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Criteria for Abandoned Mine Reclamation: Regional Planning To Develop Project Guidelines in the Blacklick Creek Watershed, Pennsylvania

United States Department of the Interior

Bureau of Mines

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By Bruce K. Ferguson, Maurice Deul, and Murray Dougherty

UNITED STATES DEPARTMENT OF THE INTERIOR
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CRITERIA FOR ABANDONED MINE RECLAMATION: REGIONAL PLANNING TO DEVELOP PROJECT GUIDELINES IN THE BLACKLICK CREEK WATERSHED, PENNSYLVANIA

By Bruce K. Ferguson,[1] Maurice Deul,[2] and Murray Dougherty[3]

ABSTRACT

Large areas of the United States were disturbed by mining before the long-term environmental consequences of certain mining practices were known. A planning procedure was formulated by the U.S. Bureau of Mines to establish reclamation objectives, and a methodology was developed to establish the most beneficial reclamation projects and priorities, given limited reclamation budgets. Objectives were established by comparing demand for reclamation with the degree of environmental damage of sites to be reclaimed. Demand factors include physiography, land use, infrastructure, demography, landform distinctiveness, and sensitivity of observed landscape; supply is controlled by mining disturbances such as surface mining features, deep mining features, stream acid load, and acid pollution sources. A matrix is used to establish priorities so that the highest priorities are for sites where disturbances are most severe and the demands greatest. It is believed that reclamation efforts following these priorities would create large and rapid reclamation benefits with the application of limited reclamation funds. Conclusions about guiding the locations and sequences of reclamation projects can be drawn from maps of reclamation priorities, no matter what reclamation technology is applied. Application of this procedure to the Blacklick Creek watershed is illustrated.

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INTRODUCTION

Coal was widely mined in the United States for more than a century before anyone realized the adverse effects of unrestrained coal extraction. Without environmental controls, a huge quantity of mine waste and mine spoil accumulated, and thousands of miles of streams were polluted. Surface mines and refuse dumps lay barren, ugly, and unused.

Mining is now performed under mandatory State and Federal reclamation regulations, but that does not correct the disturbance of the past (fig. 1). In areas mined before enactment of reclamation regulations, the noxious fumes from burning waste piles and the yellow-red precipitate of acid water make these places unfit for people to play, live, or work. The character, productivity, and value of resources throughout such mining regions have been damaged. The abandoned mines cause distress and waste resources not through some ongoing action of living human beings, but merely by virtue of their existence.

Numerous agencies at State and other levels are now beginning the long and difficult task of improving the hydrology and the landscape in old coal mining regions. The mission is complicated by the profusion of mining relics that have accumulated, the huge scale of the regions where the old mines occur, and the complexity of such large landscapes (fig. 2). Agencies seeking to reclaim old mines face the prospect of thousands of separate reclamation projects, dispersed along thousands of stream miles and over hundreds of thousands of square miles of territory, and requiring work stretching decades into the future. How will they identify the reclamation projects that will create the most benefit with limited reclamation budgets? Questions of coordination, efficiency, control, and ultimate objectives abound.

Figure 1.—Disturbance from past mining at the village of Vintondale, PA.

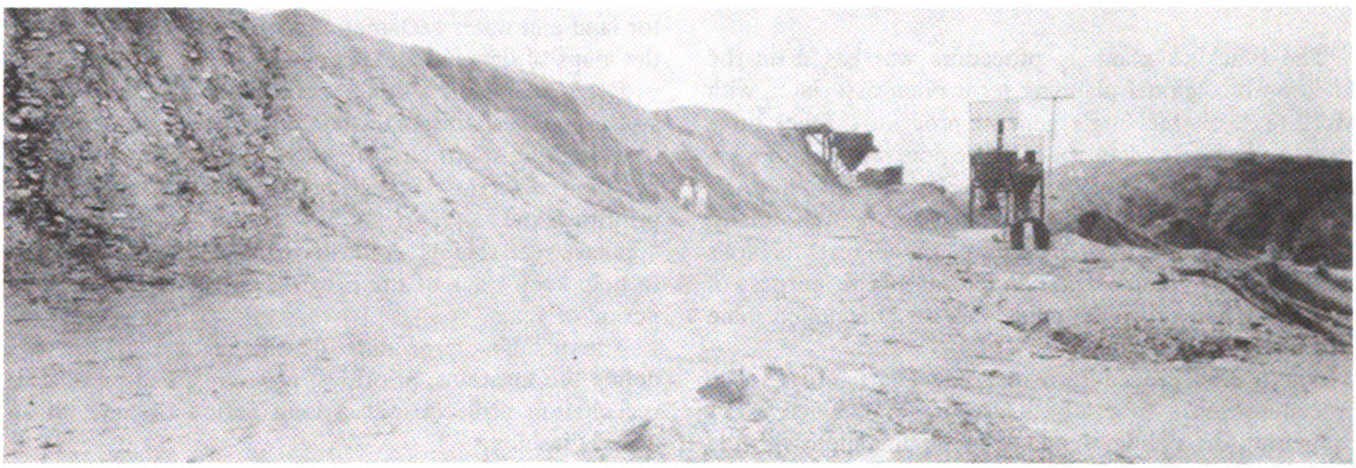

Figure 2.—Large waste bank (top) and facilities abandoned after failed attempt at reclaiming wasted coal from the waste bank (bottom).

To help answer some of these questions, the U.S. Bureau of Mines has formulated a planning procedure as part of the Abandoned Mine Lands program, which was under Bureau direction prior to transfer of these responsibilities to the Office of Surface Mining. This study was completed under Memorandum of Agreement J5130111. Procedure development was stimulated by the Bureau's interest in the experimental reclamation of abandoned mines in the Blacklick Creek watershed of Pennsylvania (fig. 3). The watershed has a population of 70,000, 420 square miles of land, 270 miles of streams, 300 surface mines, 170 refuse dumps, 200 square miles of underground mines, 90 acid pollution sources, and a 300,000-lb/d total acid production (*3, 6*).[4] The watershed is characterized by a mixture of urban and rural land, varied topography, a dense stream pattern, and private land holdings. All these

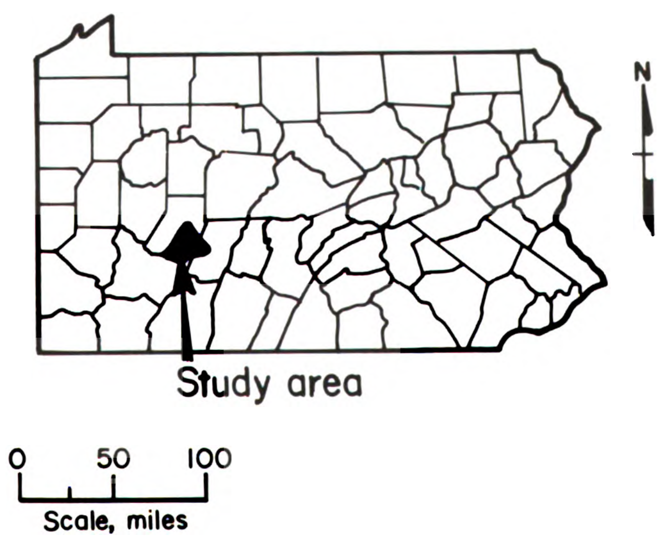

Figure 3.—Blacklick Creek watershed location map.

[4]Italic numbers in parentheses refer to items in the list of references at the end of this report.

factors make the watershed complex enough to require a regional reclamation plan before any reclamation work begins; as such, it is representative of many old mining regions in Appalachia.

Anticipating the need for rational planning, the Bureau's procedure was designed to coordinate the possibly hundreds of reclamation projects that might take place in the watershed over a period of many years. Although the experimental effort in the Blacklick watershed was tabled, the planning experience that the Bureau gained should be applied by the other agencies concerned with the abandoned mine problem; it is anticipated that similar procedures will evolve and improve with further experience in applied planning projects.

OVERVIEW OF PROCEDURE

The Blacklick planning procedure was based on the tradition of regional planning most often associated with McHarg (*7*). McHarg's general procedure relies on a broad collection of data about the region, the summarizing and displaying of the data on a series of maps, and the systematic overlaying of the maps to form land use plans. The Blacklick planning procedure, based on McHarg's basic approach, is an adaptation for the specific purpose of identifying and providing guidelines for abandoned mine reclamation projects.

The overall procedure is diagramed in figure 4. The procedure seeks to establish reclamation objectives by comparing the public "demand" for reclamation with the "supply" of mining sites to be reclaimed. The demand for reclamation comes from the human values implicit in the region's settlement patterns, traffic patterns, historic sites, and other land use resources that represent the natural and cultural context of any reclamation work to be done. The significance of these resources was evaluated using a method of resource analysis, adapted from the U.S. Forest Service (*14*), that summarizes where people are, how concerned they are about disturbances to their local environment, and the sensitivity of the perceptual setting.

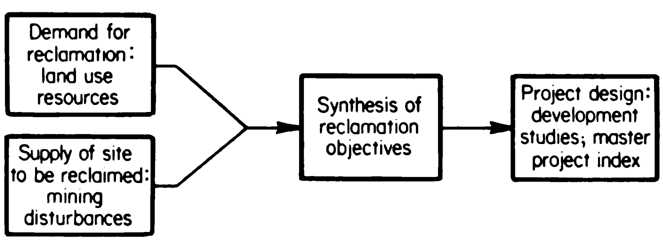

Figure 4.—Overall regional planning procedure.

The supply of sites to be reclaimed is represented by the degrees of land and water disturbance attributable to specific mining features. For example, at Blacklick, the degree of disturbance to land depended on how substandard the regrading and revegetation were; the degree of disturbance to water depended on how much pollution an old mine was discharging into the stream system. In regions with other types of mining effects, disturbance may also depend on such factors as mine fires, subsidence, landslides, and water supply damage.

Synthesis of demand and supply determine the land and water reclamation objectives. The priority for reclamation is highest where both demand and supply are greatest, where the greatest mining disturbances intrude most directly on the values of people. In this report, the synthesis is concluded with maps showing the objectives for land and water reclamation, constructed by overlaying the maps of demand and supply.

Regional planners can use the information from the synthesis to establish reclamation objectives and project designs using specific reclamation technologies. The reclamation objectives maps should govern the locations, priorities, and sequences of how any technology would be applied to the region. A master project index can be used to help keep track of the progress of reclamation over a period of years.

The planning procedure developed at Blacklick can define the locations, priorities, programs, and phasing of reclamation projects over a long period of time, in an orderly fashion.

DEMAND: LAND USE RESOURCES

Abandoned mine reclamation takes place in the context of regional development patterns, demography, growth patterns, transportation, and land and water values.

The process of evaluating land use resources consists of the application of accepted regional planning techniques, interpreted and assembled into a sequence for the particular needs of abandoned mine reclamation. The analysis steps at Blacklick are shown in figure 5. The land use resources evaluation is the focus of the analysis. It summarizes population distribution, people's concerns, and their perceptual context. Key steps in the analysis are those of physiography and land use and infrastructure.

Physiography is the classification of landforms. It integrates what is known about the materials, shapes, and structures of the land surface. It tends to be correlated with a wealth of land use and land cover characteristics, such as vegetation, settlement patterns, etc. Hence, it provides an ubiquitous background within which reclamation and other human activities are perceived. In the

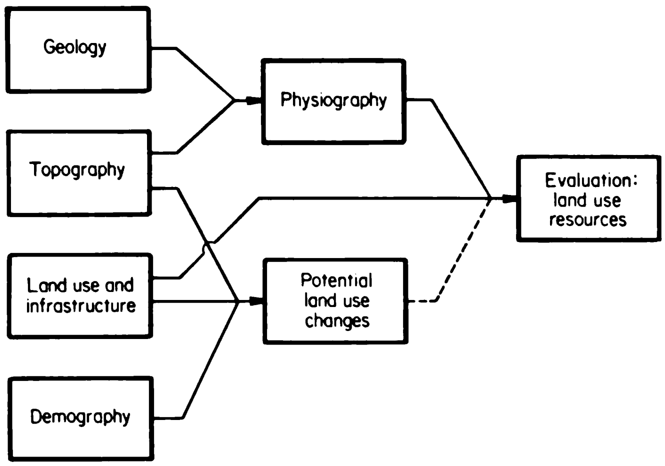

Figure 5.—Evaluation of land use resources.

Blacklick watershed, the major geologic features are structural: a system of alternating anticlines and synclines are visible on a map of geologic structural contours. The topography consists mostly of a system of ridges and valleys correlated with the geologic structures, but cut through by transverse gorges. It was natural to break down this pattern of landforms into the following five physiographic classes shown on plate 1: gorge, anticlinal mountain, anticlinal rise, synclinal valley, dissected plateau. Those classes are common denominators in the shape of the landscape, by which any two places on the map could be compared.

The land use and infrastructure analysis step involves all the human activities on the surface of the land. The range of data inventoried in the Blacklick study, which is in a semirural setting, is illustrated in plate 2. The map summarizes the multifaceted pattern of land use in the region. It shows where all the people are, their activities at each place, and transportation facilities.

The land use resource evaluation interpreted the significance of the land use and infrastructure and physiography data to the perception of human beings. The following four steps (diagramed in figure 6) were adapted from a U.S. Forest Service (*14*) method of determining and governing the perceptual impacts of timberland management.

1. *Strength of observer location.*—All the locations of people on the land use and infrastructure map (plate 2) were rated as to the strength with which the people in those locations evaluate their land environments, based on the numbers and degrees of concern of those people. All recreational, historic, and natural sites were given high ratings on the grounds that these are places where regional attention and concern are focused. The more ordinary positions—roads and settlements—were rated average or low depending on the numbers of people there.

2. *Sensitivity of observed landscape.*—The areas visible from each observer location are part of the location's environment and were rated as to sensitivity to disturbance. The closer a scene is to an observer, and the greater the strength of the observer location, the more sensitive the landscape is to disturbance, from the viewpoint of the effect upon people. The zones of sensitivity were mapped by interpreting the topography around each observer location. Some areas are hidden from all observer locations by intervening hills; these areas are defined zones of lowest sensitivity. Where zones surrounding two or more observer locations overlap, the area was given the higher of the sensitivity ratings.

3. *Landform perceptual distinctiveness.*—Each physiographic class of landform was rated as to perceptual distinctiveness. The Forest Service assumption is that perceptual distinctiveness, relative to the characteristic landscape of the region, creates a foil that may magnify the perceived impacts of land and water disturbances. A disturbance in a distinctive setting such as a mountain or gorge may be perceived as worse than an equal disturbance in a more common setting.

The type of distinctiveness ratings used at Blacklick could be improved upon by rating streams as well as landforms. Stream resources have both river and valley components (*5*). The Blacklick ratings included only the dryland, or valley, aspect. The river component can be based on such factors as discharge, riffles, channel width, etc. Although the entire river component adds up to less than half of a stream evaluation (*4*), the key role of water quality in abandoned mine reclamation could merit a special assessment of stream resources.

The quality of the ratings in all three of these steps could be improved with a quantitative perceptual study such as the procedure developed by Daniel and Boster (*2*). They have successfully tested a statistical measure of observer perceptual satisfaction based on responses to randomly photographed and displayed slides of landscape scenes. Such a measure could be used to rate the degrees of concern of observer locations, the importance of distance from observers, landform setting, and the degrees of perceived disturbance attributable to various types of mining features. Although such a procedure was not followed at Blacklick, the results of such a procedure could replace the intuitive ratings that were used with statistically valid measurements of relevant population groups.

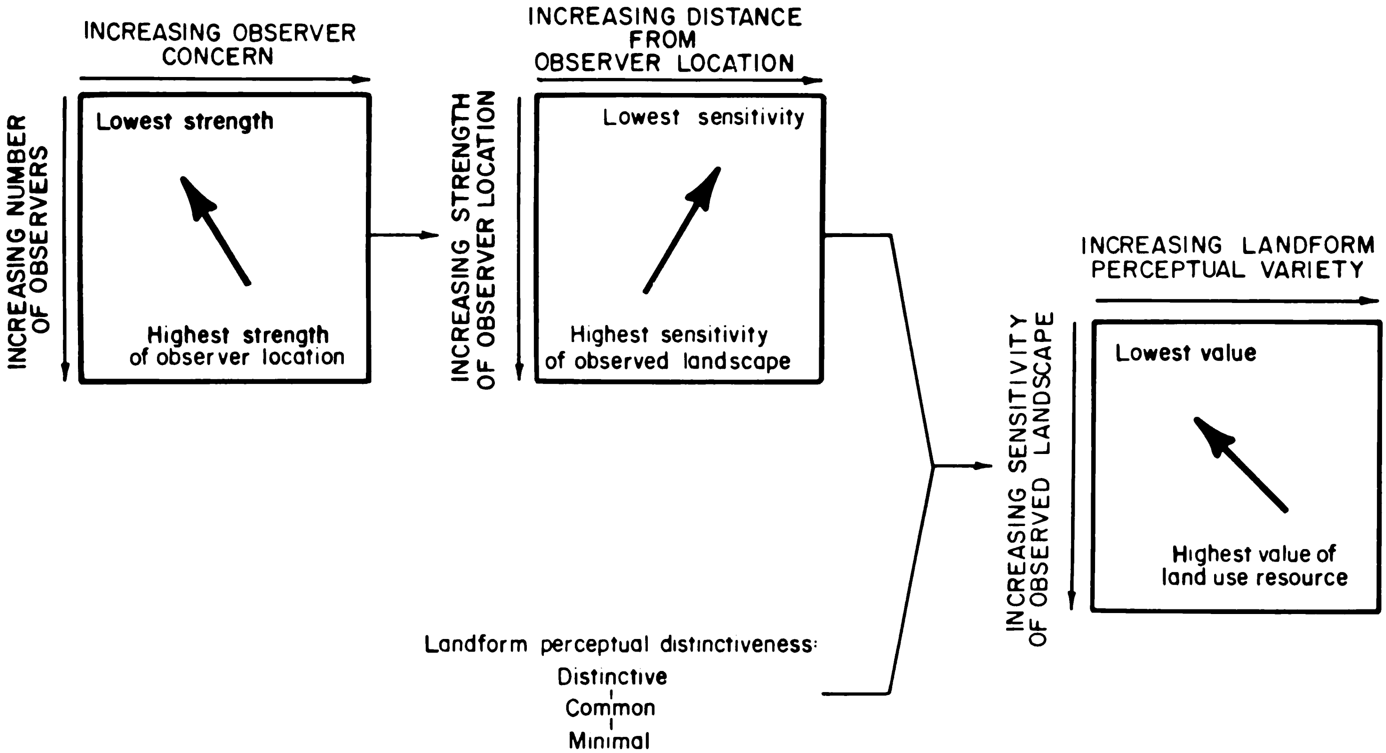

Figure 6.—Series of matrices for evaluation of land use resources.

4. *Land use resources.*—Land use resources were evaluated by comparing landform distinctiveness with sensitivity of observed landscape. This amounts to a comparison of how people are judging their environment with the distinctiveness of the setting. The highest value occurs where both sensitivity and distinctiveness are highest. Maps of sensitivity and distinctiveness were overlaid to yield a map of land use resources (plate 3).

The Forest Service had made land use resources type judgments to help prevent unacceptable disturbances to existing natural and cultural values from forest cutting and land development. At Blacklick, such judgments were used to help guide the development of a plan for the return of disturbed land and water to something like their premining value. Certainly the first purpose of any reclamation effort is to ameliorate the distress of people who are directly affected by mining damage. The observer locations (fig. 6) are the places where people live, work, play, learn, and travel. The land use resources map tells where those people are, and it tells where mining disturbances may be most intrusive in their lives. The value of the land use resource tells the demand for reclamation, where there is reclamation to be done. A high land use resource evaluation means that a mining feature located in the highly rated area should be given higher reclamation priority than a similar feature in a lower rated area.

Demographic analysis shows that the Blacklick area, like much of the northeastern United States, is experiencing diffuse growth in the large rural areas, decline of older settlements, and only limited growth near the more active towns. Demography was combined with topographic and infrastructural constraints to map potential land use changes. Because of the extremely limited future growth in concentrated, predictable locations, the potential land use changes did not alter the inventory of observer locations, and were not used in the final evaluation of land use resources. In other regions, with other land use trends, this type of information might have greater influence.

SUPPLY: MINING DISTURBANCES

The types, numbers, locations, and extent of old mines' disturbances to land and water represent the supply of sites to be reclaimed. At Blacklick, many years of study by State and Federal agencies (*3, 6, 8-13*) had resulted in a thorough inventory of the surface, subsurface, and water quality aspects of mines in the region. The planning task was to interpret these data from the viewpoint of reclamation objectives. As shown in figure 7, the evaluation of mining disturbances to land and water was based on data on the mining features themselves and the stream quality impairments resulting from acid mine drainage.

Surface mining features (fig. 7) include all the strip mines and refuse piles big enough to show up at the scale of the mapping in the Blacklick region. As shown in figure 8, the degrees of disturbance of surface features were evaluated by the extent of regrading and revegetation necessary to return the features to near-natural conditions. These factors are basic contributors to such perceptual ingredients as color, texture, and landform, and are correlated with such surface environmental effects as erosion and slope stability. The watershed's 170 refuse banks were all placed in the highest disturbance class. The strip mines vary greatly in their grading and vegetation requirements and are placed in a correspondingly wide range of disturbance classes. The map of surface mining features was coded to make a map of surface mining disturbances, representing the supply of sites for land reclamation (plate 4).

Deep mining features (fig. 7) include all the areas where subsurface mining had taken place. About half of the area of the watershed had been undermined, with some of the mines abandoned and others still active (plate 5).

Stream acid load (fig. 7) is the cumulative mass of acid from all sources that is flowing down the stream system, irrespective of how much water is flowing with it. The greater the amount of acid flow through a stream, the worse the pollution. Acid load is highly amenable to quantitative analysis because the net acid load must always equal the sum of all acid inputs from upstream. Acid load had been measured at numerous points in the Blacklick watershed, including at apparent outfalls from mining sources. These data were placed on the base map format and extended into a classification of all stream reaches (plate 6).

Acid pollution sources (fig. 7) involved the identification of the mine features that have water pollution effects, and their classification as to rate of acid production. Using an overlay of previously produced maps, the surface or subsurface drainage area of each acid outfall was delineated. The 90 identified sources were segregated from all other mining features, and placed together on the map of acid pollution sources (plate 7). Deep mines and refuse piles accounted for 95 pct of the watershed's acid pollution. The remaining 5 pct came from a few strip mines.

Unlike the load, or mass, of pollution, stream acid concentration (fig. 7) takes into account the dilution of acid by large volumes of stream water. The greater the concentration of acid in the stream, the worse the condition of the stream at that point. Measurements of stream pH, acidity in milligrams per liter, and sulfate in milligrams per liter are ways to express the concentration of acid

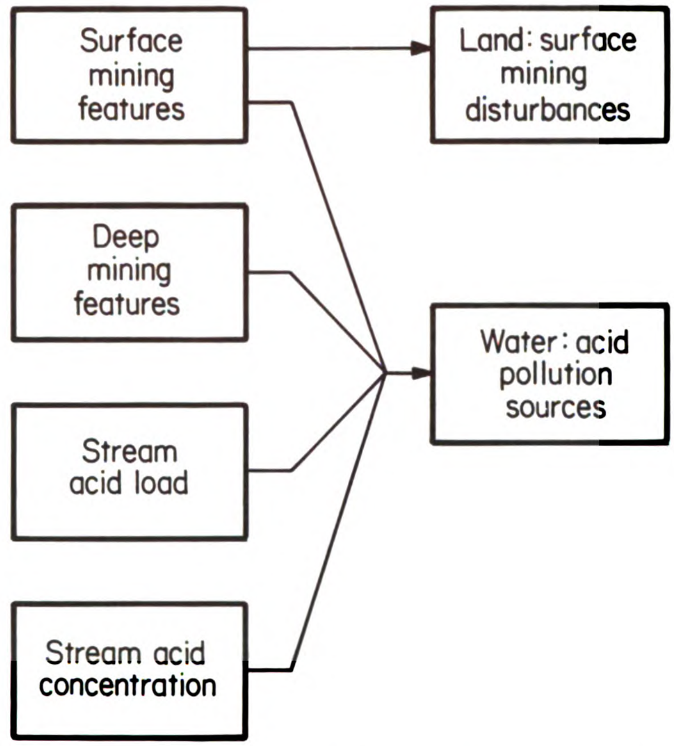

Figure 7.—Evaluation of abandoned mining disturbances.

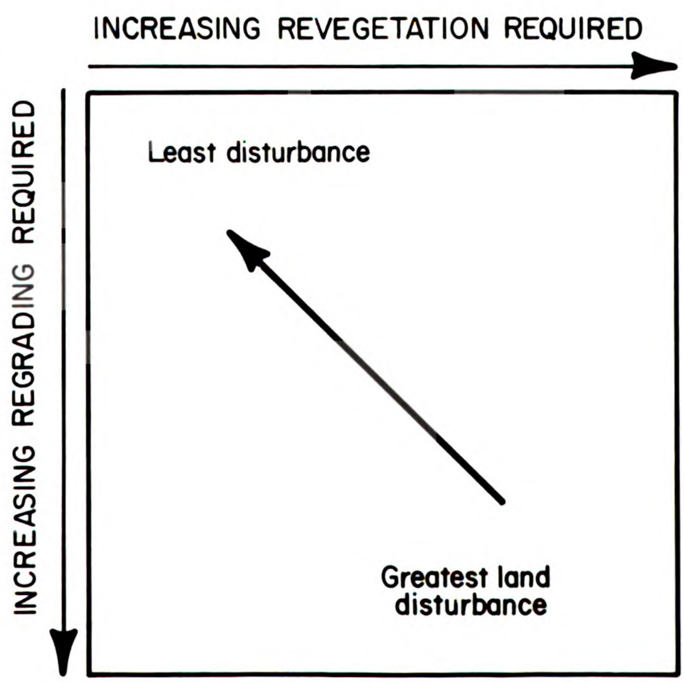

Figure 8.—Classification of degree of disturbance to land.

pollution. In the previously collected data at Blacklick, the only consistently available indicator of concentration was pH, and this measurement is not easily averaged to provide a meaningful statistic. Because of this shortcoming in the available data, acid concentration was not included in the evaluation of water disturbance; this should be attempted in future studies, characterizing acid concentration in terms of milligrams per liter or some other variable more tractable than pH. The classification of pollution sources as to degrees of water disturbance would then somehow incorporate both total pollution production and the source's effect on pollution concentration.

Figure 7 shows how acid pollution sources and surface mining disturbances are derived from mining-related data. Plates 5 and 8 represent the supply of sites to be reclaimed.

SYNTHESIS OF RECLAMATION OBJECTIVES

The synthesis of reclamation objectives compared the demand for reclamation with the supply of sites to be reclaimed. As shown in figure 9, demand is represented by the map of land use resources (plate 3), and supply by maps of surface mining disturbances and acid pollution sources (plates 4 and 7). Their combinations yield maps of land and water reclamation objectives.

The simpler synthesis is that of land objectives, because, in contrast to water disturbances, each unit of disturbed land is independent of every other unit; thus, land reclamation priority is simply a function of combining the inputs.

Land reclamation priorities were determined using the matrix shown in figure 10. The highest priorities are at the sites that are both most highly disturbed and most valuable to people. The lowest priorities are where both supply and demand are lowest. There may be many ways to arrange intermediate priorities, depending on one's relative concern for disturbance and value. However, as long as there is agreement that both demand and supply should govern land reclamation objectives, the sequence of priorities must always work in the same direction.

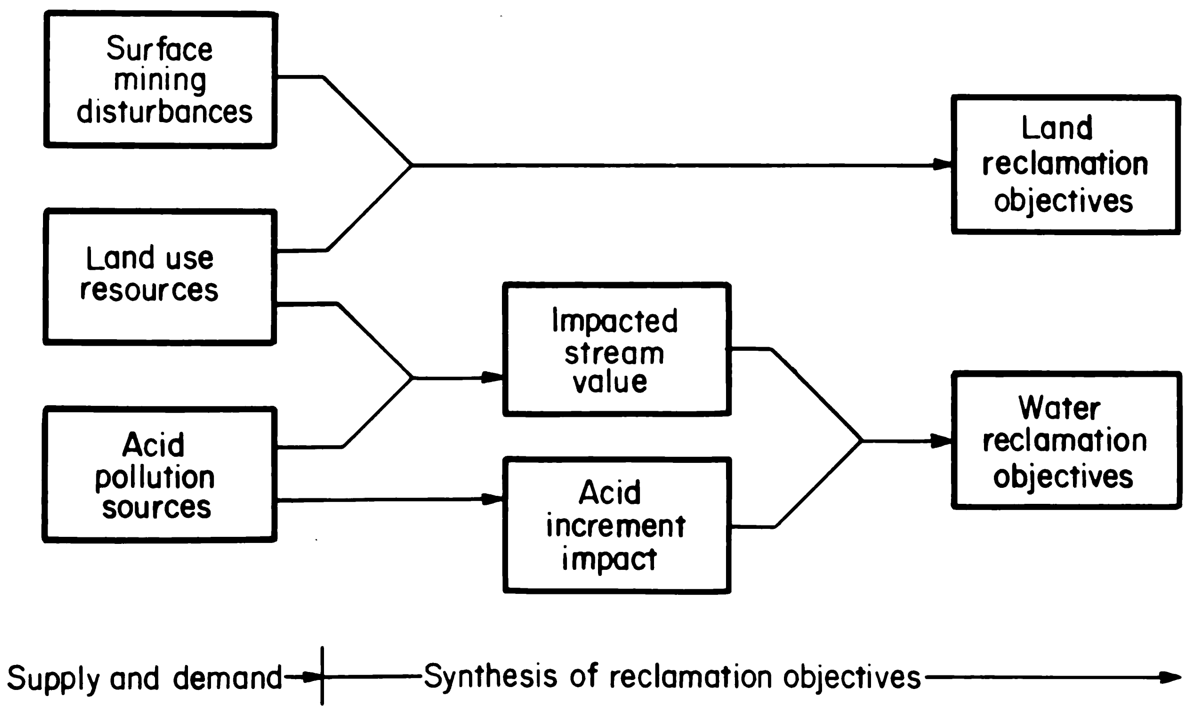

Figure 9.—Synthesis of reclamation objectives.

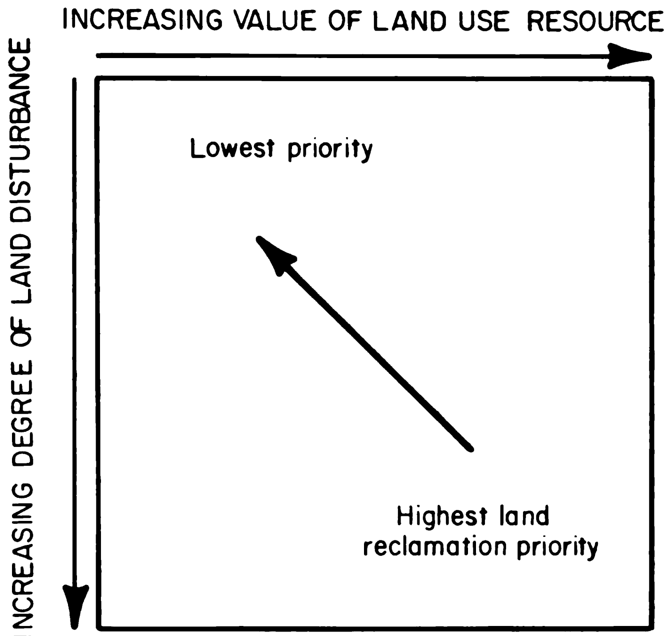

Figure 10.—Matrix for determination of land reclamation objectives.

A map of land reclamation objectives (plate 8) was constructed by overlaying the maps of surface disturbances and land use resources, and reading the resulting priorities from the priority matrix. The reclamation objectives map shows the priorities for land reclamation. No matter what combination of reclamation technologies is proposed to implement land reclamation objectives, and no matter how that combination may change over time, such a map should consistently guide the locations and sequences of land reclamation projects throughout the region. In each project, the goal would be to reduce the intrusion of mining disturbances into land use resources. The sequence of projects would begin among those with the highest priority, and work directly down the path of declining priorities.

In selecting a site for land reclamation, sites with high reclamation priorities can be found on the map; such sites have great leverage for creating substantial benefits with limited reclamation funds. An example is the incineration-income-injection idea that has been proposed as a way to abate acid mine drainage while producing income to help offset reclamation costs (*1*). It involves the incineration of acid-producing refuse material, the generation of energy from the heat to produce income, and the use of the incinerated residue to fill acid-producing deep mines in an attempt to reduce the flow of water through the mine and eventually to seal the mines. Under this concept, both refuse banks and deep mines would be worked on, to reduce sources of water pollution.

By looking at the land reclamation objectives map (plate 8), one can see that sites of high priority for land reclamation occur in and near almost all refuse banks. It might be possible to place a proposed incinerator on a site with high priority for land reclamation, and then have the incinerator work on nearby sites with high priority for water reclamation. Thus more types of reclamation benefits can be accomplished with this technology, merely by locating facilities in accord with the map.

The synthesis of water reclamation objectives is more complex than that of land reclamation, because water pollution sources are interconnected via the stream system. Two intermediate steps—acid increment impact and impacted stream value—were necessary to work up the supply and demand data to the point where reclamation objectives could be inferred.

Acid increment impact (fig. 9) shows the relative importance of the acid increment from each pollution source to the quality of the stream system. That importance can be quantified with the following equation:

Pollution source increment impact = Pollution source acid load - Upstream pollution source acid loads.

The equation is a way of comparing the source's acid load (in units such as pounds per day) with the load of acid already in the stream from upstream pollution sources. A source with positive impact generates a relatively large increment compared with upstream pollution; one with negative impact has a relatively small increment.

In the Blacklick watershed, the preceding equation was applied to an overlay of the map of pollution sources. Near the headwaters of the stream system, the acid increment impact was equal to the source's acid production, because the upstream pollution was zero. Further downstream, the cumulative upstream pollution was monitored, and subtracted from each successive pollution source. As pollution accumulated going downstream, the general tendency was toward lower impact levels, although some highly productive pollution sources still stood out with large impact levels.

Impacted stream value (fig. 9) is concerned with the value of the stream reach affected by each pollution source. The affected stream reach was defined as extending downstream to the point where the stream's total acid pollution load equaled or exceeded twice the acid production of the source. Thus all sources with impact levels of zero or less had an affected stream length of zero, because the stream's acid already equaled or exceeded the sources' contributions. Sources with positive impact levels had variable affected stream lengths.

The value of the affected reach came from the fact that its length flowed through one or more of the zones of value shown on the land use resources map. The combination of length and value was expressed in the following equation:

$$\text{Impacted stream value} = L_1V_1 + L_2V_2 + ... L_nV_n,$$

where V = value of land use resource (at Blacklick, this had a scale of 1 to 4)

and L = length (in miles) of segment with uniform V.

According to this definition, the stream reach affected by each pollution source was broken into segments, each segment flowing through one of the land use resource zones. The product of length and resource value created the value of the segment. The values of all segments were summed to give the impacted stream value attributable to the affecting pollution source.

Water reclamation objectives were determined using the matrix shown in figure 11. Reclamation priorities started at the pollution sources that were highest in both supply and demand, and worked down to those that were lowest. There may be many ways to arrange the intermediate categories of priority. A map of water reclamation objectives (plate 9) was constructed by applying the matrix to an overlay of the map of acid pollution sources (plate 7).

Ideally, water reclamation would start at a site with a very high priority according to figure 11. After completion of each project, acid impact and affected value would each have to be recalculated and remapped. The new values would establish new reclamation priorities and require a revised map. The general tendency would be for the completion of each project to cause an increase in the relative priority of nearby pollution sources because of the reduction of competing pollution in the stream system. A further complicating factor could be lumping two or more outfalls into geographic clusters for the purpose of defining project limits, which would result in a reclassification of acid productivity per cluster.

Despite the complications of project sequence, many types of useful conclusions can be drawn from the water reclamation objectives map (plate 9). The most obvious is the easy selection of sites with high water reclamation priority. The reduction of pollution from such sites would have great leverage for creating reclamation benefits with the application of limited reclamation funds. Another

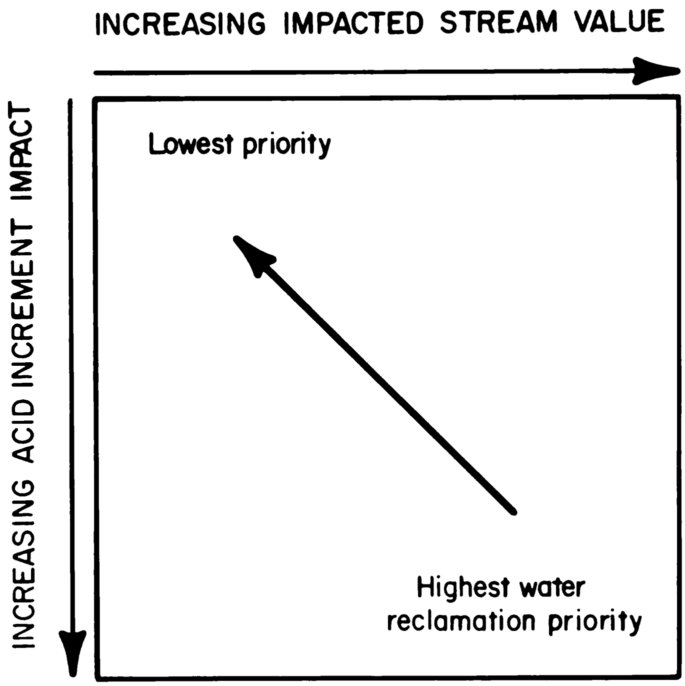

Figure 11.—Matrix for determination of water reclamation objectives.

example, already mentioned, is the incineration-income-injection proposal, which requires combinations of acid-producing refuse banks and deep mines in the same area (*1*). Such combinations can be seen on the map. Those sites with high combinations of reclamation priorities stand out as excellent sites for the implementation of the concept. A third example concerns the presence of surface features such as refuse banks and strip mines in all of the levels of water reclamation priority. Some of those features are in the higher priorities for land reclamation, as well. Thus, the reclamation of some surface features could accomplish both land and water reclamation objectives.

No matter what types of water reclamation technology are proposed, their applications to the watershed should be guided by the water reclamation objectives map. It shows the priorities and initial sequences for water reclamation. Water reclamation projects of all types can and should be conceived, and their reclamation benefits tested, against the background of this map.

An application of the use of the criteria discussed in this section is presented in the following section as a model.

RECLAMATION PRIORITIES FOR THE BLACKLICK CREEK WATERSHED

It was postulated that reclamation priority should be defined by both the value of the watershed's resources to its people and the degrees of mining damage to those resources. As shown in figure 10, the comparison of value and damage was made with a linear analysis. The demand for reclamation to be done was the value of the local environment as defined by those who inhabit it and use it, expressed in settlement patterns, topography, geology, scenic resources, recreational sites, and natural and cultural sites. Supply of sites to be reclaimed was represented by the degree of land disturbance and water pollution created by old mining features including deep mines, strip mines, and refuse piles.

The highest priorities occurred where both the value and the disturbance were greatest. In such places, the worst mining damages intrude most directly upon the lives of people. The lowest priorities occurred where both supply and demand were lowest.

A long-term, watershed-wide reclamation effort would be constantly directed by these priorities toward types of reclamation projects with great leverage for creating the greatest benefits and most rapid results for the watershed's residents from the application of limited reclamation funds.

WATERSHED VALUES

The 420-square-mile Blacklick Creek watershed is located in Cambria and Indiana Counties, PA (fig. 3), in the Allegheny Mountain section of the Appalachian Plateau physiographic province.

On the physiographic map (plate 1), the three northeast-trending anticlinal mountains emerging from the southern border of the map are apparent immediately. In the mountainous area, streams tend to originate on the flanks of the ridges, then to drain down the centers of the intervening synclinal valleys. Where the streams turn to flow through fracture zones in the ridges into other valleys, they form great gorges with massive side slopes. Other gorges are sunk into the synclinal valleys, or follow weak rock strata on the flanks of the anticlines.

Miniature versions of the anticlinal mountains, referred to as anticlinal rises on plate 1, are formed by minor anticlines between the major anticlines. Other anticlinal rises are diminutive northward extensions of the mountains, tracing the anticlinal axes where the anticlines finally sink, spread, and merge into the plateau.

The mountainous pattern is replaced on the north and west by a rippling topography with no major elevation changes. This is the classic Appalachian Plateau. Here, more or less dendritic drainage systems form dense, fine-grained dissections of the uplands with small streams. Bands of steep slopes tend to parallel the stream valleys.

The settlement of this region began two centuries ago, based originally on an agricultural economy and availability of surface water supplies (plate 2). Old agricultural and stagecoach villages are still inhabited, and such pioneer relics as stump fences, an old watermill, and the grave of Paul Bunyan's real forerunner are still visible. Immigration accelerated in the nineteenth century along with the development of coal mines, resulting in dense settlements clustered around mine entrances. One such village is Nanty Glo, which in Welsh means field of coal (fig. 12).

In 1980, the watershed had a population of 70,000. As in most of the northeastern United States, the denser old settlements are declining. Diffuse, low-density development is occurring in the expansive rural areas. Only the area around the university town of Indiana is experiencing dense, concentrated growth around an economic center. The Indiana area is the watershed's largest urban agglomeration, stretching out from the town center along growth corridors centered on major roads. South of Indiana, along Route 119, is a corridor of settlements characterized by more industrial activity than other parts of the region. The growth around Indiana and in the rural townships is largely responsible for the watershed's 12.7 pct net population growth in the decade of the 1970's.

Around Indiana is a radial pattern of roads (plate 2). The concentration of traffic moving into Indiana from all directions indicates that Indiana is the local service center. The Blacklick area is not a bedroom community for commuters to Pittsburgh. The region has its own economy and employment, based on coal, oil, gas, and the Indiana University of Pennsylvania.

Natural, historic, and recreational sites are resources where regional attention and value are focused (plate 2). Historic sites are in both town and rural locations. They include old railroad and canal structures, birthplaces, graves, iron furnaces (fig. 13), courthouses, churches, and other remains of the cultural development of the region. Natural sites include vegetative, geologic, and birding sites with unique interest. The biggest recreational site is Yellow Creek State Park. Other big recreational sites are county parks located in rural areas; smaller parks are near towns.

Where acid mine drainage has not ruined water quality, the Pennsylvania Fish Commission has classified some streams as fishing streams. The commission monitors these streams and sometimes stocks them. Canoeing streams begin where the watershed becomes large enough to support the required flow. They continue downstream until they run into highly urbanized areas, unattractive to canoeists.

On the land use and infrastructure map (plate 2) are other features that might allow combining a reclamation project with a development or improvement project by some other agency: unsafe dams, sites that have been considered for land fills by a county government, and sewage treatment plants.

The values of Blacklick's natural environment, history, and land use to the people who live in and use the watershed were assessed in a series of steps that were intended to incorporate all the important things known about the watershed's resources:

1. All the locations of people on the land use and infrastructure map (plate 2) were rated as to how the

Figure 12.—Main commercial street in Nanty Glo, PA.

Figure 13.—Early nineteenth-century iron furnace.

people in those locations evaluated their local environments, based on the numbers and degrees of concern of those people. Recreational, historic, and natural sites tended to get the highest ratings.

2. The areas that were visible from each observer location were rated as to sensitivity to disturbance. The closer an object is to an observer location, and the greater the strength of the observer location, the more sensitive the landscape is to disturbance.

3. Each type of landform on the physiography map (plate 1) was rated as to perceptual distinctiveness. A disturbance in a distinctive setting such as a mountain or gorge may be perceived as worse than an equal disturbance in a more ordinary setting.

4. The overall value assigned was based on a combination of sensitivity to disturbance and distinctiveness of landform setting. The highest value occurred where both sensitivity and distinctiveness were highest (plate 3).

A high resource evaluation means that a mining disturbance located in the highly rated area should be given higher reclamation priority than a similar disturbance in a lower rated area.

The overall pattern in plate 3 has large areas of intermediate levels of value where the landscape is densely traversed by ordinary roads and settlements. In the center and northeast parts of the watershed, lower levels of value predominate because there are few existing observer positions. The highest levels of resource value are along the streams and around natural, historic, and recreational sites. For example, there is a large complex of highly rated resources in the Brush Valley area because of the proximity of Yellow Creek State Park, a fishing stream, and seven other natural and historic sites.

MINING DISTURBANCES

Coal mining started here in the early 1800's, more than a century before controls of water pollution and land disturbance were envisioned. Coal mines proliferated as the industrial revolution developed and heavy industry in Pittsburgh demanded coal. Mining is still very active today, supporting huge regional powerplants.

The surface mining features shown on plate 4 include all visible refuse piles and strip mines that appear on the regional maps. Their combined pattern follows mostly the corridors of the major streams. Here, the big streams eroded the strata, exposing outcrops of coal, which provided access for both deep and strip mining. Other features occur on anticlinal rises, where deep-lying coalbeds have been uplifted just enough to be mined readily.

The most obvious disturbances of mining are the piles of castoff refuse of coal mining operations (fig. 1). There are about 170 refuse piles in the watershed. Because the separation methods were imperfect, the piles consist of as much as 30 pct coal. They are uniformly bare of vegetation because of their lack of soil and high acidity. They are dull black in color, and lie in jumbled, disarrayed heaps. Some of them contain millions of cubic yards of material, and rise hundreds of feet above nearby homes and roads. Some of them are burning inside.

Strip mines in the Blacklick area have overturned the earth of more than 20,000 acres of the watershed's land (fig. 14). In moving overburden to allow access to coal seams, the disturbed earth resulted in mixed soil and rock materials, with a little intermixed coal. The strip mines vary greatly in their degrees of disturbance to the form and vegetation of the land surface. The degree of previous reclamation varies with the age of the mine, and with which of the evolving reclamation regulations the mine had to comply. Some strip mines have been graded and vegetated into conformity with natural landforms, so that they are almost indistinguishable from the surrounding hillsides; others are piled in jumbled heaps, are essentially barren of vegetation, and expose hazardous highwalls.

Deep mining has occurred under about half of the area of the watershed (plate 5). Every deep mine had multiple entries for miners, coal cars, water supplies, electric lines, ventilation, and drainage. The deep mines started, like strip mines, where the coalbeds were near the land surface. Miners continued driving entries into the coalbed underground, removing 50 pct or more of the coal as they went. The distance of underground travel was extensive in a vast deep-mined area at the eastern part of the watershed. The entries once traversed by miners are now the conduits for underground water, some of it under artesian pressure. The polluted water discharges wherever the hydraulic pressure can find an outlet.

Water discharging from abandoned deep mines, strip mines, and refuse banks now transports sulfuric acid, produced from the pyrite in the coalbeds and adjacent disturbed rock strata, into Blacklick's streams and results in the associated yellow boy that is precipitated all over aquatic organisms and streambeds.

As shown on plate 6, almost all of the small headwater streams have small, or even negative, net acid loads. The acid load increases markedly as soon as a stream passes below its first acid-producing mine. It continues to increase downstream, with a major addition at each draining mine.

The acid that enters the stream system is cumulative. By the time Blacklick Creek reaches the mouth of the watershed, its acid load exceeds 330,000 lb/d. By tracing the acid load upstream to its origins, 90 pollution sources that generate more than 100 lb/d acid were identified. Their geographic pattern (plate 7) resembles the patterns on the maps of surface and deep mining features from which it was derived.

Figure 14.—Abandoned strip mine at Revloc, PA.

In terms of area, deep mines represent the largest pollution sources. Some are among the most productive sources in the watershed. In terms of acid production per source, refuse banks compete with the most productive deep mines. Strip mines are the smallest acid sources in number, area, and productivity. Some outstandingly productive pollution sources of various types are in the Homer City area and in parts of the upper Blacklick basin.

LAND RECLAMATION OBJECTIVES

The priorities for land reclamation were determined using the factors shown in table 1. It is a comparison of supply and demand.

Value of land use resource came from the land use resources map and degree of surface disturbance came from the surface mining features map. The highest priorities are at the sites where both value and disturbance are greatest. The lowest priorities are where both supply and demand are lowest.

Table 1.—Land reclamation priorities

Degree of surface disturbance (supply)	Value of land use resource (demand)— 4, lowest	3	2	1, highest
H (least disturbed) . .	5	5	5	4
G	5	5	4	3
F	5	4	4	3
E	5	4	3	2
D	4	3	2	1
C	3	2	2	1
B	3	2	1	1
A (most disturbed) . .	2	1	1	1

NOTE.—Matrix numbers are the relative priorities for land reclamation, no matter what reclamation technology is employed.

The overall geographic pattern of priorities (plate 8) is the same as that on the surface mining features map (plate 4) because all surface features have been classified as to priority. If there is a pattern of priorities within the disturbed areas, it comes from the fact that most of the people are in the valleys where there are roads. Upland mining features tend to be out of the way of people, and therefore of lower priority. When a mining site dips over the lip of a valley, it intrudes upon daily lives of people, and therefore tends to have high priority. The following are some noticeable clusters of sites with high land reclamation priorities:

- Refuse banks near settlements just east of Clymer, near Homer City, and near the village of Nanty Glo.
- Strip mines along the Blacklick Creek canoeing stream.
- A combination of strip mines and refuse banks near a village in upper Yellow Creek Valley.

One conclusion that can be drawn from the land reclamation objectives map (plate 8) concerns the proposal for land reclamation in the Dixon Run basin that was being discussed at one time. That project has been conceived as a way to perform land reclamation without losing major opportunities for water reclamation. Dixon Run is an appropriate area for that concept because it includes a large area of disturbed land but not much acid mine drainage. However, by examining the map of land reclamation objectives it can be seen that, with few exceptions, the disturbed lands in Dixon Run, extensive as they are, are remote from people, and so have low reclamation priorities. If money is going to be spent on land reclamation, it could be spent better elsewhere.

WATER RECLAMATION OBJECTIVES

Developing water reclamation objectives is more complicated than selecting land objectives, because the water pollution sources are interconnected by the stream system. First of all, whether reclamation of a pollution source would do any good depends partly on how much acid is already in the same stream. Consequently, the amount of upstream pollution was subtracted from the amount of acid produced by each source, to provide a measure of relative water disturbance. A reclamation effort that followed this scheme would begin at the pollution sources with the highest relative disturbances, then work on down the disturbance levels. There would be some movement upstream and downstream in the effort, but ultimately it would amount to a gradual progression downstream.

Second, given the relative importance of pollution sources to the water quality of their streams, what are the values of the specifically affected stream reaches to people. The value of an affected reach came from the fact that it flowed through the value zones shown on the land use resources map (plate 3). The stream reach directly affected by each pollution source was broken into segments, each segment flowing through one of the land use resource zones. The product of value level and length gave the segment's value. The values of all segments were summed for the affected reach, and assigned to the responsible pollution source.

With both questions answered, water reclamation priorities were determined as shown in table 2. The pollution source level of disturbance is the supply of damage to be abated; the value of the affected stream reach is the demand for improvement to be made. The priorities are highest where both value and disturbance are highest. They are lowest where both demand and supply are lowest. The geographic pattern of water reclamation objectives (plate 9) is the same as that on the acid pollution sources map (plate 7) because all pollution sources were classified as to priority. Eight of the sources are in the highest category of priority:

- Two deep mines in the lower Yellow Creek basin.
- Highly acid refuse piles at Colver, Revloc, Nanty Glo, and Vintondale.
- An isolated combination of a refuse pile and a deep mine on upper Yellow Creek, with very high stream value.
- A refuse pile at Clymer with both high impact and high stream value.

Table 2.—Water reclamation priorities

Relative pollution source disturbance (supply), lb/day	Value of stream affected by pollution source (demand)				
	0.1-0.9	1.0-4.9	5.0-19.9	20.0-49.9	50.0 or greater
-180,000 or less . . .	5	5	5	4	3
-10,000 to -99,999 . .	5	4	4	3	2
-1 to -9,999	5	4	3	2	1
0 to +999	4	3	2	2	1
+1,000 or greater . .	3	2	1	1	1

This group of eight sources is the one from which the first water reclamation projects should be selected, subject to such factors as accessibility, cost, etc. The completion of each water reclamation project would tend to cause an increase in the relative priority of certain other pollution sources, by the reduction of competing pollution in the stream.

One conclusion that can be drawn from the water reclamation objectives map (plate 8) concerns the Bureau's incineration-income-injection scheme that would work on both refuse banks and adjacent deep mines, several combinations of which can be seen on the map (*1*). Many of these sites are in the higher priorities for water reclamation. Those locations immediately stand out as bright prospects for the implementation of the concept.

Another conclusion concerns the presence of refuse piles and strip mines in all levels of water reclamation priority. Some of those features are in the higher priorities for land reclamation, as well. The reclamation of such features could achieve both kinds of improvement simultaneously.

DISCUSSION

The priorities shown on the maps of land and water reclamation objectives (plates 8-9) must be qualified by uncertainties in the data on which they were based. One of the Scarlift project reports (*6*) provided data on the mass balance of stream acid load but had internal inconsistencies, and it did not correlate well with the other Scarlift report (*3*), which contained data from where the two streams met. In this study, it was not possible to include concentration (as opposed to load) of stream pollution in the assessment of water disturbance because appropriate data were not consistently available. The classification of degrees of surface disturbance may have been skewed by unnecessary complications in the original data.

The authors believe that the regional maps of land and water objectives represent tangible expressions of abandoned mine reclamation intentions. They are based on the degrees of disturbance and the effects of those disturbances upon people. They form a regional plan that could govern a prolonged reclamation effort, define and establish priorities, and coordinate reclamation projects in a manner that would result in optimum benefits for the limited funds available.

The design of specific projects under the plan would depend on what types of technologies were proposed to conduct the reclamation effort. There may be several types of technologies considered in the course of a long-term program. Many such proposals were discussed during the Blacklick planning, including development of industrial parks, sites for vacation or second homes, sites for landfills, deep-mine sealing, strip mine regrading and revegetation, incineration-income-injection, and in-stream pollution controls such as water treatment plants and constructed wetlands. No matter what technology is proposed, its application to the watershed should be conceived and its reclamation benefits tested against the background of the reclamation objectives maps (plates 8-9).

One type of technology is the conventional reclamation technology set forth in the Scarlift reports (*3*, *6*). If any of the proposals in those reports are still being seriously considered, they can be mapped and compared with the reclamation objectives shown in plates 8 and 9. That would be a way to test the locations and priorities of projects, and possibly, to conceive new projects to reclaim areas at a minimum cost. Because of the interrelationship of reclamation effects, it is essential that the entire watershed be considered in formulating a plan of attack. In order to monitor the progress of the reclamation effort over a long period of time, a master project index can be used to show the status of projects: completed, in progress, and proposed. By frequently updating the map, it should be possible to keep track of how the reclamation effort is progressing through the region and to determine when further work should cease.

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