given 1973). Under these conditions, tailings ponds might be expected to be subject to collapse or flowage under a seismic shock of sufficient magnitude, but experience indicates that the risk is less than for most man-made structures (Waller and others 1974). Stabilization of 2.6 million tons of abandoned uranium tailings on 105 acres at Ambrosia Lake, New Mexico, is estimated to cost from $920,000 to $2,230,000, depending on the stringency of the procedures to be used (Ford, Bacon & Davis Utah, Inc. 1978; see Table 3.5).

Leachate from tailings and rock waste associated with open-pit mines has not been a subject for close study and is largely an unknown quantity. From considerations of geochemistry, however, the composition of leachate undoubtedly varies between the many kinds of mineral deposits and could be hazardous in some places. For example, phosphate rock that is mined in southeast Idaho contains trace amounts of arsenic, cadmium, lead, molybdenum, selenium, thallium, vanadium, zinc, uranium, and radium, all of which potentially could become contaminants of the local water as a consequence of mining. Indeed, vanadium has been measured at a concentration of 5,900 micrograms per liter in waste water from processing of phosphate rock, and arsenic has been found in the ground water (U.S. Department of the Interior and U.S. Department of Agriculture 1977). Also, minute amounts of molybdenum in the Denver water supply have been traced upstream to the

Climax molybdenum deposit (Chappell 1975). This matter is briefly discussed in Sections 3.2.1 and 3.2.3.1. A lining for a tailings pond covering 2,000 acres at a new uranium mine in Washington, which is intended to control leachate, is estimated to cost $4 million (Table 3.5).

Dumps of waste rock from copper mines are, in places, intentionally leached with weak sulfuric acid in a manner such that the resulting metal-bearing leachate can be collected and piped to a recovery plant. The solution can then be recycled. The potential effect of this process on ground water is uncertain, but, for economic reasons, current operations attempt to intercept all the leachate. The waste rock is typically placed so that the leachate can be collected by gravity, such as in an existing valley, and its site is made as impervious as practicable. Diversion ditches for natural runoff are dug above the rock waste, depending on the nature of the drainage basin, and impoundments are built downstream to collect excess runoff that may be contaminated with leachate. The integrity of the system with respect to possible pollution of ground water is generally monitored with wells. If significant seepage is detected, the operation is suspended, and such activities are then set up at another site where recovery of the leached copper can be more complete. The stability of such dumps is primarily a matter of mine safety while the leaching operation is under way. Experience has shown that structural failure of leach dumps has been limited to occasional slumping at the sides, probably from the weight of water used in the leaching process.

The slime ponds in the phosphate district of Florida have been mentioned several times (Sections 3.4.4.3, 5.2.2.2). Like the red mud from bauxite processing (see above), they have repeatedly withstood hurricanes and evidently are being constructed with satisfactory stability, at least since 1971 when new laws for their design were adopted in North Carolina and Florida (North Carolina Department of Natural Resources and Community Development, Title 15, Chapter 5, Mining, Mineral Resources Administrative Code 1978; Florida Department of Environmental Regulation, Rule No. 17-9, Florida Administrative Code 1978). Before 1971, there had been a history of failures. Still, research is continually under way to reduce the volume of slimes, or to increase their strength, by blending them with sand and overburden (Section 3.4.4.3). So far, this research has induced no change in the customary disposal practices. In short, optimum handling of the phosphate slimes is an unsolved problem. Up to 70 percent of the land mined for phosphate is used for disposal of slimes, not only in mined-out pits, but also in impoundments on the surface (Section 5.2.2.2). The years needed to dewater the slimes and their structural weakness delay and restrict opportunities for subsequent land use of these disposal areas. They are further considered to be aesthetically undesirable. Disposal of slimes and tailings by new mines in the Florida phosphate district in a manner that meets current State requirements costs $0.375 per ton of product (Table 3.5).

Leachate from phosphate mining and beneficiation does not appear to present an environmental problem under existing State and Federal regulations for management of solid waste. Also, the activity associated with mining has not yet produced an adverse change in the quality of ground water (Kaufmann and Bliss 1977). Waste materials produced by processing the phosphate, however, are another matter and represent potential contaminants of ground water. Impure gypsum is a by-product from manufacturing of phosphoric acid. Some 152 million tons have been produced in Florida, with 20 million tons being added annually (Sweeney and Timmons 1973). The gypsum has no economic use and is simply dumped on the land where it leaches slowly downward into the ground water. This problem is further complicated by the presence of uranium decay products in the gypsum, which have been transferred from the parent phosphate (Guimond 1977). In this situation, placement of an impermeable substance under the gypsum has been suggested (Kaufmann and Bliss 1977). Another potential pollutant from processing of phosphate is the sulfate salt from sulfur dioxide that is trapped in scrubber wastes. The source of this sulfate contaminant is number 6 fuel oil used in the drying process (J. Sweeney, personal communication, 1979, U.S. Bureau of Mines). This pollutant can be controlled by eliminating the drying process.

Underground mines produce solid wastes in the same manner as open-pit mines, although normally in lesser quantities. They are handled in a comparable manner and the same considerations with respect to stability and leachates are applicable. For some underground operations, the solid wastes are in part a by-product, as in the sale of limestone tailings in Missouri and eastern Tennessee for agricultural use. Disposal of tailings from such a mine--the Star-Morning Mine at Wallace, Idaho, for example--costs from $1.00 to $1.50 per ton, and the construction cost for a new tailings pond at the Homestake Mine in South Dakota, where the production is nearly 6 times larger, was more than $11 million (Table 3.5). Where oil shale would be mined by underground methods, not all the processed shale could be placed in the underground workings. If this means of disposal were found to be technically feasible, the cost would range from about $0.3 to $1.19 per ton, depending on the method of handling (Earnest and others 1977; see Section 3.4.4.1). However, such underground disposal involves the risk of contaminating ground water with salts and with possibly hazardous constituents leached from the processed shale (Brown and Stewart 1978).

Underground mining of potash in southeast New Mexico has covered 1,100 acres to an average depth of 150 feet with ordinary salt. Another 3,500 acres are occupied by brine ponds.

Solution mining for uranium involves the collection of uranium on resins in ion-exchange columns. Other constituents are simultaneously collected with the uranium and must be removed, thus producing a quantity of solid wastes. In producing 1,500 tons of uranium oxide (yellow cake) a year, the amount of solid waste generated by this process is typically 200 to 350 tons a year (Thompson and others 1978) The wastes consist mostly of calcium carbonate which has been made weakly radioactive. In current practice, these excess solids are shipped to a disposal site for radioactive wastes in Barnwell, South Carolina.

Leachate from piles of processed oil shale has been shown in some experiments to contain considerable amounts of salts and organic compounds (Fox 1979). Some of these, unless impeded by impermeable barriers, would permeate the ground and eventually reach the ground water. This source of contamination, however, is considered to be a minor matter in comparison with the pollution that would result from contact of ground water with in situ retorts (Section 5.2.7.1).

5.2.7.3 Provisions for Revegetation

508(a)(5)

The reclamation plan shall include a plan for soil reconstruction, replacement, stabilization, and appropriate revegetation.

509(a)-509(b)

The bond for performance shall reflect the difficulty of reclamation, giving consideration to revegetation potential, and shall be for the duration of the surface coal mining and reclamation operation, and for a period coincident with the operator's responsibility for revegetation.

515(b)(5) - 515(b)(6)

Remove, segregate, preserve, and replace topsoil, or other material shown to be more suitable to support vegetation.

515(b)(22)

Organic material (of the topsoil) shall be removed immediately before placement of spoil.

515(b)(19); 515(b)(20); 516(b)(6)

Revegetate disturbed areas with a diverse and permanent vegetative cover of the same seasonal variety native to the area, capable of self-regeneration, and at least equal in extent of cover to the natural vegetation. For areas disturbed by surface coal mining, assume responsibility for successful revegetation for five years after the last year of revegetation efforts, or for 10 years where the average precipitation is 26 inches or less.

5.2.7.3.1 Discussion. The revegetation requirements of the Act have some application to the reclamation needs for quarries but have not been written in the light of the lengthy timetable that is customary for these operations. In some instances, removal and preservation of the soil (Sec. 515(b)(5)) would involve stockpiling for decades. The ultimate use for this stockpile would remain uncertain while plans for final land use are undecided. Also, for humid regions, some operators consider that vegetation can be established on subsoils, even though the benefits of more fertile topsoil are undeniable (Leisman and others 1957). Indeed, topsoil is counted as a commodity in many areas and is commonly sold for off-site use. For some postmining land use plans, depending on the physical nature of the quarry, the selling of topsoil might be acceptable, provided that it has no use for on-site reclamation, such as excavation for a lake. Given the need to revegetate a quarry site for construction materials, handling the soil and establishing a vegetative cover can be accomplished in most regions of the country although with difficulty in arid regions (Section 3.5). For example, some clay quarries in Georgia were revegetated in 1976 at a cost of $680 per acre under State standards dating from 1968. The greater part of this cost was for grading and preparing the spoils for planting (Table 3.6).

Areas disturbed by open-pit mining for iron ore in Minnesota are more or less readily revegetated to forest, although this is currently done only for overburden and tailings, not for stockpiles of lean ore. But open pits in the Western States are commonly in desert lands where the success of revegetation efforts is difficult and problematical. Indeed, dumps from turquoise deposits mined centuries ago by Indians near Santa Fe, New Mexico, appear to be scarcely modified by subsequent growth of plants (National Research Council 1974). Conscientious efforts, however, using non-native species, mulches, fertilizer, and irrigation, have produced remarkable results on mine wastes in desert lands. Whether these revegetated plots can be sustained in a hands-off condition remains to be seen, but the revegetation requirements of the Act are thought to apply to even the drier sites, provided that the standard of reference is something resembling the indigenous vegetation.

Lacking an unequivocal demonstration that artificially induced vegetation can be sustained in deserts, consideration could be given to other means of surface treatment to impede erosion by wind and water. These methods might include use of chemical binding agents and placement of a cover of rocks.

Despite the climatic differences between regions where large-scale open-pit mining is practiced, the current revegetation costs (not complete reclamation) are more or less comparable: $500 per acre at the Thiele Kaolin mine in Georgia; $550-600 per acre at the Erie Mining Company taconite mine in Minnesota; and $1,000 per acre at the Highland uranium mine in Wyoming (Table 3.6). Even so, the cost at some operations can be substantially larger. ASARCO spends $1,900 per acre to revegetate embankments and construction sites at its copper mine in Arizona, $1,000 of the cost being for irrigation, and AMAX spends $1,600 to $1,800 per acre at Climax, Colorado to apply a mixture of seeds and mulch (Table 3.6).

The revegetation provisions are applicable to strip mines in the Coastal Plain, but the requirements for soil handling are considered unnecessary. The ordinary wastes and overburden are so much like the soils of this region that vegetation can be successfully established on any of these materials. Reclamation costs for new phosphate mines in Florida range from $0.418 to $0.561 per ton of product, but established operations comply with State requirements at a cost of $0.335 per ton of product (Table 3.6). In Florida, however, revegetation of the mined land is not always required under current regulations. Several postmining land uses are acceptable, only one of which demands a permanent vegetative cover of the native flora. Another exception for this region, in contrast with the timetable established in the Act (Sec. 515(b)(20)), is that a year has proved to be sufficient to determine the eventual establishment of vegetative cover (J.W. Yon, Jr., Administrator, Mines and Mine Reclamation Section, Florida Bureau of Geology, personal communication, 1978). To require a longer period would rule out the opportunity to use the land more quickly.

Strip mines for bentonite in Wyoming--and to a lesser extent in Montana and South Dakota--were formerly abandoned without reclamation with the result that spoil piles, highwalls, and shallow pits, many of them occupied intermittently by saline lakes, are very widespread. Under a Wyoming law adopted in 1972, bentonite mines are now required to be reclaimed by filling, contouring, and topsoiling, and by revegetation. The success of these efforts has been variable, showing beneficial results only where the annual precipitation is at least 10 inches and where mined areas are underlain by permeable deposits.

Revegetation of desert areas, which may receive as little as 4 to 6 inches of precipitation, has been unsuccessful. Hence, if effective revegetation were to be required on such sites, they could not be mined under provisions of the Act. The costs for grading and revegetation efforts at bentonite mines in Wyoming have ranged from $283 to $371 per acre, which represents less than 1 percent of the production cost (Table 3.6).

Underground mining for non-coal minerals is done in a wide range of places, producing various disturbances of the land surface. Revegetation of virtually all such disturbed sites, except for those places disturbed by block-caving, would seem to be embraced by the provisions of the Act. With this exception, the costs would be comparable to those for open-pit mines.

Revegetation experiments on plots of processed oil shale, and on soils placed on processed shale, have been under way for several years (Harbert and Berg 1978). Although none of these experiments has been completed, in the sense of demonstrating hands-off success for a protracted period of time, the requirements of the Act are believed to be as applicable to the oil shale region as to nearby areas of coal, provided that a soil cover is placed on the procéssed shale. However, the period required before revegetation efforts can begin is so long that some form of surety other than bonding would be appropriate.

5.2.7.4 Provisions for Other Aspects of Reclamation

<u>508(a)</u>

The reclamation plan shall include a degree of detail necessary to demonstrate that reclamation required by the Act can be accomplished.

<u>508(a)(5)</u>

The reclamation plan shall estimate the cost per acre of reclamation.

<u>510(b)(2); 511(a)(2)</u>

No permit application, or revision of an existing permit, shall be approved unless the applicant demonstrates that reclamation required by the Act can be acomplished under the reclamation plan.

<u>512(a)</u>

Regulations for coal exploration under a State or Federal program shall include provisions for reclamation in accordance with the performance standards of the Act for all lands disturbed.

508(a)(7); 515(b)(16)

Reclamation efforts shall proceed according to an estimated timetable and as contemporaneously as practicable with mining except for variances that may be allowed to combine surface mining with underground mining to assure maximum practical recovery of the mineral resources.

508(a)(10); 515(b)(23)

Achieve reclamation in accordance with the Act, considering physical, climatic, and other characteristics.

516(b)(10); 516(d)

For underground coal mining, follow the performance standards for surface coal mines, with necessary modifications as determined by the Secretary of the Interior.

519(b); 519(c)

The evaluation of a request for release from bond shall be made within 30 days and shall consider the degree of difficulty and cost to complete any remaining reclamation, whether pollution of surface and subsurface water is occurring and might continue to occur, and the amount of completion of backfilling, regrading, drainage control, revegetation, sediment control, return of soil productivity, and the need for future maintenance of a permanent impoundment permitted under the Act, according to specified schedules and conditions.

711

Provides for departures from environmental protection standards for limited experimental mining and reclamation practices if these practices are potentially at least as protective of the environment as those required by standards of the Act. (For other conditions for such departures, see provisions for social impacts and for effects on land.)

5.2.7.4.1 Discussion. The remaining provisions of the Act that deal with reclamation focus mostly on assuring that reclamation will be done in a timely manner as part of the mining operation and will be completed. These aims are reasonable and could be applied to many kinds of mining, but they are not universally applicable to the variable circumstances encountered in non-coal mining. The requirements can also be seen as being unneccessarily specific and detailed for the limited impacts caused by small mines. The operator of a clay quarry, for example, which produces only small quantities of material for specialized uses, would prefer to excavate the kind of clay actually needed and to schedule operations according to demand rather than operate under the restrictions of a formal plan. Such flexibility may be appropriate for a clay quarry, but this kind of random groping toward an undetermined objective, particularly for larger mines, can never produce premeditated reclamation. The elimination of such aimless behavior is a basic purpose of the Act's provisions for reclamation.

With the reservation that quarries may be kept open for long periods, and that plans for postmining use may not be conceived until the end of operations, the reclamation requirements of the Act could be applied to these operations. However, requirements of lesser detail probably would accomplish the same level of reclamation for most quarries. Indeed, a set of guidelines, diversified according to the situations encountered in quarry operations, might serve as well.

Solar evaporation to obtain various salts is locally practiced in the Western deserts and in some estuaries. For instance, ponds for evaporation cover 72,000 acres in the environs of Great Salt Lake, Utah, the largest area of such use (see Working Paper IX). Reclamation of such ponds is unlikely in the near future, in that they can be expected to be used indefinitely, but it would involve little more than removal of man-made structures, dikes, and roads. Revegetation would be neither appropriate nor feasible, and flooding of the reclaimed area would virtually restore the premining conditions.

The other types of mining considered here usually result in larger impacts than those of quarries and evaporation ponds, but the reclamation provisions of the Act appear to be broad enough to embrace most of their effects, for both new and existing operations. The Act's deficiencies are the lack of recognition of reclamation problems caused by the huge quantities of solid wastes associated with some mines and the lack of provisions that deal with reclamation problems related to exploration. For instance, exploration in arid lands and in arctic and alpine tundra was never contemplated in writing the reclamation provisions of the Act (Zuck and Brown 1976). Nor did the Act, being confined to coal, need to address reclamation questions that are raised by block caving, in situ mining, reprocessing of tailings, and custodial care for massive impoundments of solid waste. Such limitations in the coverage of the Act, many of which have been discussed in this section of the report, are considered further in Chapter 6.

5.2.8 Provisions that Concern Jurisdictional (Governmental) Controls

5.2.8.1 Synopsis of Provisions

503(a)

Each State that wishes to assume exclusive jurisdiction over the regulation of surface coal mining and reclamation operations on non-Federal lands shall submit to the Secretary of the Interior a State program to carry out the provisions of the Act.

503(a)(3)

A State regulatory authority shall have sufficient administrative and technical personnel, and sufficient funding, to implement responsibilities under the Act.

503(a)(6) - 504(h)

State and Federal programs for surface coal mining and reclamation shall include a process for coordinating review and issuance of permits for such operations with any other Federal or State permit process applicable to the proposed operation.

506(d)(1); 510(a); 513(a)

Upon receipt of an application for a surface coal mining and reclamation permit, or for revision or renewal of an existing permit, the State regulatory authority shall notify various local governmental bodies, planning agencies, and sewage and water treatment authorities, or water companies, of the location, within the political subdivision in which the proposed surface mine is to be located, where the application may be inspected. Local governmental officials in the local political subdivision shall be notified within 10 days after a permit has been issued.

508(a)(3)

The reclamation plan shall include comments on the proposed land use by the owners of the surface, and by State and local governments or agencies, which would have to initiate, implement, approve, or authorize the proposed use following reclamation.

513(b)

Provides opportunity for written objections and an informal conference for any person having an interest which is or may be adversely affected, or for the officer or head of any Federal, State or local governmental agency, with respect to a surface mining and reclamation permit, or for revision of an existing permit.

519(a)

A permittee requesting release of a performance bond or deposit shall, as part of the bond release application, notify adjoining property owners and local governmental bodies, planning agencies, and sewage and water treatment authorities, or water companies, of his intention to seek release from the bond.

519(e)

The State regulatory authority shall notify the municipality in which a surface coal mining operation is located at least 30 days prior to any bond release.

519(f)

Provides opportunity for written objections and a public hearing for any person with a valid legal interest which might be adversely affected by release of the bond, or for the responsible officer or head of any Federal, State, or local governmental agency which has jurisdiction by law or special expertise, with respect to a proposed release from bond.

521(a)(5)

The Secretary of the Interior shall send a copy of an order to cease surface coal mining and reclamation, or a notice for abatement of a violation, to the State regulatory authority.

522(a)(5)

Determinations of the unsuitability of land for surface coal mining shall be integrated with present and future land use planning and regulation processes at the Federal, State, and local levels.

522(b)

Prior to designating Federal lands as unsuitable for surface coal mining, the Secretary of the Interior shall consult with appropriate State and local agencies.

522(e)

Prohibits surface coal mining (except in some specified circumstances): within boundaries of units of the National

Park System, the National Wildlife Refuge Systems, the National System of Trails, the National Wilderness Preservation System, the Wild and Scenic Rivers System, including study rivers designated under section 5(a) of the Wild and Scenic Rivers Act, and National Recreation Areas designated by Act of Congress; on Federal lands within the boundaries of any national forest; that would adversely affect any publically owned park or places included in the National Register of Historic Sites; within 100 feet of a public road; within 300 feet of an occupied dwelling, public building, school, church, community or institutional building, or public park; and within 100 feet of a cemetery.

523

The Secretary of the Interior shall promulgate and implement a program applicable to all surface coal mining on Federal lands incorporating all requirements of the Act and the requirements of approved State programs. A State may elect to cooperate with the Secretary to regulate surface coal mining and reclamation on Federal lands. (See Sec. 710 for Indian lands).

710

Surface coal mining on Indian lands shall comply with provisions of the Act with respect to permit applications, reclamation plans, performance bonds, approval or denial of permits, environmental protection performance standards, surface effects of underground mining operations, inspections and monitoring, and release from performance bonds or deposits. Requests by the Indian tribe for additional terms and conditions shall be included in new leases.

713

Provides for coordination by the President of regulatory and inspection activities, particularly enforcement requirements, among departments and agencies to which such activities are assigned by this Act, the Clean Air Act, the Water Pollution Control Act, the Department of Energy Organization Act, and by existing or subsequently enacted Federal mine safety and health laws.

5.2.8.2 Discussion

The jurisdictional procedures specified in these provisions emphasize the conviction of the Congress that maximum responsibility for control of surface mining should be placed with local authorities. The provisions also specify the obligations of Federal authorities in cooperating with local governments. Such integration of jurisdictional responsibility is laudable and could avoid much needless duplication of institutional controls. Even so, the existing complexity of bureaucratic procedures at all levels is such that actual reduction in the quantity of paperwork now required, for the operators and for the regulatory authorities, undoubtedly will be a slow and difficult process (Chapter 4). It is bureaucratically easier to impose administrative authority than to remove it, once established.

To a very large extent, the concept of relying on local control and on elimination of unproductive overlaps in administration is applicable to all classes of mining activity. The following remarks concern a few aspects of non-coal minerals and suggest other ways for matching jurisdictional controls to the impacts of mining. Our focus is on effects of mining that could be considered in deciding on an appropriate level of jurisdiction. The situations summarized here are discussed more completely in Chapter 6.

Placement of responsibility with State authorities could go far in matching reclamation needs to local conditions (Sec. 508(a)), but other considerations argue for retaining Federal control over some mining activities. Also, some aspects of mining could be advantageously controlled by municipal or regional authorities rather than by a State.

Federal control over the effects of mining activities may be indicated when their environmental impacts extend beyond the jurisdiction of lesser authorities. Expressed differently, when the effects of an operation or a group of operations are dispersed, control of these distant impacts by the local government is inappropriate. This finding is one of the reasons that the Act imposes minimum standards for surface mining of coal (Section 5.1.2). Further, if the impacts are recognizable at a distance but are not explicitly traceable to their source at a mine, Federal control may also be indicated. The same conclusion applies if technical means for controlling the impacts or for monitoring them are uncertain. The argument in these cases is that local authorities would generally be unable, legally, to control actions beyond their jurisdictional boundaries and could not arbitrarily enforce practices intended to control effects of uncertain origin. However, the Federal government could apply national standards aimed at controlling these effects, as is done in setting standards for clean air and water. Finally, even though some States have conservation laws, Federal involvement may be desirable to encourage maximum recovery of mineral resources, or to inhibit wasteful practices, on the grounds that conservation of non-renewable resources is in the national public interest.

On the other hand, when an effect of mining is confined to a locality or an area, responsibility for control could rest with the lowest level of government that has jurisdiction and that embraces the affected region of public interest--depending, of course, on the nature and severity of the effect on the public and the environment (Section 6.5).

The requirement of the Act that a State shall have sufficient technical personnel (Sec. 503(a)(3)) fails to take into account that some necessary skills are found chiefly, although not entirely, in large Federal research establishments. This is notably true for monitoring of meteorological conditions and for atmospheric modeling, as well as for observations and modeling of water resources.

With regard to the need to notify jurisdictional authorities about applications for release from bond (Sec. 519(a)), the Act's failure to mention land management authorities appears to be an oversight. The same comment applies with regard to offices for Coastal Zone Management and other regional authorities that have a legitimate interest in the conduct of mining.

The control of surface mining on Indian lands (Sec. 710), is being studied separately and is beyond the scope of this report. By way of comment, however, in the light of the unique relationship between Indian tribes and the Federal Government and the Indians' legal status in American society, it appears appropriate to us that the various tribes retain jurisdiction over their non-coal minerals. Indian tribes own the mineral resources underlying their reservation lands, although some issues on tribal rights to tax, regulate, and monitor these resources are still unresolved (Owens 1978).

The Act's attention to coordination of enforcement (Sec. 713) brings to mind that coordination in balancing the intensity and location of some mining and processing activities might be warranted. For example, adjustments in the size and location of mines could benefit the public interest by promoting better dilution of air emissions, by apportioning the use of limited water resources, and by minimizing disturbances of ecologically valuable areas. Such considerations also pertain to the siting of mining activities near sensitive areas (the national parks, for instance) when alternative sites are available. Similar concepts have been applied in public decisions on the location and numbers of power plants in regions of clean air and should not be neglected in contemplating future mining.

5.2.9 Provisions that Concern Existing Land Use Plans

5.2.9.1 Synopsis of Provisions

507(d) - 508(a)(2)

The permit application shall contain a reclamation plan meeting requirements of the Act, including: existing uses; the uses preceding any mining if the land has a history of previous mining; the capability of the land prior to mining to support a variety of uses; and the productivity of the land prior to mining, including prime farm lands and yield of food, fiber, forage, or wood products.

508(a)(8)

The reclamation plan shall include consideration given to make the operation consistent with surface owner plans and with applicable State and local land use plans and programs.

510(b)(4)

No permit application, or revision of an existing permit, shall be approved if the proposed area is within an area designated as unsuitable for surface coal mining under the Act or within an area under study for such designation.

515(b)(2)

Restore affected land to a condition capable of supporting pre-mining land use or higher use, consistent with applicable land use policies and plans.

601(a) - 601(b)

The Secretary of the Interior, if requested by a Governor, may designate Federal land as unsuitable for non-coal mining if the area is predominantly urban or surburban or if mining would have an adverse impact on land used primarily for residential purposes.

5.2.9.2 Discussion

The provisions for compatibility of mining with land use plans are largely based on the premise that mining is a temporary use of the land, which is reclaimable to a condition resembling its premining productivity. The concept is not strictly applicable to most kinds of mining for non-coal minerals. Such mining commonly modifies the land by reshaping, by depositing solid wastes, and by bringing changes in biological habitats, in such a manner that the former use cannot be achieved. Indeed, the mining operation may be so long lasting, as in the case of many quarries and for most large open pits, that uses envisaged at the start of operations may fall far short of actual needs when the operation eventually comes to a close. Thus, a range of different uses for such mines can be considered (see Working Paper III). Also, a mineral commodity conceivably may be so valuable or so strategic that it is worth exploiting in the public interest, even if the mine site is not reclaimable. In actuality, however, few minerals are limited to a given locality--although certain mineral deposits may be mostly confined to a particular region--and options therefore exist to do mining where plans for reclamation can be realistically made. (See discussion of Sec. 102(c) of the Act in Section 5.1.1 of this report.)

The flexible language of the Act provides the latitude to make alternative long-term plans but considers the mining to be so brief in its disturbance that compatibility with existing plans is encouraged. This is a commendable goal but should be modified for non-coal minerals. For example, the excavations left by quarries in humid regions commonly become bodies of water and are reclaimable only for water-based recreation and wildlife (Schellie 1977). The landforms that are products of phosphate mining in Florida are restricted in their eventual uses according to the physical properties of material that are used in their construction. That is, the slime ponds, after many years, form a crust strong enough for light agriculture, although too weak for buildings; but phosphate pits backfilled with tailings (sand) and overburden are capable of many uses, including heavy buildings (Zellars-Williams, Inc. 1977). In places where underground mining involves planned subsidence, as in the block-caving operation at San Manuel, Arizona, the unavoidable chaos at the surface severely limits options for postmining land use.

5.3 ANALYSIS OF MANAGEMENT REQUIREMENTS IN THE ACT

5.3.1 Requirements that Concern Collection of Data

5.3.1.1 Synopsis of Requirements

507(b)(11)

The permit application shall contain sufficient data for an assessment of the probable cumulative impacts of all anticipated mining in the area upon the hydrology of the area and particularly upon water availability.

507(b)(12)

The permit application shall contain information on climatological factors, including precipitation, winds, and temperature.

507(b)(15) - 508(a)(12)

The permit application and the reclamation plan shall contain results of test borings, core samplings, logs of drill holes, the location of subsurface water, and chemical analyses of the coal, its sulfur content, potentially acid or toxic forming sections of the overburden, and the stratum immediately under the coal.

517(b)(1)

The operator shall: maintain appropriate records; make monthly reports to the regulatory authority; and install, use, and maintain any necessary monitoring equipment; evaluate results in a manner prescribed by the regulatory authority; and provide other information deemed reasonable and necessary by the regulatory authority.

517(b)(2)

Where surface coal mining disturbs aquifers, the operator shall, according to standards and procedures set forth by the regulatory authority, monitor: quantity and quality of surface water above and below the minesite, and in the potential zone of influence on aquifers; level, amount, and samples of potentially affected ground water; maintain records of well logs and borehole data; and precipitation.

522(a)(4)

The State shall develop a data base and an inventory system to evaluate the capacity of different land areas for reclamation of surface coal mining operations.

5.3.1.2 Discussion

The data requirements enumerated in these provisions, other than the inventory needed for designating unsuitable lands (Sec. 522(a)(4)), apparently stem from an understanding that surface coal mining may disrupt hydrologic systems and may introduce harmful constituents into water supplies. The purpose of collecting this information seems to be that, if baseline hydrologic and climatologic conditions are known, and if an adverse effect on the water is observed, then the cause can be identified and corrected. As a direct form of regulation, the Act does not need to justify this theory, but its validity should be evaluated in contemplating the data needed for monitoring non-coal mining. This is not to say that all effects must be linked to known causes in order to institute procedures for their possible control (Section 6.4.4). Certain mining activities are obviously deleterious to the environment, by some standards, even if the actual consequences are not accurately measurable. Of course, in many cases, the effects of a mine on its hydrologic environment probably can be traced back to the operation, but situations surely exist where such determinations would be unreliable. The degree of certainty about the cause and source of an observed impact could influence decisions on the best means for its institutional control (Chapter 6).

These data requirements of the Act are limited in that they avoid any consideration of impacts on air quality, biological systems, and social institutions. In light of the stated purposes of the Act (Section 5.1), such omissions suggest that the Congress either did not comprehend how to monitor these impacts or meant to concentrate on what it saw to be the most troublesome issue, namely disturbance of water supplies. Also, because impacts on water can be more or less directly tied to disturbances of the land, the Act apparently intends the data on water to serve as proxy for the success of land reclamation, which is intrinsically much harder to measure.

With respect to non-coal minerals, this rationale of the Act in making use of hydrologic data for measuring the progress of reclamation is surely applicable. Of course, where the excavated materials are small and more or less chemically inert, as in most quarries, far less chemical data would be needed. On the other hand, where the materials are voluminous and chemically complex, as in the processing of oil shale, much more chemical data would be appropriate. That is, the amount of detail suitable for measuring the impacts of a mining operation clearly would depend on its size, its degree of confinement, the nature of the mineral deposit, and the technologies for mining and processing.

The control and reclamation of non-coal mining would also clearly benefit from knowledge obtained by collecting and analyzing other categories of data. Matters of biology and sociology would be appropriate for operations that have large or far-reaching impacts on habitats and people (Sections 5.2.4, 5.2.6). Operations that generate substantial air emissions could be effectively controlled only with knowledge of meteorological conditions and with dependable atmospheric models. Also, certain mineral deposits that are mingled with other mineral resources, or that overlap them--such as oil shale, tar sands, and uranium--could not be managed in the best interests of mineral conservation without knowing the location and value of such resources.

5.3.2 Requirements that Concern Planning

5.3.2.1 Synopsis of Requirements

507(b)(13)

The permit application shall include a topographical map including all man-made features.

515(b)(22)

Place excess spoil material in a configuration suitable for intended uses. (For other requirements, see Sec. 515(b)(22) under provisions for waste control).

515(c)

Provides for variances in restoration of approximate original contour and drainage for mountain-top removal of a coal seam after certification by appropriate planning agencies that the proposed plan constitutes an equal or better economic or public use of the land and is compatible with existing State and local land use plans, and after approval of the design by the regulatory authority, subject to review within three years.

515(e)

Provides for variances in restoration of approximate original contour for surface coal mining on steep slopes after certification by appropriate planning agencies that the proposed plan constitutes an equal or better economic or public use of the land and by appropriate State environmental agencies that watershed control of the area would be improved, subject to review within three years, provided that backfilling is done to completely cover the highwall, and that spoil material is placed off the mine bench only in such amount to achieve the planned postmining land use in accordance with the Act.

522(a) - 522(b)

The State shall establish and implement a planning process to decide which areas are unsuitable for surface coal mining, including: a data base and inventory system to evaluate the capacity of different land areas for reclamation; assessment of incompatibility with existing State and local land use plans and programs; the effect of such mining on important historic, cultural, scientific, and aesthetic values and natural systems; the effect on renewable resource lands; and the effect on natural hazard lands. Determinations of unsuitability shall be integrated with present and future land use planning and regulation processes at the Federal, State, and local levels. The Secretary of the Interior shall review Federal lands and shall implement a process for designating areas unsuitable for surface coal mining using these standards and procedures after consulting with appropriate State and local agencies. Federal lands determined by the Secretary to be unsuitable for surface coal mining, using these standards, shall be withdrawn or conditioned for mineral leasing or mineral entry so as to limit surface coal mining.

5.3.2.2 Discussion

The Surface Mining Control and Reclamation Act supports the premise that successful reclamation depends on planning, but the Act can hardly be said to be a land use statute. Two of the provisions listed above are simply efforts to provide flexibility in reclamation requirements for the Appalachian region, namely, the provisions for mountain-top and steep-slope mining (Sec. 515(c); Sec. 515(d)).

The section on designating some lands as unsuitable for mining, however, (Sec. 522), is an innovative approach in planning for use of private lands (Sheridan 1978). The approach has long been used on Federal lands, where lands have been withdrawn from entry under the various mining laws to promote a variety of alternative uses (U.S. Public Land Law Review Commission 1970). The mechanisms for such action on private lands, however, are generally limited to zoning powers that are typically applied only in urban settings.

The concept of designating lands as unsuitable for mining in non-urban settings is expressed in occasional State laws, some of which are responsive to Federal initiatives. Some States (Maine, for example) have active programs to designate and secure protection of natural or historic areas. Designating some lands as unsuitable for mining is also consistent with the Florida State Comprehensive Land Use Plan and Act 250 in Vermont (Act 250 of the adjourned session of the 1969 Vermont General Assembly, Approved April 1970, 10, VSA, Chapter 150, Sections 6001, et seq.), as well as various State coastal zone management programs that have been developed in response to the Federal Coastal Zone Management Act.

Designating land use, however, usually requires that conflicts between possible uses be resolved. In particular, one view holds that certain areas--a designated wilderness, for example--should never be mined, while an opposing view holds that minerals of limited occurrence should be mined wherever they are found. Still another view is that critical minerals should be mined in wilderness areas, or in other specially designated areas, only during national emergencies. Suggestions on how to resolve such conflicts are beyond the charge to this Committee.

5.3.3 Requirements that Concern Enforcement

5.3.3.1 Synopsis of Requirements

Inspections

513(b)

Any party to the administrative proceeding on a permit application, or revision or renewal of an existing permit, shall have access to the proposed mining area upon request for the purpose of gathering relevant information.

514(b) - 514(e) - 519(b) - 519(h)

Provides for inspections by the regulatory authority of the affected land, or other operations conducted by the applicant, in connection with a permit application, a hearing on a permit application, a request for release from bond, or a hearing on a request for release from bond.

517(a) - 517(b) - 517(c)

Provides for inspections and right of entry of surface coal mines by the Secretary of the Interior and authorized representatives, without advance notice, and on an irregular basis averaging not less than one partial inspection per month and one complete inspection per calender quarter.

517(d) - 517(e)

Inspection reports adequate to enforce the Act shall be filed, and the operator and the regulatory authority shall be informed in writing of each violation found.

517(f)

Copies of any records, reports, or information obtained under provisions for control of the environmental impacts of surface coal mining, as required by the Act, shall be made immediately available to the public at convenient locations to residents in the area.

521(a)(1)

When informed of an alleged violation, the Secretary of the Interior shall notify the State regulatory authority, or--when such an authority does not exist or fails within 10 days of the notification to take the appropriate action or to show good cause for such failure, or when provided with proof of imminent danger of significant environmental harm--shall order a Federal inspection. The person who so informs the Secretary shall be allowed to accompany the inspector.

Orders and Notices

521(a)(2) - 701(8)

An order to cease surface coal mining and reclamation operations is required where a condition, practice, or violation creates an imminent danger to public health or safety or is causing or can reasonably be expected to cause significant, imminent environmental harm to land, air, or water resources.

521(a)(3)

A violation not creating imminent danger to public health or safety or expected to cause significant, imminent environmental harm shall be abated within a reasonable time but not more than 90 days.

521(a)(5)

Notices and orders with respect to violations shall specify the violation, remedial action, abatement period, and the portion of the operation to which the notice or order applies.

Penalties

512(c) - 518(a) - 518(b)

Any person or permittee who conducts coal exploration activities which substantially disturb the natural land surface in violation of the Act, or who violates any permit condition or provision of the Act, may be assessed a penalty not to exceed $5,000 per day for each violation, after the person charged has been given an opportunity for a public hearing.

518(e) - 518(f) - 518(g)

Any person or permittee convicted of willfully and knowingly violating a condition of a permit, or of making false statements or of failing or refusing to comply with any order, shall be fined not more than $10,000 or imprisoned not more than one year, or both.

518(h)

Any operator failing to correct a cited violation shall be assessed a penalty of not less that $750 for each day that such failure or violation continues beyond the period allowed for its correction.

521(a)(4)

A permit shall be suspended or revoked if the Secretary of the Interior finds that a pattern of violations exists or has existed, and finds that such violations are caused by the unwarranted failure of the permittee to comply or that such violations were willfully caused by the permittee.

5.3.3.2 Discussion

If a mining control and reclamation program were to be adopted for one or more non-coal minerals or for one or more types of mining, provisions for enforcement would surely be needed in order to replace previous weaker provisions that are inadequate for the program's objectives. The provisions of the Act establish a model for such enforcement. They provide for close scrutiny over surface coal mining, including opportunities for individuals to accompany inspectors under certain circumstances. The provisions also establish a system for issuing notices and orders for assessing civil penalties. They further provide authority to tailor enforcement actions and abatement periods to the seriousness of the violations. Thus, despite possible shortcomings if applied to the complexities of non-coal mining and processing, the enforcement provisions appear to be entirely applicable to non-coal minerals.

The maximum civil and criminal penalties under the Act are presumably commensurate with the nature of violations that may occur during coal mining. Because the circumstances of non-coal mining are more variable, consideration should be given to adjusting penalties to this variability, but suggestions for appropriate penalties are beyond the scope of this report.

5.4 DEFICIENCIES IN THE ACT FOR PROBLEMS ASSOCIATED WITH NON-COAL MINERALS

The preceding analysis of the Surface Mining Control and Reclamation Act shows its limited value in contemplating the problems associated with the mining of non-coal minerals, although many of the Act's provisions could be applied if its regulatory approach is considered to be appropriate. We evaluate the suitability of direct regulation for several mining situations in the next chapter. Our comments here concern deficiencies of the Act for dealing with mining activities that are, on the one hand, small and scattered--although very numerous--and, on the other, enormous in scope and in economic benefits--although few in number and confined to limited regions of the country.

The numerous small mines scattered over the United States, most of them being quarry operations for various kinds of construction materials, represent a kind of mining wholly unlike a typical coal mine. They serve largely local needs, often near a center of population, and are commonly kept open for decades as the deposit is gradually consumed. Except for mines in sulfide ores, few of these operations present a hazard from acid drainage, although the discharge of sediment usually must be controlled. Also, when such mines are to be reclaimed, removal of the deposit dictates that the postmining land use can rarely resemble the former use.

In these respects, the mostly small mines for construction materials clearly differ from the surface mining operations envisaged in the Act, whereby the land is temporarily occupied for excavating a coal bed, disturbing the environment as little as possible, and is then graded and revegetated to a condition something like it was before. That is, the Act addresses only a single kind of in-and-out mining, which is quickly completed. Understandably, by dealing exclusively with this style of mining, the Act's provisions are poorly suited to the multiplicity of small mining activities described in this report. These activities usually serve local needs for several generations, and most of them are not particularly harmful.

We, therefore, identify as one general category of non-coal mining the mostly small operations for construction materials that are more or less limited in their environmental effects, although necessarily causing some impacts and ultimately requiring conscientious reclamation. Procedures to serve these needs are discussed in Chapter 6.

Quite a different category of mineral development--and a category evidently far from the minds of the writers of the Act--are certain gigantic mineral deposits that extend over large regions, that are extraordinarily valuable to the nation, that require enormous capital investment for development, and that may take centuries to fully exploit. We identify these exceptional resources as follows, listing them in no particular order of significance:

1. iron ore and other metals of the Lake Superior region;

2. porphyry copper deposits of southern Arizona;

3. sedimentary uranium ore in Wyoming, Colorado, New Mexico, and Utah;

4. primary and secondary phosphate deposits in Florida; and

5. oil shale in Colorado, Utah, and Wyoming.

Economically, these resources are so vast that they are, or could be, a mainstay of the national way-of-life, but geographically they are confined to a single State or to a small group of contiguous States. They are thus of national interest, but their extraction brings irreversible social, economic, and environmental changes to local regions of the country, all of which involve trade-offs between benefits and hardships. That is, development of such resources, each with its own set of problems, results in permanent changes in the broad patterns of land use.

From the point of view of control and reclamation of land use, the complex public goals of such regions can hardly be achieved by instituting a number of performance standards, as is presumably satisfactory for surface mining of coal. Rather, development of the resource must be done in the context of what is broadly called "planning". Billions of tons of earth will be excavated, processed, and disposed of--some of it perhaps several times as the conditions for recovery change. These activities, which will last a very long time, should be planned to be compatible with the geology, hydrology, settlement patterns, demographic trends, complex patterns of land ownership, extremely large and long-term capital requirements, and the perpetual importance of the region as a place for wildlife, recreation, and the biological resources that support our life on earth.

This in essence is the extraordinary difference between these enormous mineral resources and the kind of control and reclamation considered in the Surface Mining Control and Reclamation Act. Obviously, the Act is wholly inadequate as a point of reference in trying to grapple with the complex interrelations that must be considered in planning for development of these resources.

Thus, our other broad category of non-coal minerals consists of these huge deposits for which control of mining is only one aspect of a management program that involves the full spectrum of social, economic, and environmental interactions. Procedures that could be considered in seeking to manage these mineral resources in the public interest are discussed in the next chapter.

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CHAPTER 6

ALTERNATIVE INSTITUTIONAL APPROACHES FOR SURFACE MINING CONTROL AND RECLAMATION

6.1 APPROACH

This chapter responds to the provision of PL 95-87 that requires COSMAR to "discuss alternative regulatory mechanisms designed to insure the achievement of the most beneficial postmining land use for areas affected by surface and open pit mining" (Sec. 709(a)(4)). COSMAR recognizes that coal is a special case with respect to the effects of mining and that enactment of PL 95-87 involved numerous compromises and decisions that may not apply or may be inappropriate if legislation is required for other minerals. Therefore, we discuss a broad range of alternative approaches.

COSMAR also recognizes that the discussion that follows is somewhat cursory and that some details of the alternative approaches are not discussed at all. These details will undoubtably be developed in legislative hearings if there is interest in the general approaches.

6.1.1 Meaning of Regulatory Mechanisms

We take regulatory mechanisms to mean the way in which government pursues objectives such as preventing environmental abuse, reclaiming mined lands, and securing desirable postmining land use. We prefer the term "institutional approaches" to "regulatory mechanisms" because there are ways to accomplish such objectives other than direct regulation of the activities of miners. "Institutional Approaches" is also a broad enough term to encompass the relationships among the several levels of government, which should be considered in selecting ways to achieve the desired objectives.

The approach of PL 95-87 provides for administration by the States of a fairly rigid, specialized set of standards that are tailored to the circumstances of coal mining. It is a direct regulatory approach. If the States fail to adopt acceptable procedures for implementing Federal standards, the controls will be implemented directly by the Federal government (Sec. 504). This approach has been used in much of the Federal social and environmental legislation enacted since the 1930s. The purpose of such regulatory legislation is to ensure that the desired results are achieved by forcing consideration of all costs and benefits when private decisions are made. Economists refer to this process as "internalizing external costs."

The alternative approaches described below are also intended to incorporate all external costs in the decisions of mine operators. For various reasons, alternative approaches to direct regulation have not been widely used in the United States. Nevertheless, we believe that they may be suitable in certain circumstances. At the very least, they should be evaluated with a view to improving the overall institutional approach toward limiting the adverse effects of mining.

As noted in Chapter 4, other Federal environmental protection laws, including those dealing with air and water pollution and solid waste recovery, apply to both coal and non-coal mining. This legislation is coordinated to some degree with the provisions of PL 95-87. Improved coordination of these laws with respect to mining is discussed in Section 6.6.

6.1.2 Alternative Institutional Approaches

We have considered three broad concerns that should be involved in choosing institutional approaches for controlling the impacts of mining: (1) the choice of a control technique, (2) the relationships among levels of government in controlling impacts, and (3) means for integrating and coordinating the many laws and regulations that affect mining.

For the first of these, five control techniques were identified as possible substitutes, singly or in combination, for the direct regulation approach of PL 95-87. These techniques, which present a range of increasing preemption of private control over mining activities and the use of mined lands, are: (1) education and technical assistance; (2) economic incentives; (3) regulation aimed at securing certain results following mining; (4) regulation aimed at controlling the practices that produce those results; and(5) public ownership of surface rights.

The second concern is finding ways to utilize effectively the special capabilities of the several levels of government in controlling the impacts of mining. The wide range in scale and effects of non-coal mining suggests that there is no single set of governmental responsibilities that is appropriate for all situations. Rather, various levels of involvement, and possibly even new intergovernmental arrangements, are needed to deal effectively with the variation and complexities in mining.

The third concern is providing a means for integrating, coordinating, and rationalizing the various controls that impinge on mining. One alternative to new authorities for controlling mining impacts is simply to focus existing laws and regulations on mining, an approach that has been used by some States in responding to the Federal Coastal Zone Management Act of 1972. The mechanism that appears to be best suited for integrating the various controls are plans tailored to each mining situation that weigh national, regional, and local interests and provides for consideration of all the impacts of mining (Section 4.6.4).

6.1.3 Complexity of the Task

The complexity of the mining operations studied by COSMAR poses particular problems in discussing alternative institutional approaches for achieving the most beneficial postmining land use. The many different minerals, physiographic and climatic zones, types of mining, reclamation techniques, and current and prospective land uses must all be considered. Further, mining has various effects on land, air, water, vegetation, and wildlife resources, as well as on uses of land.

The effects of mining are also dispersed to various degrees over space and time, thereby possibly involving the interests of a wide range of people. Some effects are primarily local; others can be regional, national, or even global. The effects may be temporary and felt only during the time of mining. On the other hand, they can also be more or less permanent in that they are noticeable for several generations.

In addition, there is the important distinction noted in the previous chapters between the numerous mostly small units mining construction materials scattered throughout the United States and the relatively few large operations that are usually concentrated in major mining districts. For the small scattered operations, for which alternative sources of the mined material are usually available, albeit at higher costs, necessary controls on mining and requirements for reclamation should be applied with a view toward their local impact.

On the other hand, minerals from major mining districts ordinarily have limited alternative sources. Although geographically confined, such mining activities have major regional and national impacts. It seems evident that these minerals can be exploited only in those locations and that this is best done in the context of an overall, long-term, management program that gives due regard to the interplay of national and local environmental, economic, and social consequences.

6.2 SETTING

The requirements for reclamation of coal mined lands, along with mechanisms for achieving them, as set out in PL 95-87 include restoration to original contour, elimination of high walls, restoration of prime farmlands, and maintenance of the integrity of alluvial valleys and hydrologic conditions. Congress determined these requirements as appropriate for the particular conditions of coal mining. We have found that there is wide variation in the appropriateness of such requirements for mining non-coal minerals because of the great differences in economic, environmental, and social consequences of non-coal mining.

We accept the importance and validity of the broad purposes of PL 95-87, including protection of environmental quality characteristics, providing for appropriate postmining land use, and recovery of minerals. These purposes must be accomplished in the context of providing necessary minerals for the nation. However, translating these purposes into meaningful operational objectives can only be done, we believe, if the particular conditions of each non-coal mining operation are adequately recognized. Therefore, an institutional mechanism is needed to establish mined land protection and reclamation objectives.

COSMAR believes that the public interest will generally best be served if operational objectives for mining control and reclamation are defined in land use or management plans that are specific to local or regional requirements and this may be done with Federal, State, and local involvement. This focus for planning was discussed within such a framework in Chapter 4. Control techniques, which are described in some detail in the following pages, are properly applied to meet objectives set forth in such local or regional plans. The objectives must be tailored to the nature of the mining activities, whether for the numerous small operations that satisfy local needs, or for the few mining districts of gigantic size that serve the nation as a whole.

6.2.1 Designating Land as Suitable or Unsuitable for Mining

In addition to being a mechanism for setting objectives for mined lands, the planning process is a proper vehicle for designating land as suitable or unsuitable for mining. This is recognized in PL 95-87, which provides for the designation of areas unsuitable for all or certain types of coal mining through a planning process carried out by the individual States and through a review of Federal lands (Sec. 522). The planning process provides the obvious opportunity to weigh the potential value of a tract of land devoted to mining against its values if devoted to current or prospective nonmining uses.

The value of mineral-bearing land for mining varies widely, but in all cases it is finite. For marginal mining properties, the value of the land for mining is near zero. Some shallow deposits will have a value on the order of $100,000 per acre. For a large copper mine, such as the Bingham open pit in Utah, and other higher grade copper, molybdenum and precious metal mines, the value of the land for mining may be on the order of $2 million per acre. Similarly, the value of land for nonmining uses varies widely within the same general range as that for mining, but also is finite in all cases. A major function of the land use planning process is to recognize and weigh public values for which the normal markets for land provide little or no guidance and to supplant market decisions on land use with those of the planning process.

For minerals, planning decisions could lead to designation of land as unsuitable for mining because the expected total public and private values in nonmining uses exceed the expected value in mining uses. However, such decisions could also lead to designation of areas as "suitable primarily for mining." The latter designation could be used not only to avoid needless future conflicts after incompatible developments have taken place on mineral bearing lands, but also to protect nationally important mineral lands. PL 95-87 uses designations of land as unsuitable for coal mining to protect non-mineral values. However, the great variability in non-coal mineral values, as well as the limited occurrence of some major non-coal mineral deposits, suggest that designation of limited areas as suitable primarily for mining to protect mineral values is a concept of at least equal importance.

6.2.2 Dynamics of Planning Decisions

The technology and economics of non-coal mining changes. Therefore, any planning mechanism that leads to designation of areas as suitable or unsuitable for mining and to determination of appropriate reclamation objectives must be dynamic. Boundaries and designations must be changed to meet changing conditions.

In local planning and zoning, variances are used as a mechanism to recognize changed conditions. For mining, a variance in the context of a plan for an area can also be used to respond to new conditions.

6.2.3 Land Use Plans as Frameworks for Control

Land use plans provide a framework within which techniques for controlling the impacts of mining can be effective. Plans indicate objectives to be pursued in specific areas, conditions that may affect the choice of control techniques, and decisions concerning alternative land uses. Alternatively, objectives can be defined at the national level either in legislation or through a national planning process, but these approaches are not likely to be sensitive to variations in local conditions. The next section describes several alternative control techniques, which could be viewed in the context of a planning framework, either local or national, that specifies objectives.

6.3 ALTERNATIVE CONTROL TECHNIQUES

Some control techniques are clearly regulatory in that they require operators or landowners to accomplish certain objectives, take particular actions, or stay within limits specified in laws, ordinances, or regulations. Other techniques, such as economic incentives or education and technical assistance, only encourage operators or landowners to accomplish objectives or attain specified limits. These techniques do not directly regulate an operator's actions.

The degree of government involvement in achieving beneficial postmining land use lies along a continuum of increasing restrictions. We identify five levels for consideration, ranging from the least degree of involvement to the greatest: (1) education and technical assistance, (2) economic incentives, (3) regulation aimed at results, (4) regulation aimed at practices that produce these results, and (5) public ownership of surface rights.

This continuum of government involvement corresponds to the "bundle of rights" concept as applied to property. At one extreme, that of providing technical assistance, no rights are witheld. At the other extreme, public ownership, all are witheld except as they are delegated through contracts, leases, or less formal means. A brief explanation of each technique follows.

6.3.1 Technical Assistance

This technique is based on making the benefits of basic and applied research available to mine operators through educational programs aimed at the operators at the mine site. In this way, awareness and operational knowledge of the effects of mining are improved, methods of protection against environmental degradation during mining are promoted, and reclamation following mining can be demonstrated.

To be effective, technical assistance usually depends on the operator's perception that there are advantages for him, such as reduced costs, greater recovery of the mineral resources, or greater social acceptability in the community. For example, concepts of pit design that permit effective reclamation at no added cost to the miner could be encouraged on the basis that they would lead to better relations with the local community. Willingness to accept technical assistance and adopt improved techniques is also sometimes seen as a way of avoiding direct regulation. Technical assistance programs are occasionally combined with regulation and penalties with the expectation that the technical assistance will be accepted and improved practices adopted in most cases.

Technical assistance is often used as the basic approach in other areas of environmental management, and advisory guidelines are sometimes combined with financial assistance. For instance, the U.S. Department of Agriculture, through its Soil Conservation Service, Cooperative Extension Service, and Agricultural Stabilization and Conservation Service, is heavily committed to providing farmers with technical assistance. Also, mine safety programs have been based largely on technical assistance. The Office of Biological Services of the U.S. Fish and Wildlife Service has an active program dealing with the disruption of wildlife habitat by mining, and provides manuals and guidelines (U.S. Fish and Wildlife Service 1977). Other agencies that provide technical assistance include the U.S. Geological Survey, the Bureau of Land Management, the Bureau of Mines, and the Forest Service, as well as State agencies and universities.

6.3.2 Economic Incentives

Effluent charges, tax benefits, and other forms of economic incentives can be used to encourage operators to meet public objectives. Effluent charges have been used to some extent to control water pollution in western Europe and Japan (Anderson and others 1977:39). There has been little experience in the United States with effluent charges, although economic incentives in the form of investment credits and writeoffs on taxes have been widely used.

The concept of using effluent charges is that charges per unit of effluent are set at a level that makes it cost effective for the operator to find some means of limiting discharges to a level compatible with an established environmental objective. They provide an economic incentive to innovate and to modify processes and ways to control environmental disruption as costs and prices change. There is a growing body of literature on the use of economic incentives for environmental improvement (Anderson and others 1977, Schultze 1977, Kneese and Schultze 1975, Mills 1978).

If they are to work effectively, economic incentives must reflect market conditions accurately and be sensitive to changes in prices and technology. Use of such incentives further requires that environmental objectives be accurately specified, and that movement toward them be in measurable increments. Thus, in most cases where effluent charges are used or where their use has been discussed in the literature, the applications are for water and air pollution. Although we are not suggesting that present water and air pollution control legislation be changed, effluent charges are a feasible technique for controlling point source pollution, at least in those cases where some level of pollutants in the ambient environment can be tolerated. Where absolute control of toxic substances is desired, effluent charges may not be suitable.

For control of non-point source air and water pollution, the use of effluent charges faces the added difficulty of tracing measurable changes in the amount of pollutants in the environment to particular mining operations. Where there is a single operation in a watershed or airshed, this identification is feasible. For example, iron ore mines and associated facilities on the Mesabi Range are usually separated with respect to impacts on bodies of water. On the other hand, problems with fugitive dust from the copper mines south of Tucson are not well suited to being controlled with effluent charges.

Use of effluent charges to accomplish objectives related to the form in which land is left following mining or to revegetation faces added difficulties in defining these objectives in measurable terms. For example, while restoration to approximate original contours or elimination of high walls can be defined in relatively unambiguous terms, little meaning can be attached to meeting such objectives in part. As an objective, achieving satisfactory revegetation can be defined and measures for partially satisfying this objective can be devised, but problems in maintaining satisfactory revegetation over a number of years remain. However, the same problems exist whether the approach is use of economic incentives or direct regulation.

Tax benefits are a form of economic incentive, but their use presupposes the existence of a taxing system that bears some relation to a measurable environmental problem. Although all forms of taxation affect a miner's ability to operate profitably, the connection between the usual income, sales, and property taxes and the environmental effects of mining are obscure. This fact suggests that effluent charges, or variations of effluent charges applicable to surface effects of mining, are more likely to be useful in controlling the effects of mining than are tax incentives.

During congressional deliberations on PL 95-87, there was consideration of a proposal to levy a charge of $2.50 per ton of surface-mined coal with credits for meeting specified environmental control actions. This idea, a form of economic incentive, was reportedly discarded because there was not enough time to work out some of the issues in its administration, rather than because of a basic dislike of the approach (Donald Crane, Office of Surface Mining, personal communication).

6.3.3 Regulation of Results

This technique stipulates desired results in terms of conditions that are to be achieved following mining and reclamation or in terms of conditions that are to be maintained in the ambient environment during and following mining. Choosing a means to accomplish the desired results is left to the operator, which encourages operators to search for cost-effective means to achieve specified results. It permits the adoption of new and changing technology without basic changes in the requirements of the regulations.

In its broadest form, regulation of results of mining might be defined in terms of returning the mined area to beneficial postmining land use, which is one of the overriding purposes of PL 95-87. This is similar to the broad purpose of the 1972 Federal Water Pollution Control Act, which is to secure swimmable, fishable streams and lakes. The operational meaning of such objectives, however, must usually be further defined. Thus, in PL 95-87, requirements specify return to approximate original contour and elimination of highwalls, both of which can be viewed as subordinate forms of regulation of results.

Regulation of results based on stream standards was the basic approach used in government efforts to reduce water pollution in the 1960s. It is generally conceded that this effort was ineffective because of the difficulty of tracing general stream pollution to particular sources, and the approach was dropped in favor of effluent discharge limitations. The effectiveness of mining regulations defined in terms of desirable results would depend on availability of means to trace effects back to the mining operation that caused them.

For water and even air pollution from some kinds of mining operations, this may be much easier and less confusing than it proved to be for industrial water pollution controls in the 1960s. For mining operations that are relatively isolated from similar operations or for mining effluents that are readily distinguishable from those of other operations, regulation of results is feasible. Examples include gold and silver mines, whose effluents contain specific constituents such as arsenic, cobalt, copper, lead, molybdenum, nickel, selenium, tellurium, and zinc, and isolated mining operations such as some of those on the Mesabi Range.

Regulation of results is likely to be impractical if applied to water or air pollution where the pollutants from mining are indistinguishable from those generated by other kinds of operations. For example, sedimentation from gravel pits may be difficult to distinguish from sedimentation from agricultural or urban land uses. Similarly, where a number of mines are grouped together, as in the copper district south of Tucson, controlling water or air pollution by regulating results would be difficult because of the problem of assigning responsibility, at least as long as it is necessary to impose regulations individually on each mining operation. However, regulation of results could be used in such a case if an institutional mechanism could be devised to assign responsibility for meeting control objectives jointly among the several operations. For example, a contract between the control agency and the several mining operations acting jointly could be used to carry out the intent of the regulations. The contract could require that the mining operators themselves determine which operation is failing to meet the regulations and how the fines or other penalties are to be allocated among the operators.

For other objectives of mined land reclamation--including those concerned with land forms, stability of slopes, restoring to previous levels of use capability, revegetation, and protecting wildlife and natural values--regulation of results is a feasible approach if these objectives can be specified operationally. Impacts of mining in terms of these objectives are readily traced to the operation that causes them.

Meaningful definitions of the objectives are necessary if mine operators are to find ways to achieve them and if progress toward them is to be monitored. This is more difficult for those objectives that are primarily aesthetic than for those that involve stability or productivity of land. For example, defining objectives to be sought with respect to land forms following mining involves aesthetic judgments that are largely absent from those that concern revegetation. Where results of mining are unpredictable, as they may be with respect to the timing of subsidence over underground mines, regulation of results may be impractical because the burden of failing to meet the objectives is placed entirely on the mine operator. In contrast, regulation of practices to be followed by the operator, which may be set arbitrarily, forces the regulator who specifies the practices to at least consider the availability of technologies to achieve objectives.

Regulation of results of mining promotes innovation on the part of the mine operator, because it leaves room for the operator to adopt cost efficient means to achieve the desired results. This technique is generally well suited to cases where impacts can be traced to the operation that causes them and where failure to meet objectives does not lead to release of toxic substances or other pernicious results. For example, it appears appropriate for most aspects of returning the surface to suitable postmining conditions and for those aspects of air and water pollution where results can be traced to specific operations. On the other hand, control of impacts on ground water from in situ, solution, and other underground mining may require a different approach.

6.3.4 Regulation of Practices or Means

This technique stipulates the practices the operator must use during the course of the mining operation and for reclamation. The required practices are based on a judgment by the regulatory agency that they are the most effective and efficient means of accomplishing the desired results. Although usually stated in inflexible terms, many regulations of this type provide for variances if the operator can demonstrate that different practices will achieve the desired results. However, changes in regulations at intervals are usually necessary to keep pace with changing technology and mining conditions.

Regulation of practices is the approach to controlling water pollution that was adopted by Congress in the 1972 Federal Water Pollution Control Act when it was judged that the approach used in the 1960s (regulation of results) was not achieving the desired objectives. Permits issued under the National Pollutant Discharge Elimination System (NPDES) of the 1972 Act specify the effluent discharges permitted for point sources of pollution at each industrial, municipal, or other operation, including mining operations.

Practices to be adopted to meet the broad objectives of the Act are based on studies by the U.S. Environmental Protection Agency, and negotiations between that agency and the affected industry, firm, or municipality.

The "performance standards" in Sec. 515 and 516 of PL 95-87 require a broadly similar approach, although requirements to be met by mine operators in some cases are specified in the law rather than in permits. For example, requirements for handling topsoil (Sec. 515(b)(5), 515(b)(6), and 515(b)(7)) are more specific than parallel requirements in the Federal Water Pollution Control Act.

Regulation of practices was adopted as the favored approach in PL 95-87 because of a concern with the problems caused by coal mining, a lack of satisfactory experience with other control techniques, and a concern that other approaches would be avoided or evaded by coal mine operators (personal communication, Donald Crane, Office of Surface Mining). Clearly, regulation of practices backed up by effective monitoring and enforcement provides some assurance that specified objectives will be achieved. This may be particularly important where toxic materials may be released or irreversible actions may occur. For example, regulation of practices may be the most effective way to deal with emissions of radioactive materials from uranium mines or heavy metals from mercury mines. Once there is agreement on a practice, this approach tends to stifle innovation unless it is applied sensitively. It is well suited to environmental problems of mining that involve considerable uncertainty, where step-by-step development of information and control practices is appropriately shared by mine operators and government. Examples include the development of in situ procedures for oil shale and solution mining for uranium.

6.3.5 Public Ownership of Surface Rights

Public ownership places direct control of mining activities in the hands of the public through a governmental agency. PL 95-87 provides for this alternative as a last resort for reclamation of abandoned lands that have been mined for coal.

In itself, public ownership accomplishes nothing in terms of better control over the environmental impacts of mining, as shown by damage on Federal lands mined under the Mining Law of 1872. The Ninth Annual Report of the Council on Environmental Quality (CEQ 1978:291) notes that the Mining Law "does not allow adequate control of environmental damage caused by mineral development." Regulations adopted in 1974 for the national forests, which include about one-third of the Federal lands open to the 1872 Mining Law, require operating plans for mining, but provide only limited control over environmental impacts. Parallel regulations for Federal lands administered by the Bureau of Land Management have not been adopted (Office of Technology Assessment 1979:193-196). Some form of control is still necessary on public lands to assure that mining will achieve environmental quality and reclamation goals.

Public ownership, however, has advantages where important environmental objectives are strongly in conflict with other objectives of mining. Public ownership may be the only equitable approach where requirements for environmental control would be confiscatory if the land were in private ownership. If mining is to be permitted on such public lands, choices must still be made among the techniques described above in permitting mining to take place.

6.4 SELECTING ALTERNATIVE CONTROL TECHNIQUES

The usefulness of the five alternative control techniques, singly or collectively, depends on their suitability relative to the characteristics of specific mining operations. Some of the considerations that should be used to select the appropriate control technique for each situation were discussed in the previous section. They include factors that describe the nature of the impacts of mining, relate to the relative hazard to the public well-being of such impacts, and concern the administration of the control technique.

The importance of each of these considerations will vary from one mining situation to another. Generally, we believe that government involvement in mining and reclamation should be confined to that which is necessary to keep the effects of mining within socially acceptable limits. Government should take from the bundle of property rights only those privileges that are necessary to accomplish specific objectives. The considerations or criteria described below should be viewed in the context of selecting effective control techniques for mining impacts that incorporate only that degree of government involvement which is needed.

6.4.1 Factors that Describe Impacts

There are several factors that can be used to describe the impacts of mining in terms that are useful in selecting control techniques.

6.4.1.1 Dispersion

Are the effects of mining confined, or closely limited, to the mining site, or are they widely dispersed? Generally, effects that extend beyond the limits of the mining site are of public concern, but some that are limited to a mine may be of little public interest, (e.g., confined dust that poses no safety or health hazard to workers). Others may be hard to ignore even if confined, because dispersion of effects must be construed in a social sense (e.g., maintaining the long-run productivity of prime farmland--which Congress found important in the case of coal mining--or protecting a national park that is enjoyed by people who travel long distances to visit it).

6.4.1.2 Longevity

Are the effects short-lived (essentially concurrent with mining) or long-lived (persisting after mining)? Some effects of mining persist for generations, even though the action that causes them occurs only once (e.g., changes in land forms from open pits or spoil banks). Other effects persist long after mining because mining creates conditions that lead to continuing environmental impacts, such as leaching from spoil banks. Short lived effects, such as dust from trucks or noise and ground vibrations from blasting, occur only while mining is actually under way.

6.4.1.3 Predictability

Can the effects of mining be predicted with reasonable certainty? The answer is not always obvious. Although many effects of mining are predictable and can be traced to particular actions, others are not, either because of a lack of adequate baseline information (e.g., effects of mine drainage on ground water) or because of inherent randomness in time or in place. As better information becomes available, confidence limits on effects will be narrowed, and fewer actions will have unpredictable results.

6.4.1.4 Measurability

Can the effects of mining be measured? Some effects can be measured more or less exactly: grams per liter of suspended solids in water, or particles per cubic centimeter of air. Also, some reclamation results can be measured in terms of accomplishment: percent of an area revegetated. Other effects, such as impacts on the landscape and the social environment, are less readily quantifiable, or are perhaps unquantifiable.

6.4.1.5 Controllability

Is there an available control technology? Can the effects of mining be controlled by existing and available means and equipment? Control technology in this context can mean either methods to limit the effects of mining as they occur (e.g., yield of sediment) or methods to later reclaim an area to acceptable conditions (e.g., restoration to original contour).

6.4.2 Factors Related to Hazard

The degree to which failure to achieve the desired objectives of control can be tolerated is a consideration in selecting a control technique. Those impacts that pose substantial hazard to the public well-being must be controlled with more assurance than those whose impacts are less serious.

Impacts of mining pose a broad range of hazard to the public from the benign to the very hazardous. Release of toxic materials into the environment is usually considered a significant threat to the public well-being, while judgments about the seriousness of impacts on surface uses vary widely among the public. Some uses of the surface, such as protection of endangered species, are defined in law as uses for which little or no disruption can be tolerated. There is wide variation, on the other hand, in tolerance to the aesthetic impacts of mining.

Where little or no deviation from desired results can be tolerated, those control techniques that rely on encouragement or incentives to mine operators are usually perceived as providing less assurance than those that rely on direct regulation.

6.4.3 Factors Related to Administration

Cost and public acceptability are factors that relate to the administration of control techniques. We have not collected information on these factors, but have some observations. Sections 2.4 and 2.5 discuss these factors in more detail.

Costs include both the cost to government of administering control programs and the cost to operators of complying with them. Generally, we would expect that costs of administration would tend to increase with the degree of government involvement in mining and reclamation decisions. Similarly, we would expect that costs of compliance would also tend, in general, to increase with the degree of government involvement. However, these generalities can be misleading with respect to specific situations, especially where consideration is not given to the extent to which desired results are achieved.

Public acceptability of the various control techniques will depend on perceptions of their effectiveness, cost of implementation, seriousness of the problem, and the proper role of government in mining decisions. We have addressed the first three of these considerations throughout this report.

6.4.4 Management Requirements for Control Techniques

Any technique for controlling the impacts of mining must include steps or procedures to: (a) define goals and standards that must be met in achieving the goals, (b) validate data used to judge whether the standards are being met, (c) monitor impacts, and (d) provide for enforcement, if necessary. PL 95-87 established goals and standards, provided for planning by the States to identify areas unsuitable for mining, required collection of data on hydrology, required States to develop data on reclamation capabilities of different land areas, and provided for inspections and enforcement of regulations (Section 5.3.3).

Effective control of environmental impacts, whether accomplished through a voluntary (incentive) or mandatory approach, depends on good information. Technical information relating mining activities to impacts on the environment is needed to relate standards to the objectives of effective control. Accurate data are needed to establish a basis for monitoring impacts. These requirements recur in many of the approaches, whether based on incentives or regulation of results of mining or of mining practices.

Once goals have been selected in relation to a mining situation (e.g., sand and gravel pits or large open pit mines), the kind and extent of information required will be much the same, whether the control technique is providing technical assistance or direct regulation of mining activities. The need to define standards, to determine how the standards can best be met, and to monitor accomplishments cannot be avoided with any of the techniques.

Responsibility for providing information can be assigned to the mine operator or to the government. PL 95-87 requires the operator to provide hydrologic and climatological information and information on the character of the coal deposit (Sec. 507(b)(11),(12),(15)). States are required to provide information on the reclamation capabilities of the land in response to a petition. (Sec. 522(a)(4)). Information requirements for setting standards and monitoring that are not assigned to others remain as a responsibility of the Federal government.

Even in the case of nonmandatory controls, as in providing technical assistance, operators could be required to provide information in advance of mining that would be used, together with other information, as a basis for the technical assistance. They could also be required to monitor the impacts of mining and provide information to government agencies responsible for overseeing the technical assistance programs. For mandatory controls, the same kind of requirements for providing information could be established. Considerations in assigning responsibility for collecting information to the mine operator or to government agencies include (a) the extent to which the information is needed for normal mining activities, (b) whether or not the data collection can be restricted to the mine site, (c) requirements for special equipment or techniques for data collection, and (d) the length of time over which data collection must take place.

Enforcement is needed only for approaches involving direct regulation or where special requirements (e.g., for providing hydrologic data) are placed on the mine operator. It is not required for those approaches (technical assistance and economic incentives) that are based on making the self-interest of the mine operator consistent with the public's interest.

6.5 ASSIGNING GOVERNMENTAL RESPONSIBILITY FOR CONTROLLING EFFECTS OF MINING

The responsibility for initiating and implementing a program to control the effects of mining must be assigned to an appropriate level of government. As noted earlier, responsibility for defining the standards in PL 95-87 and most environmental control legislation is assigned to the Federal government, which approves programs by each State to meet the Federal standards. This is the case for air and water pollution control legislation. Controls over the use of land have generally been left to the States, most of which have adopted enabling legislation to permit local zoning.

A range of considerations has been used in deciding where responsibilities for regulatory programs should be lodged, including: (a) ability, especially the technical ability, and willingness to establish a program to control problems where they exist; (b) necessity to gain acceptance of those whose actions are controlled and those most immediately affected by control; and (c) the need to incorporate the appropriate community of interest in decisions (i.e., assign responsibilities so that those interests that are clearly affected are reflected in the decisions).

The first of these considerations is often used as an argument for Federal responsibility because of the superior funding capabilities and national scope of the Federal government. The second consideration is usually seen as favoring local control. For the third consideration--incorporating the appropriate community of interest--three measures of dispersion are involved: geographical, temporal, and social or cultural dispersions.

Geographical dispersion has been a major reason for Federal control of water and air pollution (Soper 1974:22, Zener 1974:692, Jorling 1974:1060). Although effects that are confined to local jurisdictions may be locally controlled, technical and political limitations hamper local governments' ability to control effects that are dispersed over wider areas. Thus, local dust problems from mining can perhaps be controlled locally, but control of sulfur dioxide from smelters that is dispersed over great distances may require State or Federal control.

Geographical dispersion of the effects of mining involves more than just physical factors. For example, scenic disruption of a national park is not confined to the immediate area of the mine. Such considerations may provide justification for Federal intervention that is not provided by dispersion of the simple physical effects of mining.

Some effects of mining extend for generations and it is practically impossible for present-day decisions to include directly the views of all people that will ultimately be affected by a mining operation. Because of people's mobility, it is almost a certainty that, over a period of time, the makeup of a local population will change. Thus, a broader representation of views than local government can provide may be required to reflect future changes. That is, State or national government may provide a better forum for considering effects that are dispersed over time. Government at these levels often represents a greater diversity of interests than that represented by a homogeneous locality.

Finally, dispersion of effects among socially and culturally distinct segments of the society must be recognized. Simply assigning responsibility for control to a particular level of government will not necessarily assure representation of disparate views. This can only be accomplished by having decisions made at a level that encompasses social and cultural diversity and by providing a mechanism for reflecting this diversity.

6.5.1 "Thresholds"

In certain cases, including some in PL 95-87, "thresholds" are used to indicate when an effect or problem is serious enough to warrant a change in approach. For example, coal mines producing less than 100,000 tons per year are treated differently in some parts of PL 95-87 than those producing more. Two kinds of "thresholds" are appropriate for aiding in assigning responsibilities for limiting the effects of mining.

One is scale or size of operation. Above some scale of a mining operation--whether measured in terms of volume of ore or waste rock moved, number of people impacted, or value of minerals produced--it may be presumed that more than local interest should be involved in decisions to limit the impacts of mining. We hesitate to suggest appropriate threshold levels. Measures of scale may differ between kinds of minerals or mining situations.

The second threshold mechanism is uniqueness of the mineral and of the environmental or cultural resources that would be impacted. As noted elsewhere in this report, some minerals are found in minable quantities only in limited circumstances. The beryllium deposit at Spor Mountain, Utah is an example. For such minerals the presumption could be established that their availability for mining is of national concern and decisions on control should be made with more than just local input. Similarly, where environmental or cultural resources are unique, a national interest is involved and should be considered. For example, mining that would affect national parks or national historic or cultural sites could be presumed to affect the national interest and require inputs from the national level.

6.5.2 Regional Intergovernmental Approaches

Depending on its scale and character, a single mining operation can have effects that range from purely local to national in importance. Many sand and gravel pits, clay pits, and quarries, for example, may have only local impacts. At the other extreme is the possible development of the oil shale resources in Colorado, Utah, and Wyoming. Impacts could range from local ones (fugitive dust, disruption of lifestyles) to national ones (high salt levels in the Colorado River, disruption of scenic and cultural resources such as Dinosaur National Monument).

It would be possible to control each level of impact of oil shale development through separate actions by Federal, State, and local governments. At best, this approach would probably lead to some overlap and conflict between levels of government. At worst, it could frustrate development of a potentially valuable resource or lead to inadequate recognition of local or national interests, or both. Furthermore, there may be some question concerning the ability of local government, and even State government, to affect actions on Federal lands, which contain most of the potential oil shale resources.

A possible way to give adequate representation to local, State or region, and national interests in the development of major mining districts is by establishing special-purpose commissions with planning authority for mineral development in each such district. Each commission would be made up of representatives of local, State, and Federal interests. The function of the commission would be to establish and maintain oversight on plans for the development of minerals in the district and for the control of mining impacts. Such a plan would be the basis for regulation or other institutional approaches for limiting impacts and achieving reclamation.

Development of oil shale is an obvious case where such an institutional approach may be warranted. Other examples are not so obvious. For example, control of the impacts of iron mining on the Mesabi Range in Minnesota by the State and counties appears to meet the purposes of PL 95-87 without a Federal presence (see Working Paper V). Presumably, little would be gained in this case by forcing establishment of a joint Federal-State-local commission. On the other hand, in areas where control is less than adequate or where there is a potentially important national interest at stake, a joint Federal-State-local commission would provide a mechanism for responding to all relevant viewpoints.

6.6 IMPROVING THE USE OF EXISTING LAWS

As noted in Chapter 4, many of the impacts of mining non-coal minerals are already controlled under a variety of Federal and State laws and local ordinances. It has become clear to us that the variety and complexity of these laws cause problems for mine operators today. Better coordination and integration of existing laws and regulations to focus on problems caused by non-coal mining is needed.

Whatever decisions are made regarding new laws and regulations, we believe it is important that the overall system of control be rationalized. Where the effects of mining are to be controlled by permits, coordination of the permitting process is needed to limit the potential for conflicting controls and to encourage the simultaneous consideration of the purposes and costs of control.

6.6.1 "Networking" as an Alternative to New Controls

An alternative to new controls on mining is to require by law that existing Federal, State, and local laws and regulations on mining be coordinated and focused. This approach for implementing Federal legislation has been used by some States in responding to the Federal Coastal Zone Management Act of 1972 and is referred to as "networking."

The idea is that the failure of existing laws and regulations to meet desired objectives is a result of inadequate coordination and inattention to particular objectives. These failures can be overcome by policies that focus attention on the desired objective, an assignment of responsibility for meeting these objectives, and a definition of authority to use existing laws to meet the desired objectives. The use of "networking" in responding to the Coastal Zone Management Act has involved the coordination of State programs under Federal water pollution control legislation, State wetlands management legislation, various other State permitting authorities, the use of State environmental impact statements, and controls on public lands. Control of the "networking" process rests with the States that have adopted this approach.

The effectiveness of "networking" is limited by gaps in present laws with respect to problems caused by mining, by possible resistance to changes in responsibility among agencies, by potential duplication of effort if responsibilities are not clearly defined, and by ineffective enforcement of present laws. As noted elsewhere, the existing structure of laws and regulations concerning the environmental impacts of mining give only spotty treatment to the effects on land resources. Just "networking" present laws would do nothing to fill those gaps.

6.7 LAND USE PLANNING: THE FRAMEWORK FOR CONTROLS

As noted in Chapter 4, mining takes place in the context of a multitude of decisions that have been made on the location and character of transportation networks, industrial development, community expansion, sewer systems, and municipal services. Where such decisions are made as part of a public planning process, mining typically is considered as a major activity comparable to industrial development, one that makes certain demands on transportation and other municipal services and that has certain impacts on other land uses. Where such planning does not occur, demands on services and impacts on other uses are necessarily considered on an *ad hoc* basis, if at all.

Because mining has major impacts on the natural environment, on municipal services, and, in some cases, on State and national economies, we believe it is necessary that mining be conducted in the context of land use plans that: (a) limit unnecessary conflicts between mining and current and future land uses; (b) establish objectives for environmental protection during mining and for postmining use of the mined area; and (c) provide a basis for decisions on providing government services.

The scale and impacts of land use planning should vary with the scale and character of mining impacts. Where mining operations involve only local impacts, it is unnecessary to involve the Federal government in planning. However, a mechanism should be provided to assure that national interests are reflected in plans where they are, in fact, important. It appears that the proper procedure is for land use plans, which are prepared at the local level, to be reviewed at the State or Federal level if (a) the environmental effects of mining extend beyond local or State jurisdictions or (b) the markets for the mineral in question are national or international. For example, designating lands as unsuitable for mining is appropriately a local decision if the mineral in question is marketed locally and if the alternative use is for housing or municipal uses. However, such decisions should be reviewed at higher levels if the mineral is marketed nationally (and presumably has few alternative sources) or if the alternative use of the land for natural, cultural, or economic uses is of more than local interest.

6.7.1 Coordination with Other Control Mechanisms

Other mechanisms are now used to control various aspects of mining (permits for effluent discharge, State or Federal environmental impact statements). To avoid conflict, the land use planning process should serve as a coordinating device for the various mechanisms. This approach has been used effectively for planning on national forest lands, where the land use plan is combined with the required environmental impact statement (Office of Technology Assessment 1979:183).

Coordinating the various control mechanisms through the land use plan provides an opportunity for systematic participation of landowners, mine operators, and other interested parties, such as is now required in preparation of environmental impact statements and land use plans for Federal lands. The advantage of focusing such participation on the land use planning process is that this is the most inclusive set of decisions and involves weighing at one time all of the expected consequences of mining.

6.7.2 Long-Term Commitments of Land Use

In the extreme case, such as some very large open pits, mining is irreversible commitment of land to a single use, at least for many years. Thus, the choice is posed in the market place or in the land use planning process between commitment of the land to mining, for which reclamation is not economically feasible in some cases, or to alternative land uses. The choice is made on the basis of the value of the land area when devoted to mining or to the alternative uses.

Under PL 95-87, coal mining is not permitted if reclamation is not feasible. The character of mining for some non-coal minerals and the lack of suitable alternative deposits suggest, for example, that the requirement for reclamation as envisaged in the Act would effectively preclude mining of some minerals in the United States. For example, the terrain in which the few minable deposits of molybdenum are found and the size of the deposits make restoration to the approximate original contour unfeasible. But unlike coal, there are almost no alternative domestic, or even foreign, sources of molybdenum. As a result, prohibition of mining because reclamation is unfeasible would limit the availability of a vital mineral.

We believe that there are circumstances in which mining non-coal minerals should take place even though the land can not be reclaimed. The uniqueness and importance of the mineral deposits in the nation at large and the values of alternative uses of the land, also in the context of the nation at large, define these situations. We further believe that these values can be weighed and rational choices made if there is adequate opportunity to consider values that may not be fully reflected in the market place. These would include the importance of the mineral to the national economy (although this is usually reflected in the mineral's price), and the importance of unique or environmental or cultural resources. It is evident that some process, a land use planning process, that involves government must overlay market decisions to resolve questions involving mining where national interests are at stake, and that mining of some non-coal minerals should not be automatically precluded where reclamation is not feasible.

Comparing values of mining with alternative uses of the land also leads to the proposition that there are some lands for which current and prospective values are so low that reclamation should not be required. That is, once actions have been taken to minimize off-site impacts, should reclamation be required where the costs of reclamation vastly exceed current and prospective values of the reclaimed land, even where a national interest in mining can not be demonstrated? We have not resolved this matter to our satisfaction. However, non-coal minerals are now being mined in some areas where alternative land values are very low and where the cost of reclamation could be very high because of climate, terrain, and character of the mining operation. We simply point out that this is the kind of decision that can be made in the context of a land use planning process that is responsive to differences in conditions from place to place.

6.8 CESSATION OF MINING OPERATIONS

Defining the point at which an ore body is mined out and a mine ceases to operate is difficult for some non-coal minerals. Volatile markets and blending different grades of ore from different pits lead to cessation and reopening of operations on an irregular schedule that may extend over many years. Nevertheless, at some point, mining, in at least a discrete part of a mine, ceases without plans for reopening. At this point, custodial care may be needed to minimize the effects of processes that cannot be stopped when mining itself ceases. An example is underground seepage and drainage containing heavy metals from an underground mine. This process could continue for generations.

It is clear that the costs of future actions to mitigate effects of mining that extend beyond the life of a mine should be internalized in the present cost of mining. We did not address this matter in detail, but we suggest that consideration be given to a trust fund for custodial care and to requirements for plans to mitigate such effects once mining has ceased. Relevant factors for consideration include the differences from mine to mine and the importance of assigning costs equitably among mining operations.

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ANNEX

Dr. Ronald Little believes that Section 2.5 as it is included in the report is condensed from the Socioeconomic Working Paper prepared for COSMAR to such an extent that readers may not draw the right conclusions about the empirical realities and may infer that social considerations are unimportant in the development of surface mines.

In consultation with members of the Socioeconomic Subcommittee Dr. Little prepared the material that follows to amplify his views on the social consequences of surface mining.

This material is not accepted by COSMAR as a whole.

SOME SOCIAL CONSEQUENCES OF SURFACE MINING

1. THE SOCIAL ENVIRONMENT

Mining takes place in a social as well as a physical (natural and man-made) environment. The purpose of PL 95-87 is to protect both the social and physical environments from the negative consequences of the surface mining of coal (see Socioeconomic Subcommittee Working Paper for a more detailed discussion of the social provisions of the Act especially Section 101).

The social environment, composed of people and their complex interactions which are acted out in cultural and physical settings, can be altered (c.f., Dunlap and Catton 1978). The stimulus for alterations may come from changes in the physical environment or from changes in the activities of groups within the social system. Recent social science investigations of Western energy boomtowns[1] and transplanted manufacturing industries in the Mid-West demonstrate that the social consequences of industrial growth, including surface mining, can be manifold. Some of these consequences are felt by individuals, some by families, and some by entire communities. Some consequences affect the infrastructural basis of communitiies, while some the educational, political, social, recreational, and/or religious institutions of communities. Some consequences are beneficial and some are not, and of those that are not, some are mitigatable and some are not. The consequences, whether for individuals, groups, or institutional structures are not equally distributed. Some are affected, both positively and negatively, by surface mining activities more than others, creating distributional inequities.

Even though site specific data (physical and social) are limited, studies of Western energy development and rural industrialization have identified the major factors influencing the consequences for individuals and communities of new industrial developments (e.g., Freudenburg 1978, Cortese and Jones 1977, Little 1975, Little and Lovejoy 1977, Summers and others 1976). While space limitations prohibit an extended discussion, the major factors can be organized around the three main actors in any surface mining activity: government (all levels), industry, and local communities; the primary constituents of each of these categories are listed below (see Working Paper XI for discussion of the factors and their inter-relationships):

1. Governmental Policies and Regulations: environmental standards; taxation powers and policies; aid to impacted areas; zoning; coordination between levels of government.

2. Industry Characteristics: size of requisite labor force; duration of project; technology employed; geographic relationships between local populations; policies for avoiding or mitigating social impacts.

3. Local Communities: size and distribution; infrastructure development; economy; community social structure and composition; political structure.

Of the three main actors in a surface mining activity, only the communities near the mine site remain relatively unprotected from adverse social consequence. Well-integrated, organized and financially sound communities with well developed planning and zoning ordinances are currently the best protected. Even they, however, are vulnerable to unwanted social disruptions when the mining occurs on public lands. Government and national interests are protected by an enormous bureaucratic structure. Industry protects its interests with intense economic analysis and lobbying organizations. Further, the economic cost and benefits to industry, either for mining or regulation, are readily quantifiable and understood (see Section 2.4 of the COSMAR report). Industry costs and benefits are part of the market structure and amenable to standard decision-making practices and to cost-benefit analysis.

Even the interests of those citizens not directly associated with surface mining and who reside outside of the impact region are reflected in the market economy of the region and the nation. Their desires and needs for minerals are translated into actions through the profit mechanism, and their economic and social interests are thus acknowledged, if not satisfied. Likewise, the interests of special interest groups such as environmental organizations are protected variously by Public Law 95-87, the National Environmental Policy Act of 1969, and other legislation and/or regulation.

At the local level, however, impacted communities are presently not part of the decision-making process. Local interests are only imperfectly protected from potential negative consequences, while the benefits are assumed. The aggregate benefits to the general area and some of the costs, especially those related to infra-structure improvements, are relatively simple to calculate and generally are taken into consideration. The process of specifying <u>who</u> absorbs which costs and who gains from which benefits is, however, more complex and is only infrequently attempted. For this as well as other reasons, communities absorb hidden costs associated with development (see U.S. Department of Housing and Urban Development 1976). Furthermore, the costs and benefits of development are disproportionately shared. For example, the relative economic position of women and the elderly tends to decrease in rural communities undergoing industrialization (Clemen 1975).

The strictly social costs and benefits are even more difficult to measure. Changes in community patterns of neighboring, or group conflict seldom conform to interval or ratio measurement levels and thus do not accommodate to standard cost-benefit or other metric analyses. Neither are the strictly social costs and benefits integrated into the market economy, and are thus difficult to evaluate in standard units (dollars). Social and economic cost and benefits are therefore difficult to compare and evaluate, and, as a result, are often relegated to informal comparisons if considered at all.

The importance and, hence, value of social costs is dependent upon whether an individual or community is experiencing a favorable or unfavorable mix of economic/social costs and benefits from a mining operation. Unfortunately, the social component of the mix has been generally ignored until fairly recently, except by a few social scientists. However, the American Institute of Professional Geologists, in a recent statement regarding future resource development has noted that:

> Although the domestic production of minerals is of vital importance to the people of the United States, such production may be viewed as an environmental loss by the producing communities. A way must be found to compensate communities from which minerals are produced for our nation proportionally to the value to the nation of the minerals produced. Alternately, compensation might be proportional to the need to construct new infrastructure... (1979:6).

It appears then that an increasing range of the scientific community is acknowledging the importance of including social costs and benefits in the decisions regarding resource development.

2. PROTECTING THE SOCIAL ENVIRONMENT: INHERENT DIFFICULTIES

The specific provisions of PL 95-87 which protect some aspects of the social environment are discussed in Chapter

6. Unfortunately, the means for protecting the social environment are generally underspecified (see Socioeconomic Subcommittee Working Paper). That the Act treats the social consequences of surface mining in a rather non-specific fashion is not, however, surprising. Man's ability to adapt to an extraordinary range of physical conditions deflects attention away from the adaptations and attendant social considerations, while at the same time provides a ready rationale for slighting social factors. Man's immense adaptability, when taken in conjunction with America's devotion to economic and material growth, makes the meager concern for social factors not unexpected (see Dunlap 1976).

In addition to man's adaptive capacity, scientific, economic, and political factors have also contributed to the minor emphasis placed upon the social consequences of surface mining. Social science research is a vital element in the protection of the social environment just as it would be for the implementation of the social elements of PL 95-87 for non-coal minerals. Although the social science research on the consequences of rapid industrial developments is growing, the current research literature on the social consequences of surface mining and the varying sizes of surface mining operations is modest. It appears especially modest when it is compared with the volume of mineralogical, hydrological, geological, chemical, biological, and economic research that has been focused on surface mining and its effects. The number of studies necessary to examine all permutations of communities, minerals, company practices, and technologies employed in order to bring the social science research literature up to par with the research literature pertinent to the physical, biological, economic, and engineering issues associated with surface mining would be staggering. Just as the sulfur content of coal varies depending upon whether it is mined in Montana or New Mexico, community characteristics (personality, social, and cultural systems as well as population) vary. Communities in Wyoming, while sharing some social characteristics with communities in West Virginia or Pennsylvania, are quite different in other respects (e.g., past experience with mining). Scientific inquiries on the social consequences of surface mining are not extensive and where inquiries have been conducted they are not always comparable with one another. Specific studies of the 80 minerals under investigation in this study are simply not available, but should be. There is, however, information on the impact of coal mining on rural communities which provides a basis for generalizations to non-coal minerals.

3. MINING AND THE SOCIAL ENVIRONMENT: THREE EXAMPLES

The discussion that follows attempts to illustrate the range of intensity with which mining may interact with the social environment. Three examples are presented that are thought to be representative of mining activities: a small quarry in an urban setting; the mining district in the Mesabi range of Minnesota; and contemporary Western boom towns.

A stone quarry near an urban community would generally create limited negative impacts on the neighboring community and a similar number of social or economic benefits. Negative social impacts would be restricted to the extent that the community had a well developed economy and infrastructure, as well as satisfactory planning and zoning. The principal nuisances would be from noise (chiefly blasting), dust, vibrations from blasting, truck traffic, and unsightliness during the life of the operation. These effects obviously would be of greatest concern to nearby residents, who might organize to close or modify an offensive project. Such grass roots efforts would amount to a new political component and would thus constitute a change in the local political structure. Pushed to the limit, if this political activity leads to hardened conflict, the social structure would be altered, and the political structure could be completely reorganized. On the other hand, users of the stone would presumably benefit from low prices, and the local economy would be strengthened, although to only modest extent. Employees on the project would most likely come from the local labor force and, hence, would place no additional burden on municipal services. Even if some of the labor force came from outside, these workers would be few in number and could be absorbed without strain by the community infrastructure. Furthermore, the heterogeneity of extant social groupings in the city would make it relatively easy for new residents to integrate successfully. Profit from the quarry, assuming the operation is locally owned, as is likely, would largely remain within the community. In short, problems that could result from such a quarry would likely be confined to the immediate neighborhood and would not necessarily be disruptive to a wider community, if disruptive at all.

At the other extreme in scale of operations and in the degree of industry concentration is the case of iron mining in the Mesabi Range of Minnesota. In contrast to the potential threat to the extant social structure represented by the development of a new quarrying operation in an urban setting, the social structure in the Mesabi Range is the result of the physical environment. Iron ore deposits provided the stimulus for a new social structure. Not only did the social structure development revolve about mining activities, but it evolved over a period of time, allowing for the development of a consensus regarding appropriate economic activities. Further, the social structure was dependent on mining for its economic well-being, a factor which aided in the development of consensus. Currently, more than a third of the jobs are directly involved in mining, with a large proportion of the remainder providing support services. The early settlement pattern was typified by mining towns adjacent to the pits. With the growth of the automobile, however, that pattern has given way to the concentration of workers in distant communities, until at present the labor force resides throughout a region of 12,000 square miles (Minnesota, Copper-Nickel Study 1979). Despite a long history of extensive mining activities, only 1 percent of this region is currently used for mining and urban development (Brown and others 1976). The taconite industry, however, has brought about a change in the land utilization patterns because of mine tailings. This new use is expected to require 36 percent of the total land area when the Mesabi range is mined out, some 200 years hence.

Faced with this potential for long-term mineral development and land use, there is a clear need for social and economic planning. Fortunately, this planning requirement does not represent nearly so insurrmountable a problem as does planning in some other surface mining situations. First, there is advance notice of the potential mining activities as well as past experience with mining. Second, economic strains for any infrastructure improvements will be lessened because of the area's current economic position. The per-capita expenditures by local government for services in public improvement have long been significantly more than those in the rest of Minnesota. This is partially the result of local taxes paid by the mining industry, and partially the result of State funds distributed to the region. Third, several planning organizations are in place and function. The planning currently involves mining companies and the local, State, and Federal governments working through these planning units. As shall be seen, the absence of advance notice of mining plans, experience with mining, funding, and functioning planning organizations all present potential difficulties for some surface mining endeavors. For the Mesabi Range, none of these appear to be major problem areas, and the Range appears to face social problems resulting from surface mining which are quite ammenable to solutions acceptable to a population organized around surface mining and related activities.

While urban stone quarrying and the Mesabi Iron Range represent opposite ends of the continuum regarding the size and concentration of mining operations, they occupy similar positions on the continuum of potential negative social impacts. These two examples represent potential negative social impacts which are limited to moderate, depending upon the configuration of important variables at a given point in time. Solutions to the potential problems created by surface mining activities, should they occur, do not appear unduly difficult.

The extreme position on the continuum of negative social impacts resulting from surface mining is represented by the rapid development of large-scale surface mining in sparsely populated regions. This phenomenon is commonly referred to as the boomtown syndrome and has been extensively studied by sociologists, psychologists, anthropologists, political scientists, and economists. The literature which has resulted from the several empirical studies of boomtowns represents the most extensive and systematic of the social science literature devoted specifically to surface mining, and provides a basis for generalizing to surface mining activities and locations as yet unexamined by social scientists.

Obviously, mineral developments which are responsible for boomtowns are not the norm or the average result of surface mining, but some surface mine plans portent boomtown developments, especially in the development of capital Western oil shale and uranium. These are extreme examples of the negative social consequences which can result from certain surface mining operations. As extreme examples, they serve as benchmarks for evaluating potential negative social impacts expected or known to derive from specified surface mining activities, and also as a means for illuminating negative social impacts which under less extreme circumstances are not obvious to the untrained observer. Boomtowns certainly display a wider range of negative social ipacts than are typically found in less extreme cases. The discussion of the most extreme negative social impacts is therefore invaluable for determining the necessity for and nature of the future regulation of surface mining.

4. COMMUNITY IMPACTS

4.1 Population and Growth

The single most important factor determining the extent of social impact in a community is the size of a labor force necessary for extracting, processing, and transporting the minerals. All other things being equal, the greater the number of workers necessary, the greater the number of in-migrants. The greater the number of new residents, the greater the strains placed on the local community.

The extent of the social impacts are not, however, a direct function of numbers. It is obvious that New York City would hardly notice 5,000 new residents. The newcomers would represent only a small fraction of the population base. Further, the infrastructure already in place could acommodate the in-migrants, and New Yorkers, accustomed to diverse behaviors would pay little heed to the new residents. For the in-migrant, the city's heterogeneous population would provide ample opportunity for integration into one or more social systems.

Sparsely populated rural areas are much more severely affected by influxes of migrants than are cities. Even 200 migrants can drastically alter social patterns and thus create serious social strains in some communities; even 200 in-migrants may represent a population increase of 50 to 100 percent. Evidence in Western communities impacted by energy developments indicates that most communities experience serious social strain when the population growth rate exceeds 4 to 5 percent per annum (Gilmore and Duff 1975:2, U.S. Department of Health, Education and Welfare 1976:2). Social strains become severe and communities become unmanageable when the growth rate exceeds 10 or 15 percent per annum. Such communities are not only less than desirable places to live, they are likely to be less than optimal locations for business (Gilmore 1976:535, Ives and others 1976).

Interestingly, small rural communities would appear to support and encourage mining developments to a greater extent than urban communities. Also, they probably represent fewer potential political and/or legal challenges over new mines. Freudenburg and others (1977), Clemente and Krannich (1976), Little (1975), and Andrews and Bauder (1968) have all noted strong support for several types of rural industrialization, including mining. Hardin, Montana, for example, indicated in a community survey that the residents were overwhelmingly in favor of surface mines and electric generating facilities situated nearby. Over 80 percent of those rural respondents gave their support to past energy developments. However, only approximately 55 percent of those sampled favored hypothetical future projects (Little 1978:72). A similar decline in enthusiasm for additional development appears to have occurred among local residents in Craig, Colorado (Fradkin 1977, Freudenburg and others 1977). This evidence suggests that the relative value of social and environmental costs has increased in comparison to the economic benefits associated with furhter development.

4.2 The Local Economy

Although national economic priorities serve as a major focus of PL 95-87, local economic issues must not be ignored. Improvements in the local economy are frequently cited by industry, government, and local residents as the reason for approving or supporting a new mining development. Certainly, the residents of areas impacted, or about to be, by industrial and mining developments <u>believe</u> that they stand to benefit directly as a result of them (Little 1978, Andrews and Bauder 1968).[2]

Unfortunately, the promise and expectation of new jobs for local residents, at least jobs in the incoming industry, appear to be more myth than reality. The available evidence indicates that the proportion of jobs going to local people is moderate to small. In the least, the proportion is generally far below industry claims and local aspirations. The proportion of new jobs which is absorbed by local residents is a function of the interaction of industry and community factors. Industries' hiring practices and technological skill requirements, as well as the willingness, ability, and availability of local residents to fill available positions determines the final mix of local and migrant employees. While some studies have projected as many as 40 or 50 percent of the jobs going to local residents (see Mountain West Research 1975), the bulk of the evidence seems to indicate that fewer than 20 percent of the new jobs are captured by locals in rural areas and many of these are in the lower skill categories (Little and Lovejoy 1979, Summers 1973, Gray 1969, Andrews and Bauder 1968).[3]

Part of the in-migrants' success in obtaining the new jobs is due to their superior educational attainment or possession of requisite technical skills (Little and Lovejoy 1979, Chinitz 1971, Somers 1958, Maitland and Cowhig 1958). This seems to be the case with small rural industrial projects as well as large-scale energy projects. Whatever the multiple reasons which explain this result, it is obvious that jobs filled by in-migrants are denied to local people as are the associated economic benefits (see Little and Lovejoy 1979:27-29, Summers 1976:24-29). While lessening the economic advances of locals in the basic sector, in-migrants are at the same time increasing the strains on the infrastructure, a point to which we will return. Positive contributions by in-migrants to the infrastructure as well as to social structure occur only some time after the strains have been felt.

The failure of local residents to benefit as they anticipated from newly created rural jobs is not the only negative social consequence the local economy may face. Although as a whole, existing rural businesses prosper economically from industrialization in their area, there are nevertheless some exceptions.

Local townspeople and ranchers may exhibit considerable hostility toward business people whom they previously considered friends because the businessmen may be perceived as the only local beneficiaries of industrial development (see Freudenburg 1979, Andrews and Bauder 1968). At the same time, the newcomer construction workers in boom towns frequently feel that they are being gouged by local establishments (Little 1977).

Thus, businessmen must continually cope with such hostilities while at the same time conducting their operations in a more formal and less relaxed set of circumstances brought about by the influx of newcomers. Those circumstances frequently require them to restrict personal services, update procedures, increase merchandise and capital equipment, withdraw credit, employ security forces, adopt a greater advertising budget, and compete with the newly arrived entrepreneurs (see Cortese and Jones 1977, Freudenburg 1977).

Many local businessmen are not up to the challenge. Researchers often find business people who felt they were going to get rich as a result of a boom, but who instead have lost their businesses, sold their stores, retired, or joined a national chain store operation. In fact, a major source of concern for business people in rapidly growing communities is the arrival of the chain operation. Besides competition, the higher wages and benefits offered by the national concerns and the new industry may entice employees away from the established businesses and contribute to business failures (see Freudenburg 1979, Cortese and Jones 1977).

The high rate of business turnover in rapidly growing communities comes as a surprise to those who viewed the new industry as a boon to business. Unfortunately, even under the best of circumstances, growth in the non-basic sector seldom matches local expectations or official projections. The existing evidence indicates that in rural areas, new firms are linked to external networks that consume money, which under situations with more diversified economies, might be received by local indigenous businesses (Summers et al. 1976:59). Too, there is also considerable leakage: income generated in the impacted community "leaks" out of the immediate environs through purchase of consumer goods (including staples) in distant cities, paying off old debts, banking out of the area, and increasing savings (Longbrake and Geyler 1979, Krannich 1977, Denver Research Institute 1975, Wadsworth and Conrad 1966). Finally, the local economy frequently faces inflation. High industry wages and increased demand for goods and services push local prices up. It is not uncommon to find a trailer renting for $500 to $600 a month in boom towns. The effects of inflation are not felt equally by all segments of a community, however. Those enjoying the higher wages paid by the new industry, i.e., many in-migrants, suffer least. Unskilled locals, the aged, those on fixed incomes, women, and minorities are generally worse off financially than they were before the arrival of the new industry (Summers and others 1976, Clemente and Summers 1973, Clemente 1973).

4.3 Infrastructure Problems

The local infrastructure is strained whenever rapid population expansion occurs. The impacts upon the infrastructure are readily evident even to the casual observer. It requires no specialized training to sense when community services are inadequate. Only the opportunity to observe the crowded schools, roads, and health care and recreational facilities is necessary.

Consequently, there has been strong motivation for examining such problems, and a great deal of time and effort has been expended measuring, monitoring, and forecasting. Large portions of the socioeconomic sections of environmental impact statements are devoted to population projections and infrastructure requirements, to the relative exclusion of other, more strictly social impacts (e.g., U.S. Department of Interior 1976a, 1976b, 1976c, 1975, 1974). All too often infrastructure problems are treated as the only social impacts, ignoring the consequences of an insufficient infrastructure upon the social structure.

Solutions for avoiding or mitigating the problems are fairly straightforward, and planning is an absolute necessity. In many rapidly growing communities, planning for infrastructure development lags behind needs, and the game becomes one of catch-up. Small rural communities simply cannot afford planners in many instances, and if they can, a planner becomes available only after it is late in the game. Adequate planning requires that the industry supply community officials with early notification of mining plans. However, this notification is of no consequence if front-end money is not available to finance the time-consuming and expensive planning activities necessary. Few communities have the excess capital or the bonding capacity to finance the early planning or the resultant improvements (U.S. Department of Energy 1978, Gilmore and others 1976, Gilmore and Moore 1975).

The solution to the problem is clear: impacted communities need financial aid. Costs to communities for improved public facilities necessary to facilitate the growth resulting from new mining activities previously borne by local communities and States are increasingly being viewed as the responsibility of industry (see American Institute of Professional Geologists 1979). The argument runs that surface mining activities externalize the social costs, which are picked up by the local population (see Brock 1969). The argument receives strong support from the simple reality that tax revenues from mining operations may not equal community expenditures for capital improvements for many years. In the meantime, local communities are in effect subsidizing the industry (see Little 1977, U.S. Department of Housing and Urban Development 1976:29).

Part of the funding problem stems from the fact that--especially in the rural West--surface mine operations are located in the counties, while the infrastructure improvements are needed in the city. This jurisdictional mismatch, with one governmental unit collecting tax revenues and the other governmental unit spending revenues, raises a final issue: intergovernmental cooperation.

Because of the divided governmental authority, intergovernmental cooperation becomes imperative. Unfortunately, in some instances the transfer of funds from one level or unit of government to another is legally impossible. In extreme cases, State constitutions must be changed before revenue transfers are possible.

A variety of governmental strategies for coping with the jurisdictional mismatch have been tried, from creating special taxing districts, to the pre-payment of taxes by industry (see Wilson 1976, U.S. Department of Housing and Urban Development 1976, Rapp 1976, Gilmore and Moore 1975). Solutions to the mismatch issue must ultimately be resolved on a site-by-site basis. Structural requirements of individual governmental entities preclude the development of a master solution.

4.4 The Local Social Structure

The social impacts that accompany industrial and mining developments as discussed thus far, have the advantage of being reasonably obvious and reasonably simple to measure, e.g., the number of business failures, new jobs, and in-migrants. Few decision-makers have difficulty understanding the numbers derived from those measurements and they can be converted to standard cost-benefit analysis. While such numbers reflect some of the consequences to the social environment occasioned by industrialization, they represent only a small, and, perhaps from the perspective of rural residents particularly, a less significant form of the social impacts that they experience.

The number of business failures, new jobs and in-migrants requires consideration and perhaps action, but at the same time they are reflections of subtle and less obvious changes in the social structure. Business failures, for example, generally imply a change of economic status for those so affected. In turn, a change in economic status might require intra- and inter-community migration, bringing with it new and different associates, schools for the children, or a host of other changes, all of which alter the social structure. Substantial new economic activities in non-urban locales affect and alter family, extended kin and neighborhood structures, as well as the formal institutional structures, such as education, religion, and government.

Because the reclamation of the social structures to original contours is virtually impossible, once the changes have occurred, they can seldom if ever be reversed.

Informal and formal social structures[4] are difficult to discern by an untrained observer, leading some to conclude that they do not exist or are not important. They are also difficult and expensive to measure and monitor. Measurement problems notwithstanding, a direct and convincing measure of strains upon a social system comes in the form of increases in the crime rate. The general pattern observed in boom communities is that a high and positive correlation exists between population growth and crime (Little 1977). In Craig, Colorado, a community without an administratively separate police force until 1975, an annual police budget of $300,000 and a twenty-two man force was required by 1977 as it bugeoned into an energy community (Freudenburg et al. 1977). Even though Craig may have experienced an extreme case of population growth, the trends observed there are not unusual. A study of 188 boom towns of various magnitudes scattered throughout Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming (Federal District VIII), found that during a three year period, crimes against property increased 222 percent while crimes against persons increased 900 percent (U.S. Department of Health, Education and Welfare, 1976:3).

Crime statistics do not provide the only direct evidence of stress upon a social system. Other indicators have been documented which illustrate the social problems confronting communities which have experienced boom growth. Drastic increases in suicide attempts, alcoholism, divorce, spouse abuse, and depression have all been documented in Western boom towns (see Freudenburg et al. 1977, Kohrs 1974). The litany need not be extended. It is enough to know that personal and structural disorganization is common and often severe in rapidly growing communities.

Social problems affecting the general population are quickly reflected in the schools, the place where the old and the new populations come into the earliest and most intense interaction. In a number of communities, educators report conflict in values, commitments, and lifestyles between the local students and the newcomers and state that a great deal of their time is spent integrating new students into the classroom (Cortese and Jones 1977, Kohrs 1974). Freudenburg (1979) has found that high school students in boomtowns felt worse about their school, their community, their relationship with peers and with the local environment than did students in three "pre-boom" communities.

The institutional mission of the local school system is thwarted by high turnover of students and teachers, overcrowded classrooms, and an overwhelming increase in paper work for administrators and counselors. Socialization of the young breaks down in a boom situation. As the rules change, the youth in these communities react to the changes around them, and there is a corresponding rise in deviance and delinquency.

Like the educational structure the political structure in a small community is strained when new economic activities, especially large-scale ones, bring old and new populations together. Elected officials experience personal stress and a deterioration in the quality of services and the administration of justice often occurs (Kiernash 1972:101-105).

Many small town city councils members and mayors are part-time officials who serve with few monetary rewards. Their main motivation for holding office is public service and the benefits they receive are more often the psychological ones of enjoying the status and the sense of satisfaction from performing a citizen's duty (Ingram McCaine and others, forthcoming).

Rapid population growth may have a sharply detrimental effect upon the non-material rewards that can be derived from public service. If new constituents differ dramatically from long-term residents, the level of local conflict may increase substantially. If so, local officials will find themselves receiving less respect while at the same time increasingly criticized for their job performance. Voluntary retirement and election defeat are not at all uncommon among local government officials. Eulau and Prewitt (1973) found that many city council members simply quit their jobs when service became no longer fun or when they no longer felt appreciated. The representative's functions become far more difficult when the population is transient and groups are sharply divided. It may be that citizens' views in changing communities become more difficult to represent adequately just at a time when willing public officials become most difficult to recruit (see Berba and Nie 1972).

Difficult to recruit or not, the new official may be a newcomer to the community. Even though the in-migration was relatively small, Andrews and Bauder (1968) found a tendency for the in-migrants to fill elected as well as civic and religious positions formerly held by long-time residents. The possibility of electing a newcomer is also enhanced by their higher educational attainment (Summers and others 1976) and the fact that the in-migrants frequently share common political and/or economic philosophies which differ from those of original community residents. By voting in numbers they may thus shift the traditional community power structure (see Nellis 1974, Gold 1978), and exacerbate intracommunity conflict. Such conflicts and hostilities, which will alter and reflect the changes in the patterns of social behavior, have been documented in energy boom towns (see Gold 1978, Freudenburg 1979, Little 1977b, Freudenburg et al. 1977, Kohrs 1974).

5. SOME ALTERNATIVES

The available scientific evidence supports the conclusion that communities which provide the municipal services and housing for the participants in mining activities bear a significant portion of the social costs generated from these economic endeavors. In economic terms, local communities have been liable for the externalities generated by surface mining, associated activities, and reclamation. Unfortunately, the measurement of these social costs is neither simple nor straightforward. To a large extent, social costs are qualitative rather than quantitative. By their very nature they do not yield to shadow pricing. This does not mean, however, that they should be excluded from measurement, analysis, or future regulation of surface mining. One method, and perhaps the most efficient, for internalizing the predominately qualitative social consequences, both positive and negative, is to involve the affected people in the planning and scheduling for surface mining activities.

5.1 Balanced Representation

To the extent that the goal is to minimize negative social impacts, produce an efficient regulatory process, and internalize all of the costs of mining development, the local population must be allowed an active role in the decision-making process. The great virtue of citizen participation is that it is the most fundamental of democratic processes. To be effective, the participants in such a process must be representative of the interests within the community at large. Thus, three tasks have to be performed if the participatory process is to have credibility. First, the affected interests must be identified. Second, representatives of these interests must be sought in a way that ensures balanced representation. And third, each of the representatives must be convinced that it is in his or her interest to participate constructively in the process.

Identifying the interests to be represented in such a process is a difficult task. Social impacts do not respect geographical or political boundaries. Should neighborhoods or groups which are only slightly affected by the proposed action be represented in the same proportion as are other groups which are radically affected? (See Bacow and Rose 1978.)

There are three general solutions to the representation problem just described. First the decision-maker may simply invite those people whom he deems to be representative of the interests affected by the development. The potential bias associated with this solution is obvious. Second, the process can be opened up to all parties interested in participating. This approach relies upon the willingness of affected parties to come forward and participate as a means for ensuring balanced representation (Susskind 1977). Finally, it is possible to create a new governmental entity to handle problems which cut across existing jurisdictional boundaries. Unfortunately, experience with "special" governmental units has not been encouraging (Susskind 1975).

Even if interests can be identified and representatives selected, they must be convinced that it is in their interest to participate. To the extent that individuals can exert leverage over a regulatory decision at a subsequent stage in the decision-making process, they are unlikely to participate constructively in a collective decision-making enterprise. It is easier to influence the official who must make the final decision.

There are two possible approaches for ensuring that all necessary parties actually participate in a collective decision-making process. First, the collective decision-making body can be given major responsibility for making the regulatory decision. By giving the participatory process veto power over local mining operations, all parties, favorably disposed or not towards the development, would participate.

The second approach entails providing incentives for people to participate in and abide by the decision of the collective body. In some cases, it is possible to obtain the consent of those who oppose a project and remove their incentive for subsequent opposition by offering compensation for the adverse impacts they are likely to incur should the project go forward (O'Hare 1977). Compensation is likely to be helpful, however, only when it is easy to (1) identify the parties eligible for compensation, and (2) determine the appropriate level or form of compensation to be paid. Compensation is not a particularly useful tool for resolving conflict if the conflict arises because people possess fundamentally different views of how a particular town should develop or whether or not development should occur (Bacow and Rose 1978).

5.2 Community Capability for Decision-Making

Proper representation alone does not ensure good community decision-making. Communities must possess a minimum degree of technical sophistication if they are to address the complex issues that are raised by surface mining development. Specifically, both community representatives and the general public will need to be educated as to the social, economic, and environmental consequences of alternative courses of action. Most communities do not at present possess this expertise. Moreover, the type of information necessary for responsible decision-making is not currently available through the environmental impact assessment process. Environmental impact statements are typically too long, too technical and not sufficiently focused to be of use to techically unsophisticated citizens. Equally important, they generally ignore important social issues.

Recent research suggests that a better way to inform the public would be to provide citizen groups with direct access to planning grants and consultants (O'Hare 1979). Such an approach is likely to provide information that is far more responsive to the individual needs and interests of the community than that provided by the impact assessment process. Unfortunately, planning grants to local communities suffer from two shortcomings. First, local officials must develop the expertise to obtain grants. Second, duplication occurs as communities recreate the information and knowledge of previous planning grants.

To the extent that the regulatory process demands continuing involvement of the community, staff is necessary to ensure effective community decision-making. Communities which often receive the greatest negative social impacts, small rural towns, seldom have the financial capacity to fund such a staff and must rely instead on volunteer services. Volunteer staffs, however, are difficult to recruit, maintain, and generally lack scientific expertise. If local communities are to participate effectively in the planning and scheduling of surface mining development, they must have access to adequate staff support as well as unbiased sources of information.

As an alternative method of providing expert assistance to the decision-makers and community residents, access to technical and social information could be achieved through the creation of a regional or national clearing house, perhaps modeled after the Educational Research and Information Clearinghouse. The clearinghouse should contain a library of social impact assessments; social science and historical literature on boom towns, rural industrialization and energy development; and related reports and publications. Each item should be indexed by subject and key words and annotated for quick comprehension by interested readers. Such a clearinghouse should possess a computer retrieval system and a means for reproducing requested annotated references as well as the reports and literature themselves. A clearinghouse so designed would thus be able to supply a basic library of the relevant social research materials to all interested parties at a reasonable price.

To provide additional technical assistance the clearinghouse could also incorporate a pool of expert social scientists and historians capable of explaining social, economic, political, and other related community consequences resulting from surface mining developments. Upon request, with a brief description of the community and proposed mining activities, a list of experts could be provided, or the clearinghouse could make suggestions as to the appropriate scientist(s).

Inasmuch as the stimulus for gathering, mastering, and effectively utilizing the technical social science information would come from industry planning and governmental regulations, it seems appropriate that the funding for the clearinghouse concept be jointly shared by both industry and government. Funding should provide not only for the cataloging, storing, and copying of information, but it should also include monies for the consultants' fees for assisting local communities. The advantage of such funding for consultants is that it would help the experts retain their independence from special interest groups, including government agencies. With a clearinghouse, unpopular conclusions reached by scientists would have no effect upon their future employment. Inasmuch as the clearinghouse itself would have no vested interest in either supporting or opposing a mining operation, explicit or implicit pressures to reach "appropriate" conclusions would be minimal.

5.3 Public Participation

The information compiled by a clearinghouse, as well as the advice of the scientists, should be made available not only to community officials, it should be provided to as many members of the affected population as possible so that representative community participation is assured. Without wide dissemination, the public might, as in the past, base its decisions on beliefs, hopes, wishes, and hearsay. The information could be disseminated in public meetings sponsored by the involved industry, by local civic and business groups, or by one of the several levels of government. Special reports in local newspapers, on local radio stations, and other media present additional alternatives. All information dissemination should come well in advance of the signing of leases on public lands or the approval of mining plans. Prior notification of the planning and information is necessary to enable affected citizens the time to discuss, form opinions, evaluate the advantages and disadvantages, and generally draw their own conclusions regarding the potential social impacts on their lives, both individually and communally. Inasmuch as many social costs are often non-quantifiable, it follows that only the affected individuals themselves are capable of placing a value on many of the changes to which they must adapt as a consequence of surface mining activities or reclamation in their communities.

In order to evaluate the several perspectives likely to develop, assuming that sufficient relevant information has been made available, it becomes important to tap the attitudes, values, and preferences of the local populations. Without sampling such community views, it is impossible to establish a basis for the inclusion and consideration of the values and desires of the local population. The gathering of local opinions and attitudes could be accomplished through standard survey techniques. This information, too, should be disseminated to local residents so that each may know how his neighbors evaluate a proposed mining project.

If Indian lands are to be included in new regulations governing surface mining of non-coal minerals, the processes just discussed for non-Indian communities would be largely appropriate for Indian communities as well. If surface mining operations are to occur on Federal land adjacent to Indian land, or if the air quality, water quality, water quantity, or biota on Indian reservations will be influenced by a mining operation on non-Indian land, joint public meetings should be held for the non-Indian and Indian populations in which both could be apprised of the consequences to their economies, cultures, and environments.

5.4 Structural Barriers to Public Participation

Although Section 513 of PL 95-87 provides for public hearings prior to issuance of a surface mining permit, the Act remains national in scope. It defines the rights and obligations of mine operators, while Department of Interior regulations further clarify the actual reclamation requirements. Although the States and Indian tribes may play a primary role in the implementation of the Act, no provisions exist for incorporating local communities into the regulatory process beyond the public hearings requirement. Thus, PL 95-87 permits communities to speak out, but it does not permit them to exercise any formal authority over the development process aside from the power they possess in implementing local land use controls (i.e., zoning permits, water permits, building permits, etc.).

A means must be found to balance the interests of local communities and higher levels of government. Currently, this balance is struck in favor of the States or the Nation. A surface mining development may proceed because it provides economic benefits to a State or region, local social costs notwithstanding. If, on the other hand, local communities were given final authority to approve or disapprove a mine and reclamation plan, parochial priorities could possibly supersede State or regional interests. Either alternative would appear unsatisfactory to large segments of the population.

No simple solution to the problem has been forthcoming, but it is clear that a solution must be found in the name of equity. One option might be to allow States to delegate authority over the approval process to the impact area, with the State retaining the right to override the decision. The increased power of the local community vis-a-vis the mining industry would provide motivation to industry to avoid or mitigate the negative social consequences of their operations. Any industry tendency to influence State decision-makers and to ignore local wishes could be tempered by a provision allowing impacted areas whose decisions had been overturned by the State, the option, perhaps with financial support, to litigate against the mining company involved. On the other hand, impacted areas would be unlikely to pursue a course of litigation unless community sentiment against the surface mining operation was high. Perhaps under these or similar circumstances, all parties to the decision would be motivated to bargain in good faith, adopting a perspective which included the legitimate concerns of one another.

NOTES

1. It should be noted that personal economic gain, real or perceived, is not the only factor which influences local citizen's support for new or additional prjects. Contributing to national needs, satisfying job requirements for kin, and the maintenance of the local social structure all provide additional motivation (see Little and Lovejoy 1979, Seyfrit 1977, Summers and others 1976, Andrews and Bauder 1968).

2. Obviously, the proportion of jobs going to local residents wil be higher when the mining operations are located in urban areas with a larger and more diverse labor pool to draw from.

3. The term boom town refers to a community with a population growth rate that exceeds a community's ability to provide services and support for its population.

4. Informal social structures are those in which the patterned behaviors are not governed by codified rules. Formal structures, like schools, on the other hand, possess detailed requirements for behavior within the institution.

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APPENDIX

PANEL WORKING PAPERS PREPARED FOR THE COMMITTEE ON SURFACE MINING AND RECLAMATION

I Working Paper Prepared by the Panel on Clays and Bauxite

II Working Paper Prepared by the Panel on Coastal Plain Deposits

III Working Paper on Sand and Gravel, Crushed Stone Quarries and Blasting, and Other Construction Minerals

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Note to the Reader: The Index that follows is limited to geographical locations, commodities, sections of PL 95-87, The Surface Mining Control and Reclamation Act of 1977, and other statutes cited in the report.