EPA

Decision Series

United States Environmental Protection Agency

Office of Research and Development

Energy, Minerals and Industry

EPA-600/9-77-018

August 1977

Appalachian Mineral Resource Development: Environmental Factors

THE ENERGY/ENVIRONMENT
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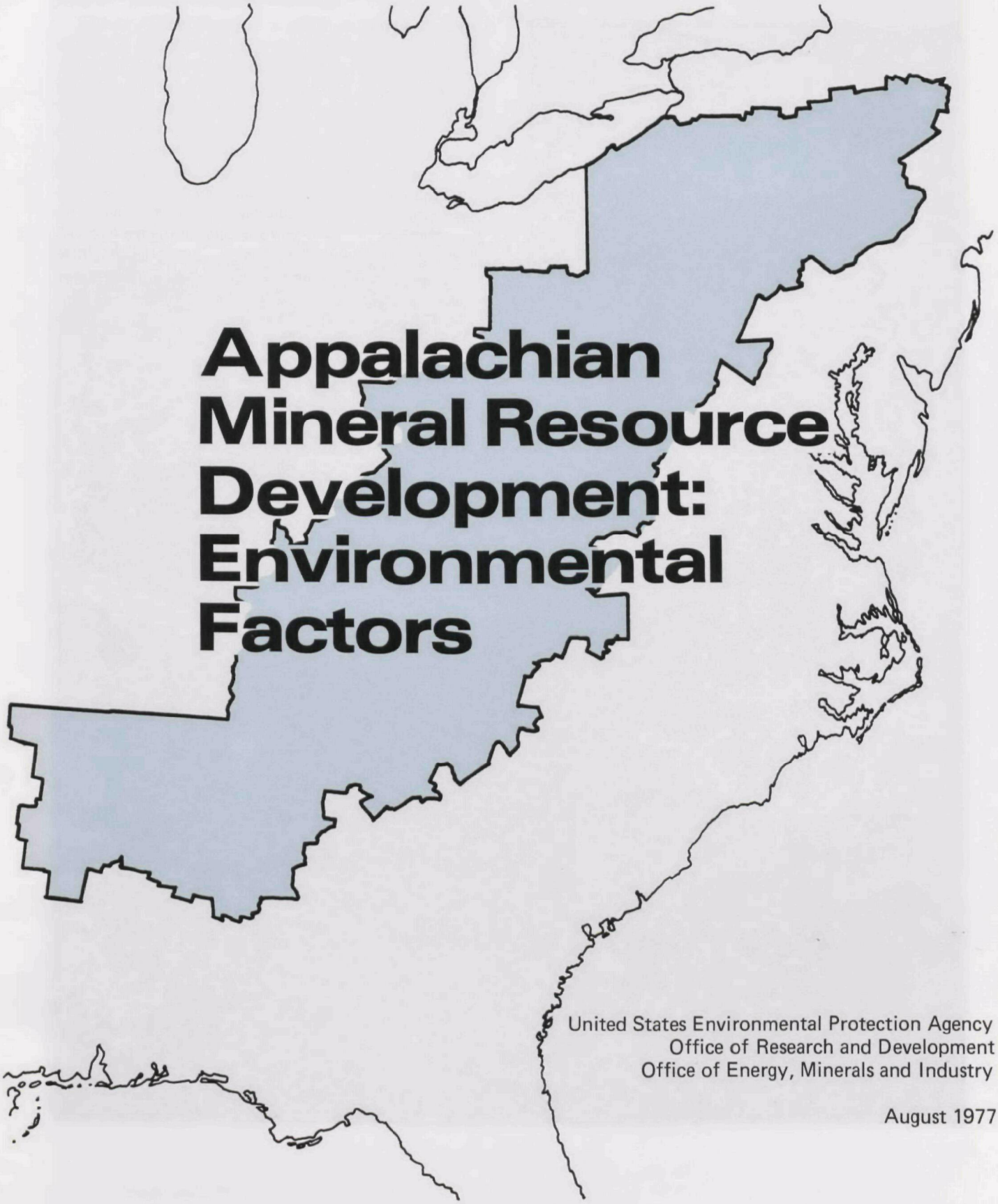

Appalachian Mineral Resource Development: Environmental Factors

United States Environmental Protection Agency
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Appalachian Stream Valley

Introduction

The Appalachian region is rich in a variety of natural resources, not the least of which are its scenic beauty, its mineral deposits, its forests and other vegetation, and its plentiful supply of clean air and water. These contribute to the attractiveness of the region as a place to live and as a seasonal and year-round recreational area.

In the past, certain of these resources were developed to the detriment of others. This policy is no longer necessary or economically defensible from the standpoint of enlightened regional development. We now have available technological control measures that will permit extensive development of mineral resources without severe or permanent adverse impacts upon the environment.

EPA has performed substantial research and development on methods of controlling environmental pollution from mines, mainly coal mines, in Appalachia. The Agency has also done considerable work on pollution control for other mineral extraction and processing operations. Most of the latter were not located in Appalachia. Nevertheless, there are overall similarities between an open quarry, a fireclay mine and its associated facilities, and many Appalachian coal mines and preparation plants. In general, the control technology principles developed for coal mines and mineral extraction operations outside the Appalachian area are applicable to the extraction and processing of non-fuel mineral resources in the Appalachian Region.

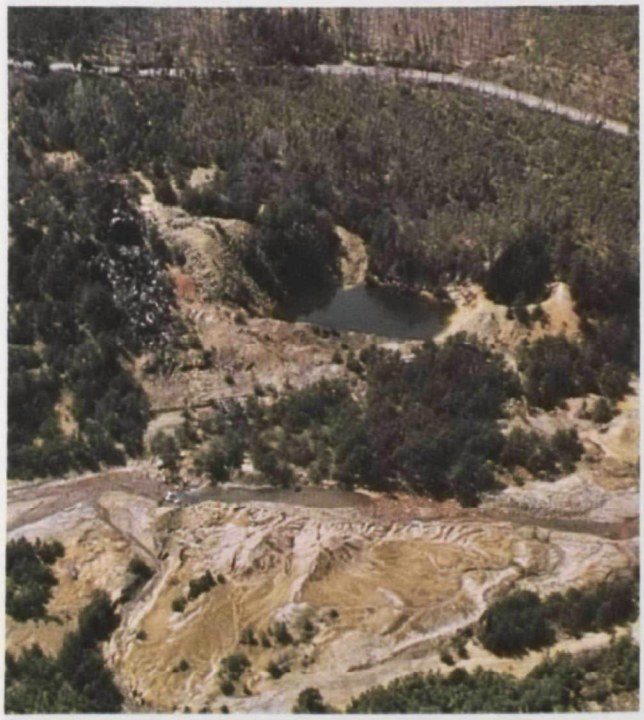
Open Stone Quarry

Mining and Processing Impacts on Water

Mineral extraction and processing can affect ground water as well as surface water. The principal effects are caused by acid drainage, sediments, dissolved metals, slimes, and process chemicals.

Acid Drainage

One of the principal environmental effects of mining or mineral processing is acidic pollution of surface waters that is caused by mine drainage or by runoff from refuse piles. The largely uncontrolled discharge of acid-bearing material has had devastating effects on many Appalachian streams. This problem has been seriously complicated by the release of acid drainage from abandoned mines, some of which have flooded or partially collapsed, and from unattended refuse banks. Acid drainage can occur wherever oxidizable sulfur compounds, such as pyrites, in the ore or mineral matrix are exposed to the air under oxidizing conditions. It is by no means limited to coal mines. A sulfur (pyrites) mine near Culpeper, Virginia has polluted Contrary Creek with acid runoff as the pictures on this page graphically show.



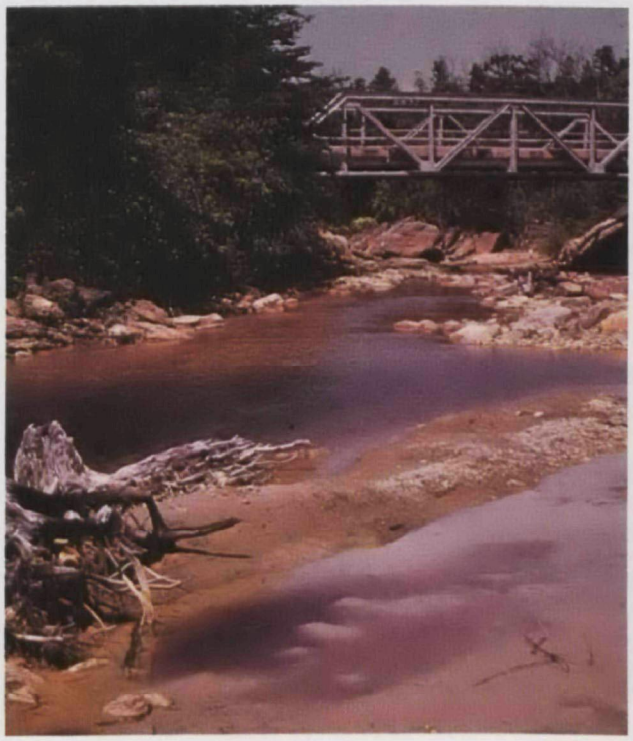
Fortunately, acid drainage can be controlled when the flow of drainage or runoff can be diverted to treatment facilities where the drainage is neutralized. For example, at a fireclay surface mine in Pennsylvania, the clay deposits are interspersed with seams of coal and the runoff is acidic. The runoff is channeled to a treatment facility where it is neutralized by contact with limestone slurry. From a storage tower, the limestone slurry flows through a trough which is baffled to maximize contact between the acidic runoff and the limestone slurry, thereby effecting maximum neutralization.

SUMMARY:
MINERAL EXTRACTION AND PROCESSING IMPACTS ON WATER

IMPACTS
- Acid waters
- Sediments
- Dissolved metals
- Slimes
- Processing chemicals

SOURCES
- Mine drainage
- Processing/beneficiation plants
- Trailing pile runoff/leaching to surface or ground water
- Access roads

EFFECTS
- Destruction of aquatic and other wildlife
- Interference with water supplies



Sediments

Far more extensive than acid drainage and, in the aggregate, far more damaging is the presence of sediment in surface water. Some analysts consider sediment the most serious water pollutant that results from mining because of its widespread occurrence as well as the severity of its impact on the aquatic environment. Whenever soil is exposed to rain or melting snow in non-arid climate—in direct mining operations or in associated development such as haul roads, temporary or permanent housing sites, and large equipment installations—erosion occurs unless careful control measures are implemented. When soil does erode, the rate of sediment yield is, of course, much higher on sloping terrain such as that typical of Appalachia.

Physical damage from sediment transport takes the form of disrupted flow patterns in streams, reduction of capacity and altered hydrologic characteristics of lakes and reservoirs, and weakening of dams and other retention or diversion structures. Biological damage includes clogging the gills of fish and blanketing river bottoms with silt which inhibits the reproduction of fish and benthic (bottom-dwelling) organisms. In addition, increased turbidity caused by suspended sediment reduces light transmission and affects the growth of aquatic plants.

Sediment Loss from Logging Road

MINERAL EXTRACTION AND PROCESSING — SEDIMENTS

SOURCES
- Earthmoving
  - Excavation/overburden removal
  - Road construction
  - Site preparation
- Beneficiation

EFFECTS
- Erosion
- Siltation of streams, lakes, reservoirs
- Destruction of aquatic life

A variety of sediment-control measures are available. Among the most common are settling ponds—areas where the velocity of a sediment-bearing stream is slowed. As a result of the decrease in velocity, much of the sediment settles out. Settling ponds work well for relatively heavy particles, but they are less effective for smaller, lower density particles. Sediment control can sometimes be facilitated by addition of agglomerating agents to settling ponds.

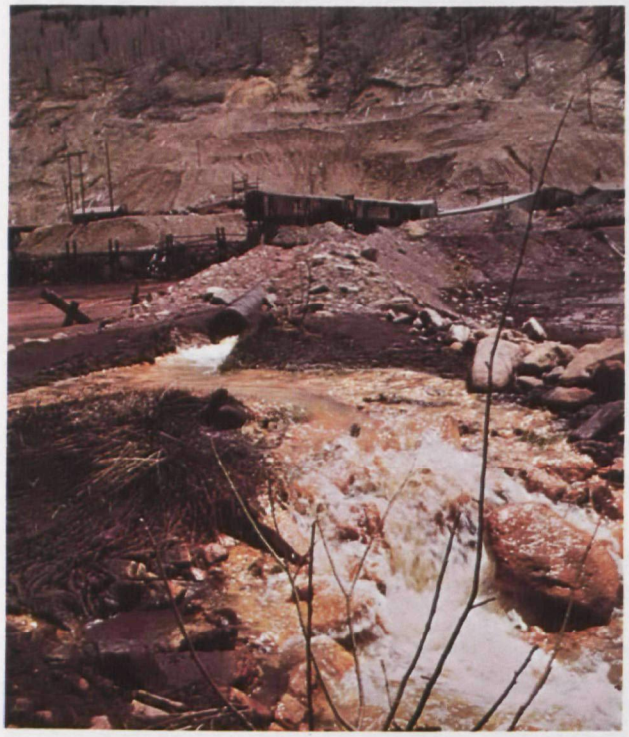
Haul roads are a significant source of sediment in the Appalachian Region. Generally, sediment-bearing runoff from construction sites for roads and other ancillary facilities cannot be contained for diversion through settling ponds.

EPA has studied control of sediment loss from logging roads in the northwestern U.S. A recently undertaken EPA project is evaluating methods for controlling sediment caused by construction of haul roads for a new mine in Kentucky. Baseline measurements are being made to determine sediment yield from existing roads. The control methods under study include: (1) sloping the road surface so that runoff occurs toward the hill rather than toward the downhill side, thereby facilitating collection of the runoff for subsequent treatment; (2) different types of road surfaces; (3) rapid stabilization of exposed banks; and (4) control of bank and shoulder slopes.

Sediment from mining and beneficiation (e.g., crushing and washing of the ore) operations is relatively simple to control. Most of the water flows can be contained (except during flood conditions) and passed through settling ponds or other treatment facilities.

Dissolved Metals

When the soil or refuse from mining contains water-soluble metallic compounds, or materials that oxidize upon exposure to weather to form soluble compounds, drainage from the mine or refuse pile contains metallic ions or compounds. In general, the solubility of metallic compounds is greater when the water is more acidic. The problem of dissolved metals present in runoff can persist long after a mine has been deactivated.



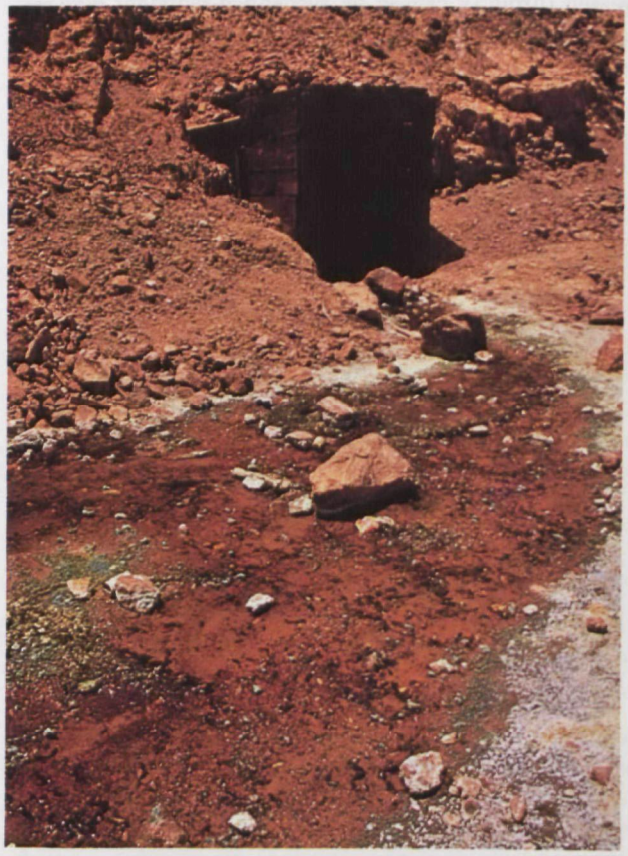
Metal Tailings Drainage

Many of these dissolved metals are toxic to humans, animals, fish, and vegetation. Low concentration of heavy metals in the runoff can harm aquatic life in the receiving waters, and common metals can be detrimental at high concentrations. Nonmetals such as fluorides may also be present in runoff at harmful concentrations.

In addition to the problem of toxicity, dissolved metals can impart color, taste, and hardness characteristics to the receiving waters. They may even render the water unsuitable for direct industrial use.

An EPA-sponsored study is investigating methods of using sewage sludges to reduce both the metals content and the acidity of runoff (and leachate) from the tailings piles at an abandoned pyrites mine on Contrary Creek near Culpeper, Virginia. The pyrites extracted from this deep-shaft mine were used as a source of sulfur, not of metals. At this mine, the tailings areas constituted the major source of water pollutants. Control measures consisted of regrading the land, applying sewage sludge to condition the soil, applying lime and nutrients, and establishing new vegetation (primarily grasses and legumes). The lime neutralizes the soil, thereby reducing acidity of the runoff and rendering the metals less soluble. In addition, the heavy metals tend to form organic complexes with organic material present in the sludge and this also reduces their solubility.

Other treatment methods are available to remove most of the undesirable metals. These techniques, however, can be applied only when the drainage or runoff is in a relatively concentrated form, that is, before it reaches the receiving stream. These treatments involve such techniques as precipitation (rendering the compounds insoluble so that they separate out from the runoff), flocculation (aggregating suspended particles so that they can be easily removed mechanically), and chelation (reactions in which the metal ions are combined, usually with organic compounds, to form less soluble substances.)



Dissolved Metal Drainage from Closed Mine

Slimes

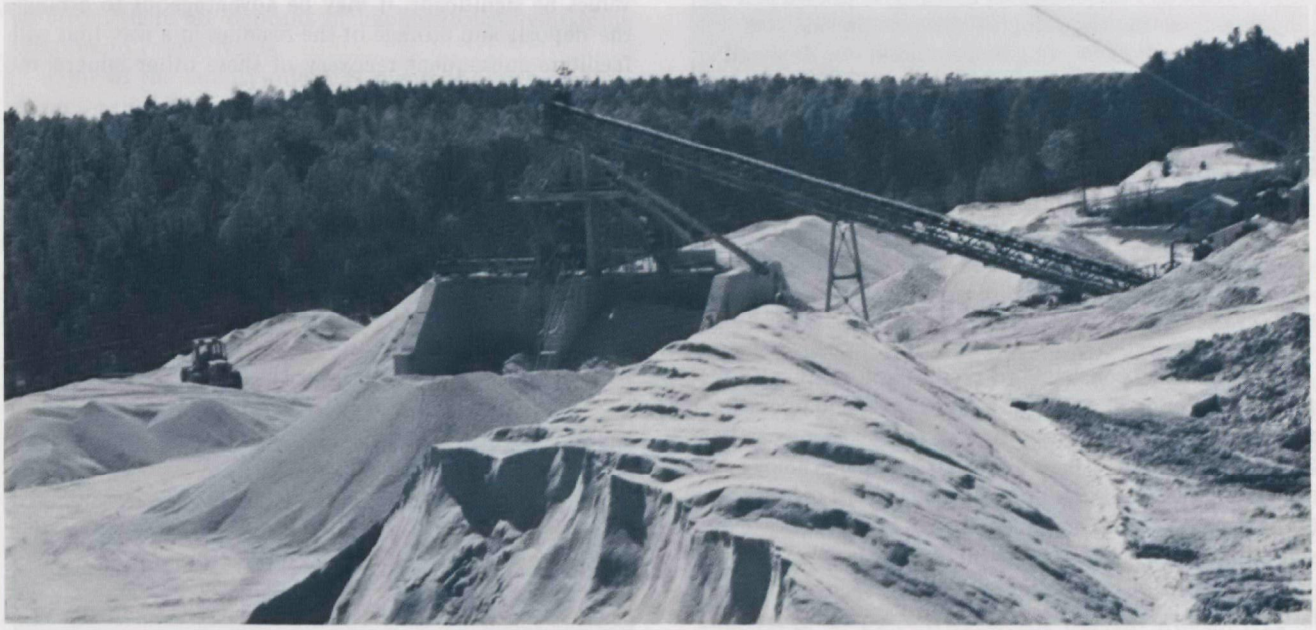
Slimes constitute a major problem that arises from the extraction of certain types of clays and gravel. Slimes consist of a dilute suspension of very fine mineral particles in water; they tend to stay in suspension for long periods of time—in the form of a cloudy liquid or a gel. Increased turbidity of a stream decreases the amount of sunlight penetrating the water and therefore the rate of photosynthesis of the aquatic flora. The entire biome of the stream can be affected.

Slimes must be treated by evaporation or by storage for extended periods. Either approach, as currently employed, can involve substantial investment in treatment facilities or in land for storage of the slimes. The period of settling may last as long as three months although flocculating agents can reduce the required time to a few hours.

The picture opposite shows a mine from which clay is extracted for the production of fuller's earth, oil-sorbent materials, and cat litter. Also visible in the picture is the settling pond that is used for treating runoff from the mine. At the processing plant, the mined clay is crushed and screened, then dried and calcined. The latter processes generate dust, and wet scrubbers remove fine particles of clay from the waste air streams. Scrubber water is discharged into a recycle pond; the slimes settle out and the water is recycled through the wet scrubbers.

EPA is supporting efforts to improve the control of slimes from stone-processing operations. The research is being conducted at five separate gravel production sites near Raleigh, North Carolina. The clay slimes that are generated in these operations are voluminous and difficult to thicken. One of the techniques being used for slime control is the settling pond. EPA's research project at these production sites will characterize the different types of slime at the different sites in terms of particle size distribution, chemical and mineralogical constituents, filterability, and other characteristics. The project will also evaluate methods for more efficient slime handling and reclamation—faster thickening by addition of coagulants, centrifugation, filtration, etc.—with the aim of producing a stable landfill residue that can be cultivated and that will support a plant cover.

General View of Clay Mine



Sand & Gravel Quarry

Extraction and Processing Impacts on Air

In addition to the problems of water pollution, mining and mineral processing operations can also affect air quality. The principal air pollutant is fine particles. These range from harmless materials to suspected carcinogens such as asbestos fibers, depending on the type of mineral being processed. When containment of the processing operations is possible, control of many types of airborne particles can be accomplished by such measures as filtration, wet scrubbing, electrostatic precipitation, and inertial separation (e.g., by cyclone devices). When extraction and processing occurs in the open, dust is a persistent problem.

MINERAL EXTRACTION AND PROCESSING IMPACTS ON AIR

IMPACTS
- Dust
- Exhaust fumes
- Evaporation from chemical-containing ponds

SOURCES
- Mining and quarrying operations
- Stone crushing and grinding
- Power equipment

EFFECTS
- Inhalation/ingestion of airborne particulates
- Formation of smog by interaction of dust and exhaust with terpenes and other organic compounds volatilized from trees

Clay Processing Wet Scrubber

Preplanning of mining and processing operations should include an assessment of the values of the secondary minerals in the overburden and refuse. Should these values be significant, it may be advantageous to arrange the deposit and storage of the residues in a way that will facilitate subsequent recovery of these other mineral resources.

The Impact of Mining Residues

Refuse banks consisting of accumulations of solid residues from mineral extraction and processing operations may be sources of water pollutants and airborne particulates. However, they may also constitute rich sources of minerals other than the one being extracted in each particular mine. For example seams of high quality clays sometimes occur interspersed with coal deposits; in some cases only one of these minerals is being recovered. Similarly, the refuse from pyrites mines may someday become an economical source of iron or copper.

MINERAL EXTRACTION AND PROCESSING — SOLID RESIDUE

SOURCES
- Overburden
- Mining spoil
- Refuse from beneficiation

EFFECTS
- Unsightly accumulations
- Sources of dust, polluted drainage, leachate

POSSIBLE BENEFIT
- Source of secondary minerals

Increased Mineral Production in Appalachia

In order to understand better the possible environmental impacts of increased mineral production in Appalachia, three hypothetical situations involving mineral development will be discussed in greater depth. These are:

- Increased used of domestic aluminum ores
- Increased production of base metals in Appalachia (copper, zinc)
- Expanded use of industrial rock near Appalachia

No attempt will be made, in these examples, to assert either the economic feasibility or the technical soundness of these hypothetical scenarios.

Scenario:

Aluminum Production

Let us hypothesize that national policy requires that, for whatever reason, as much as possible of our aluminum supply be obtained from domestic sources. United States Geological Survey statistics indicate that domestic supplies of bauxite, the primary source of aluminum, are inadequate for meeting our needs and would have to be supplemented by other aluminum-bearing minerals. Deposits of two such minerals—aluminous saprolite and aluminous shale—are located in Appalachia and the southern Piedmont. Another source is kaolinitic clays which are found in the southeastern Piedmont. In addition, there are deposits of kaolinitic clay containing diaspore in Pennsylvania.

Four of the twenty-odd U.S. plants in which alumina is presently reduced to metal are located in different parts of Appalachia (Ohio, Tennessee, West Virginia, and Alabama). These four plants constitute about 25 percent of the total U.S. production capacity. Let us assume that these plants could be appropriately modified to process the bauxite substitutes to metallic aluminum. (We are ignoring the step of producing alumina from ore, with its subsequent reduction to the metallic state.) An additional power requirement—perhaps 15-20 percent—would be involved, but that would be acceptable. Because of available power and ample water supplies, the Appalachian plants would be retained in their present locations.

The ores would be mined in the southern Piedmont areas or in Pennsylvania and shipped to the nearest aluminum plant. What would the environmental consequences be? For simplicity and brevity, we shall consider only the effects within Appalachia, not at the extraction sites in other regions.

FIRST SCENARIO — ALUMINUM

ASSUMPTIONS

- Existing Appalachian aluminum mills continue in operation
- Non-bauxite ores shipped in from nearby states
- Some ore extraction in Appalachian states
- Little change in infrastructure

PRIMARY ENVIRONMENTAL IMPACTS

- Direct
  - Different solid residues
  - Greater quantities of residue
  - Higher energy requirements
- Indirect
  - Increased sediment from new roads, railroads, power transmission lines

First, and possibly the most important factor, is transportation—hauling the ore from the new source to the mill. This may involve construction of rail lines or heavy duty highways over hilly terrain which has the potential for widespread soil erosion and production of sediment.

Second, depending on which aluminum-bearing mineral was used, it may be necessary to treat and dispose of types of wastes different from the "red mud" and other residues that are typical of bauxite refining. In any event, greater quantities of solid residues would derive from the substitute, lower quality ores, thereby exacerbating the solid waste disposal problem.

Third, there would be a need for additional electric power. Installation of additional transmission facilities may be required; this would cause sediment release and have adverse impacts on the scenery.

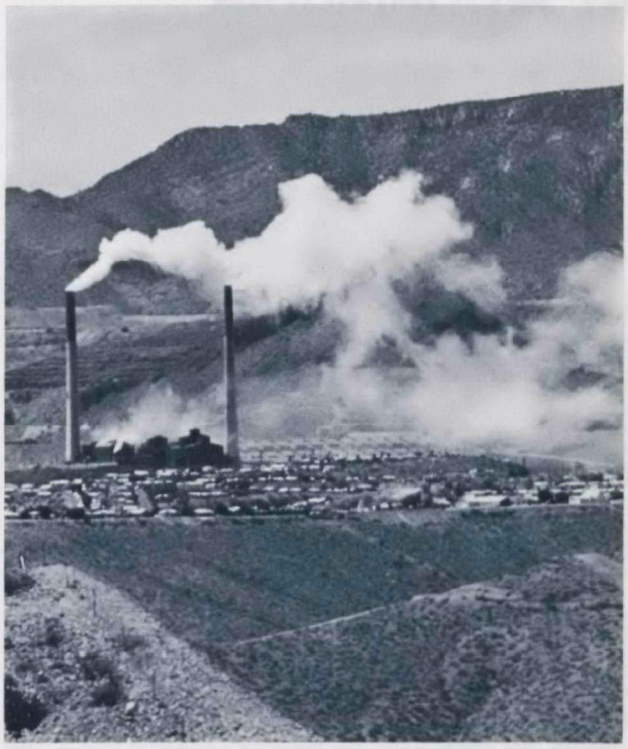
It is unlikely that any significant shift in population or change in the supporting infrastructure in Appalachia would be caused by the described changes in type and location of ore supply. The major potential environmental effects in Appalachia would result from ancillary developments (road, railroad, electric transmission line construction) and the disposal of solid residues and slimes. Suitable control methods—e.g., well designed haul roads to prevent sediment release—will prevent or minimize the adverse impacts of these developments.

Scenario: Production of Base Metals - Copper

Copper-bearing deposits have been identified in northeastern Alabama, Tennessee, northern Georgia, western North Carolina, western Virginia, and Pennsylvania. Copper is now mined in the Ducktown District of Tennessee and in western North Carolina; these mines account for about one percent of U.S. production of copper.

If copper mining were expanded in Appalachia and processing were carried through to the metallic product, additional mines, beneficiation plants, and smelters would be required. The construction of mines and industrial development would probably necessitate establishment of new communities or expansion of existing communities to support this development.

The environmental impacts of these developments would be diverse. Because pyritic minerals are associated with the copper ore, runoff and leachate would probably be acidic with high concentrations of dissolved metals. Sediment could derive from ore beneficiation processes, and sulfur-containing gases and dusts could be emitted from smelters. Underground mining, if used, could result in surface subsidence in future years should shafts collapse in exhausted and abandoned mines. The development of supporting residential and commercial areas and construction of roadways would produce sediments. The quantities of municipal and industrial solid wastes would increase.



Typical Western Copper Smelter

SECOND SCENARIO — BASE METALS (COPPER, ZINC)

ASSUMPTIONS

- New mines, production facilities needed
- New roads, residential areas needed

PRIMARY ENVIRONMENTAL IMPACTS

- From support facilities
  - Sediment from roads, mining camps, etc.
  - Municipal wastes, sewage
- From copper (direct)
  - Acid drainage
  - Dissolved metals
  - Smelter fumes, dust
  - Additional solid residue
- From zinc (direct)
  - Overburden (if strip mining is used)
  - Large amounts of solid residue

Fortunately, available control technology can prevent most of these adverse environmental effects. There have been problems with the application of some types of control techniques to prevent emissions from smelters, and the control of sediment from large-area sources remains a problem. Nevertheless, with the application of appropriate technological measures, the most serious environmental impacts can be controlled.

Base Metals - Zinc

About one-fourth of domestic zinc is produced in the Appalachian areas of Tennessee, Virginia, and North Carolina. There are also zinc deposits in central Pennsylvania, northwestern Georgia, central Tennessee, and central Kentucky.

The impacts from further development of zinc resources in Appalachia would probably be minimal compared with those that would result from the expansion of copper production. Currently, most zinc deposits are mined underground. The large deposits of zinc ores in Appalachia permit mechanical mining on a larger scale at relatively low cost.

Zinc deposits occur in an alkaline matrix, and consequently the problems of acidic runoff and dissolved metals are minimum. The solid residue from zinc mining and extraction can be utilized. Pebbles in the residue are useful for concrete aggregate, and the waste material from the mills, which is almost all carbonate rock, can be sold for use as agricultural lime and aggregate material. However, should strip mining be used, the removed overburden would comprise large quantities of solid residue that may not be usable. There is also, of course, the problem of sediments that would be generated by mining and beneficiation operations.

The proximity of many zinc deposits to mainline rail and modern highway facilities and to high density population areas is also a major factor that favors growth of the industry. The development of residential and other community facilities to support expanded zinc production would therefore probably be much less than that required for expanded copper mining, and environmental effects would be correspondingly fewer.

Scenario: Stone Production

At present, stone in its various forms is the most valuable non-fuel mineral commodity produced in the Appalachian region, comprising 31 percent of the total value of non-fuel mineral production in the area. Stone deposits are principally limestone, but granite and sandstone are also present in substantial quantities. Deposits are ubiquitous throughout the region in virtually unlimited quantity. Production of dimension, crushed, and ground stone is limited only by demand, capacity of production facilities, economic factors including transportation costs, and environmental considerations.

THIRD SCENARIO – INDUSTRIAL ROCK

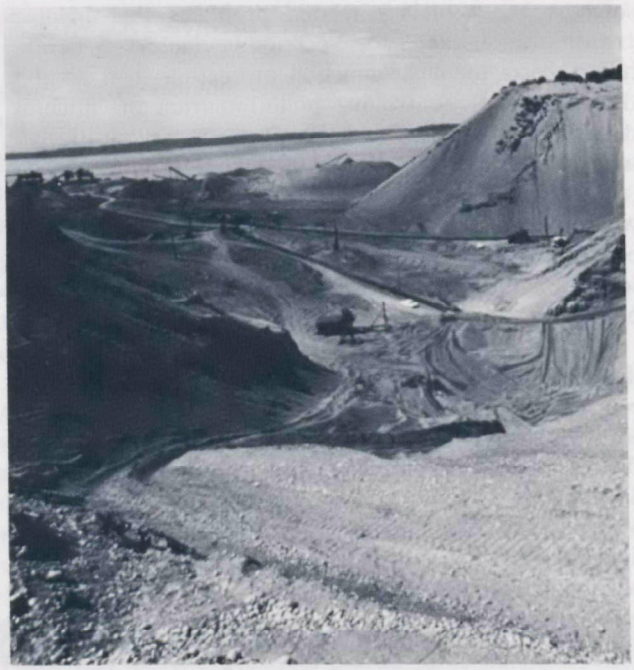
ASSUMPTION

- Most additional production will occur near urban or populated areas

PRIMARY ENVIRONMENTAL IMPACTS

- Dust, airborne particles
- Solid residue
- Pits, drainage retention ponds
- Suspended solids in drainage, runoff
- Slimes from washing operations
- Competition for high-value real estate

Because of its weight and bulk, stone is costly to transport. Stone is therefore generally quarried as close as possible to the point of use—developed, urbanized areas. Stone quarries and processing plants usually require large land areas for their operations and for disposal or treatment of solid residue. Slime-containing ponds may also be large. The quarry area itself is generally not a thing of beauty. Stone quarries and processing plants must compete with other land uses for scarce land in urban areas or in the limited area stream valleys of Appalachia.



Typical Stone Quarry Operation

Stone production generates large quantities of waste materials, mainly oversized or undersized crushed stone, which require disposal. Processing and crushing operations are noisy and create dust. Pit water pumpout and process water usually contain high concentrations of suspended solids. These materials are generally of a benign nature and tend to settle rapidly. However, some wash waters do contain clay-sized particles that form slimes, which present the disposal and treatment problems discussed earlier.

The principal direct environmental impacts of stone extraction and processing operations are dust in the air, suspended sediment and possibly slime and alkalinity in the water, and noise. Secondary impacts are those resulting from specialized transportation requirements (mainly sediment in runoff) and the possible effects on land values.

Internalization of Total Costs

In any scheme for development of the Appalachian mineral resources, several important cost factors must be considered if the development is to be economically feasible. Obviously, environmental costs are *now* a major input to any decision on whether to develop a given resource and how to proceed with the development.

Increasingly, we are learning that environmental cost factors are not limited simply to abatement of water and air pollution at the extraction and processing site. In some cases, secondary related problems that involve transportation and socio-economic factors generate higher costs for environmental protection than do the direct costs of controlling pollution from the mineral development itself. Examples of secondary problems, which were discussed above, include cutting new roads in the Appalachian terrain, providing housing for workers and their families, and providing the ancillary community services of water supply, sewage disposal, schools, and social amenities that large scale mining and processing development would necessitate.

The key point in development cost analysis is that *all* significant environmental costs should be identified and considered along with the usual capital and construction costs. If this is done properly, the potential developer, the concerned regulatory agencies, and the affected public will have a sound basis for deciding, first, whether to proceed at all, and then, what the cost-effective alternatives are. In this way, environmental protection costs can be included from the beginning stage and paid out during the course of the mining and processing development.

The listing (below) of the costs of mineral development is by no means all-inclusive, and certainly any feasibility study in a region so large and diverse as Appalachia will have to be site-specific. The list is useful, however, as an indication of some of the generic problem areas that must be considered in a good cost analysis.

At first glance it may appear that the numerous factors, beyond the usual basic development considerations, would be overwhelming for anyone attempting to analyze total costs. In fact, much of the data for cost analysis is included in the environmental impact statement that is often required under Federal and even state law for any new large development.

The different types of information needed for the cost analysis are listed on the following page, together with data sources. For example, baseline water quality discharge data; air quality, emissions, and control information; and demographic data, including present and projected population, housing, employment, taxes, etc., are available from the appropriate government agencies. In addition, it should be noted that new mineral mining and processing industries are subject to EPA's Effluent Limitations Guidelines that have been promulgated for certain segments of the mineral extraction and processing industries, namely: minerals for construction; clays, ceramics, and refractory minerals; and ore mining and dressing.

TOTAL COSTS OF MINERAL DEVELOPMENT — CONSIDERATIONS

POLLUTION CONTROL

- Water
  - Runoff/drainage
  - Process wastes
  - Leachates
- Air
  - Dust, airborne particles
  - Aerosols
  - Fumes
- Noise
- Solid residue
  - Storage
  - Leaching prevention
  - Reclamation

AESTHETIC/AMENITY DAMAGE

IMPACT ON WILDLIFE/FRAGILE OR RARE ECOSYSTEMS

SECONDARY DEVELOPMENT

- Workforce and family housing
- Schools
- Road construction/maintenance
- Water supply
- Sewage treatment
- Social amenities

ALTERNATIVE LAND USE AT SITE

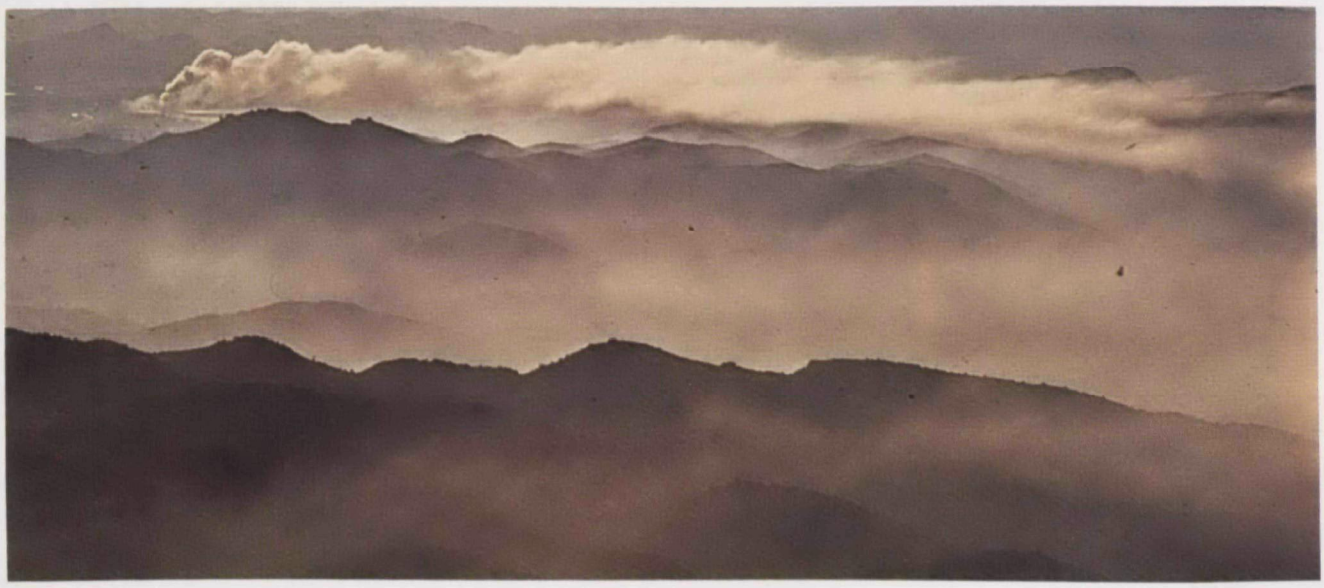
- Residential
- Agricultural
- Recreational
- Mineral development
- Industrial (other)

AVAILABILITY OF OTHER RESOURCES

- Energy
- Water
- Chemicals
- Other process-specific resource needs

TYPICAL SOURCES OF INFORMATION FOR TOTAL COST ANALYSIS	
FACTOR	SOURCE
Water Pollution Control	EPA Effluent Guidelines Documents
Air Pollution Control	EPA New Source Performance Standards; State Air Quality Implementation Plans
Housing	Census Data; Department of Housing and Urban Development (HUD) Documents
Community Water Supply	State/County Health Departments; State and U.S. Geological Surveys; Soil and Water Conservation Districts
Community Sewage Treatment	State/County Health Departments and Departments of Public Works
Schools	State/Local School Boards; Census Data
Public Services	State/Local Officials; Census Data
Transportation	State Department of Transportation (DOT); County Highway Departments; DOT Studies
Social Amenities	Census Data; State Departments of Parks and Recreation
Energy Availability	State Public Utilities Commissions

It is important that responsibility be designated for continuing the control of pollution after an extraction or processing operation is closed down. Although present effluent guidelines recommend that control measures be continued for about five years after a mine ceases operations, the site may persist as a source of pollution for a much longer time. Regulatory guidance is needed to provide for long term protection of the environment from discontinued mineral extraction and processing operations.

When the overall costs for control of primary and secondary environmental impacts as well as for installation of the necessary infrastructure have been reviewed, then the ultimate decision about mineral development should be made by an analysis of trade-off parameters.

In the spirit of the National Environmental Policy Act, we should undertake a total cost assessment of minerals development in the Appalachian Region. The price paid to expand minerals development in Appalachia should include the full costs of environmental control at each phase of development planning, and these costs should be paid for as part of the development process. In this way, there will be reasonable assurance that the right decisions are being made, the most cost-effective alternatives are being selected, and the development is proceeding in an environmentally sound manner.