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(Getting The Rock In The Box Isn't Like It Use To Be)

Minnesota Department of Natural Resources
Division of Waters, Soils and Minerals

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"MINESITE" A BASIS FOR MINERAL RESOURCE PLANNING (GETTING THE ROCK IN THE BOX ISN'T LIKE IT USE TO BE)

by William C. Brice, David L. Brostrom and Perry A. Canton

Mineral Resources Environmental Coordinator
Department of Natural Resources
Planner, Department of Natural Resources
Geological Engineer, Department of Natural Resources
St. Paul, Minnesota

The business of mineral exploration and development has become much more than simply a problem of locating orebodies and designing mines. Favorable economic analysis of mining and processing feasibility is no longer sufficient to justify the development of a mine. New laws, enacted by virtually every level of government, require comprehensive land use planning, environmental analysis, mineland reclamation, mine safety studies, and many other considerations.

This profusion of new laws says in effect, that the mining company is no longer responsible only to its stockholders. Mineral development today can be compared to a partnership. As in all partnerships, the risks and liabilities as well as the benefits are held jointly by all the participants. In addition to the mining operator, this partnership consists of the public, through its many levels of government, interest groups, and individual citizens. Therefore, you'd better know your partner very well - his responsibilities and capabilities. Mining is considered a high risk venture. The risk on the part of the operator and the lending institutions has long been recognized. The risk that the public and its government take in these mining ventures has now been recognized also. The people and their government have learned that they inherit, through abandonment or forfeiture, the mistakes and problems of individuals and companies regarding these natural resources.

In looking through the "Mining Engineering Handbook" recently published by the Society of Mining Engineers, I noted that in their discussion of liability for excavations, the authors quoted from the book of Exodus, 20th chap., where Moses said to his people: "When a man leaves a pit open, or when a man digs a pit and does not cover it, and an ox or an ass falls into it, the owner of the pit shall make it good; he shall give money to its owner, and the dead beast will be his." Unfortunately, when the owner has long since abandoned the pit or left the area, government has often been forced to become the proprietor. The "meek shall inherit the earth", including the problems and mistakes that are made and are too costly for an individual or company to correct. We must recognize that the public is no longer content to be "meek".

In order to consider the obligations and responsibilities of government and industry in mineral resource planning, the following approach will be utilized. The new laws dealing with environmental and land use subjects will be considered briefly, emphasizing their effect on the traditional roles in mineral exploration and development. The government roles will then be illustrated using three examples from the Minnesota Department of Natural Resources'programs in mineral resource planning.

NEW LAWS INFLUENCE MINERAL RESOURCE DEVELOPMENT

In order to fully assess the changes in the role of industry and government in the development of our mineral resources, it is necessary to examine the laws which have necessitated these role changes. In general, these laws do not relate to the mineral industry specifically, but rather, address themselves to the basic issue of environmental degradation.

The most noteworthy of the recently passed legislation regarding environmental quality, is the National Environmental Policy Act (NEPA).(1). This act contains two major provisions. First, it requires a detailed environmental impact statement on all federal actions "significantly affecting the quality of the human environment." Second, it creates the Council on Environmental Quality in the Executive office of the President.

In addition to NEPA, several states, Minnesota among them, have enacted environmental policy acts of their own which contain provisions similar to the federal act. The statutory language of MEPA, the Minnesota Environmental Policy Act(2), is a bit more definitive than the federal act, stating that "where there is potential for significant environmental effects resulting from any major governmental action or from any major private action of more than local significance, such action shall be preceded by a detailed statement...". Some of the issues which must be addressed in the Environmental Impact Statement (EIS) under the MEPA provisions, are: the gross environmental impact of the proposed action; any adverse and unavoidable environmental, economic, and employment effects of the proposed action; alternatives to the proposed action; and the relationship between short term and long term uses of the environment, in regard to the proposed project.

What does the implementation of these two acts, NEPA and MEPA, mean to industry and government in relation to mineral resource development? As indicated earlier, NEPA, along with MEPA, in Minnesota's case, requires a dramatic change in mine planning. It is hard to imagine a mining operation in Minnesota which would not have to be preceded by an EIS. Therefore, the basic change involved is this: economic considerations can no longer be the only influence on where and how a mining operation will be carried out or whether it will be carried out at all. An equally important consideration must also be the environmental and socio-cultural effects of an operation.

In addition to the EIS requirements, a recent department report(5) shows that prior to the last legislative session there were at least 12 state, federal, and local agencies that could have some jurisdiction over one or more phases of metal mining operations, and that any new operation would be required to secure at least three dozen approvals dealing with various environmental aspects from these agencies. This has been further compounded by new regulatory legislation enacted in 1973.

The 1973 session of the Minnesota Legislature, and this may also be true of other state legislatures as well, saw more and farther-reaching regulatory legislation than that enacted in any past session. A number of these new laws are related to our mineral resources in general and to mining in particular. To name a few: The Environmental Policy Act, as already mentioned provides for environmental impact statements; the Wild and Scenic Rivers Act; substantial strengthening of the Mineland Reclamation Act; and the Registration of Severed Mineral Interests, including a new provision for taxation of such interests; and the Critical Areas Act.

These are but a few of the examples of legislation which can have an effect on mineral development in Minnesota. Wisely implemented and administered, this new legislation will provide greatly increased protection of our natural resources and be a benefit to the citizens of the State. Misdirected, it could cause social and economic disaster in certain areas.

The State, through its departments and agencies, and the legislature, through its various committees, are going through a period of "sorting out" this new legislation--reviewing both inadequacies and overlaps. The Department of Natural Resources, the Health Department, Department of Labor and Industry, Minnesota Pollution Control Agency, State Planning Agency--all have been directed to promulgate rules and regulations, much of which will, at least to some extent, affect the mineral industry.

Under Minnesota's newly strengthened Mineland Reclamation Act, the Department of Natural Resources is required to adopt rules and regulations providing for environmental protection and reclamation in connection with metallic mining operations that occur on <u>any lands</u> within the State. The new law as enacted, contains two basic requirements. First, each operator in the state must apply for and receive a "permit-to-mine" from the Department of Natural Resources. The second requirement, upon which the "permit-to-mine" is contingent, is the formulation of a reclamation plan. The reclamation of mined lands is viewed as an on-going operation, which is initiated in the original mine planning phase and is carried out as a part of the business of mining. Requiring a reclamation plan before actual mining commences ensures the most important consideration in mineland reclamation, which is the pre-planning of these operations.

Finally, Minnesota, along with several other states, have followed the federal government's lead in passing an environmental rights act. Entitled the Minnesota Environmental Rights Act, it provides for citizen participation in the litigation of environmental issues. The passage of this act is an implicit acknowledgment that the public does indeed inherit the earth, and they should therefore have a role in determining how the resources of the earth are managed.

This paper does not attempt to discuss the merits and intricacies of the flood of environmental legislation. It is important that the volume of environmental legislation and rule making authority that has been enacted is understood, because this legislation represents not only a recognition of new and pressing considerations but the beginning of a philosophical shift on a societal level in this country. This awareness calls for the implementation of a conservation ethic by industry and government, as well as the American people themselves. This awareness has now been written into law and the mining industry, due to its extractive nature and the degree to which it has disturbed the environment, has been and is today, a ready target.

Collectively, all of this legislation calls for sweeping changes in the manner in which we develop our mineral resources. The aspect of environmental planning must be adopted by both industry and government throughout the exploration and development phases of mineral resource development.

Industry Roles

Traditional steps in the mineral exploration and development sequence, as discussed by Bailly(4) in 1966, include four sequential exploration stages leading up to the feasibility analysis and the mine plan.

> "A complete exploration sequence begins with the appraisal of large regions for the purpose of selecting those regions permissive of the occurrence of mineralization of interest (first stage). This appraisal is followed by reconnaissance of the favorable regions in search of target areas, each with characteristics permissive of the occurrence of a mineral deposit (second stage). Such target areas are investigated in detail, first on the surface,

(third state) and then, if warranted, by a three-dimensional physical sampling (fourth stage). This last stage is often called "physical exploration;" but the techniques commonly used in the previous reconnaissance stages, especially in areas where targets, if any, may be buried under post-mineral barren rock formations."(4)

In the United States, land acquisition usually occurs after the second stage and must be completed before commencement of the fourth stage. Although some environmental analysis has been required from companies during the land acquisition process, the major impact of new laws is on the fourth stage of exploration and the succeeding mine development stages. In the past, these development stages have been one of mine design and feasibility analysis along with acquiring the necessary governmental approvals. Three fundamental changes in these stages have resulted in a significant increase in the work required of the industry.

1. Collection of data necessary to determine the present state of the natural and human environment in the project area. Depending on the parameters being considered, the boundaries of the project area should fluctuate. For example, when considering hydrologic data, watershed boundaries should be utilized to determine the project area. When socio-cultural data is being considered, the boundaries should be determined by developmental districts or some similar type of designation which most states have.

Some examples of data that should be collected include: hydrology and water quality, climatology, surficial and bedrock geology including soil profiles, plant and animal ecology, physiography, air quality, land use capability, historical, archeological and scenic resources, etc.

2. Techniques must then be developed, along with their degree of reliability, that are suitable for determining the environmental impacts that would result from a specific proposed project.

3. A project plan can then be prepared. The EIS procedures require that alternatives both to the project and to ways of implementing the project should be considered (this includes both alternative processing techniques and specific facility sites). A significant increase in the number of permits has occurred. These applications must also be prepared at this time.

In order to carry out these three functions, a level of expertise not previously required of mining companies is necessary. Both MEPA and NEPA require that public agencies utilize a systematic interdisciplinary approach that will insure that the natural and social sciences and the environmental arts will be considered in the planning and decision making process. With this kind of direction to government, it is difficult to imagine how a mining company can afford not having this type of interdisciplinary capability available to carry out the necessary data collection and planning for a new mining operation. Whether this work is done through consultants or as a company staff function, it seems fairly clear that an interdisciplinary pre-planning approach is an essential new requirement of the mining industry when developing and operating mines.

Government Roles

Government has two distinct but inseparable functions in a mineral exploration and development program. First, it is the responsibility of government to aid in the development of the earth's mineral resources. Second, and equally important, government must protect those natural and cultural resource values to which the public has given a high priority. One role cannot be carried out without carefully assessing the other. In making the decisions regarding what action to take on a specific mineral proposal, government must determine what risk the public is taking and act accordingly.

The first step in government's participation in the mineral development process is in developing an overall picture of where potential mineral resources might occur and determining the nature of these resources. This involves geological and geophysical mapping, the type of which is commonly undertaken by the USGS and many state geological surveys.

When interest is subsequently shown in exploring a particular area, government is then responsible for determining to what degree it is willing to make its lands available. In Minnesota, this involves more than simply putting all lands which indicate a potential for mineralization "up for grabs". The lands within the area or areas of interest are carefully screened, and those which have high natural or cultural resource values are either withheld, or if made available, receive particularly close monitoring to ensure that conflicts will not arise.

As companies began to locate mineral resources in a particular geologic formation, mine district pre-planning should begin. The first step is to develop potential mine models. This is done by assessing the types of orebodies that would be expected, the types of mining and processing that could be utilized, and the capability of the area to sustain an operation such as that which is projected. As this is done, initial boundaries of a potential mining district can be drawn. This assumes that exploration is progressing successfully. Obviously, many exploration prospects never reach this stage.

At this point, the pre-operational monitoring stage is initiated. Of all the functions which must be carried out, this one requires the greatest expenditure of effort, in terms of time, staff, and expertise. Whereas industry is responsible for providing to government detailed data requested for a specific proposal, government should collect the background data necessary for the regional analysis. This would involve such categories as air and water quality, hydrology, climatology, plant and animal ecology, surficial and bedrock geology, soils, physiography, land use capability, historical, archeological and scenic sites, and others. In addition to the regional pre-operational monitoring, on-going technical experiments on such factors as environmental effects and new processing techniques must be carried out. This type of research is necessary in order that environmental impacts can be minimized and land use conflicts reduced.

Once the data base has been established, and potential mining models developed, alternative sites for mine facilities can be identified. These sites should be based both on the engineering and environmental requirements necessary for a facility site. For example, some of the considerations for a taconite tailings basin should be as follows:

1. Required tailings basin capacity.
2. Proximity of the tailings sites to the mineral resources.
3. Minimize dam construction and dam height by utilizing existing topography.
4. Avoid streams, lakes and shorelines.
5. Avoid conflicting land uses and mineral potential areas.

It is now possible to develop a framework for an overall land use plan for the mining district. This is of particular importance in those areas where there is high potential for conflict between land use values and mining operations. By this stage, it has been determined where there is a potential for a mining operation, what type of operation it is likely to be, and what the land use characteristics are in the region. This does not mean that specific sites are reserved for specific uses. Wherever possible, no use will be allowed in an area which will destroy or foreclose uses of higher value in that same area. Unless this type of plan is followed, such land use decisions are often made in an arbitrary manner, with little regard for consequence. Historically, this has often been the case.

At this stage, individual proposals can be reviewed and evaluated. These final steps, that is, individual proposals, draft EIS preparation, public hearings, final EIS preparation, and permit issuance or denial, have been the subject of most of the environmental legislation discussed earlier. The earlier functions are carried out primarily to facilitate these final steps. Perhaps the best way to illustrate these final stages is to use the State of Minnesota EIS procedure as an example.

Upon the submission of a proposal for a specific mining operation, the State EQC designates a lead agency for the preparation of the EIS. The proposal is reviewed by several state agencies. At least three agencies give the proposal comprehensive review: the Department of Natural Resources, the Pollution Control Agency, and the State Planning Agency. After a draft EIS has been prepared public hearings are held on the proposal. Comments and reaction is obtained from the public sector through public hearings, after which a final EIS is prepared and distributed. On the basis of the final EIS, a decision is made on whether to approve the project and to issue or deny the necessary permits.

Finally, it should be noted that public participation is invited as a part of the governmental roles in mineral exploration and development. This public participation, which includes individuals and public interest groups has an important input into the process, from the early stage of making land available for exploration to the issuance or denial of the permits.

Summary of Government and Industry Roles

Figure 1 summarizes the general sequence of government and industry steps in mine exploration and development. Without following a sequence of this type, with continuous public involvement, it would appear that the probability of an orebody developing into a working mine would be substantially reduced. For industry, the basic procedure was originally discussed by Bailly(4) and has been updated to reflect requirements of new laws. The government roles are largely existing functions, however, with a significant change in emphasis. This shift in emphasis is particularly apparent in steps 3 through 7 dealing with land use planning and 8 through 10 dealing with the environmental analysis (particularly the Environmental Impact Statement and expanded permit requirements). Items on the summary are grouped according to approximate time frame. Government and industry roles cannot be developed into a specific sequence. Although several steps may occur simultaneously, the separation lines denote comparative time frames for a general case.

EXAMPLES OF DNR PROJECTS ILLUSTRATING GOVERNMENT ROLES

Like most other States, Minnesota has numerous laws pertaining to the exploration and development of mineral resources within its boundaries. Policy statements contained in the Minnesota Mineland Reclamation Act of 1969 describe the major elements of policy as set forth elsewhere in the statutes in relation to more specialized mining subjects.(3) This policy and regulatory authority provides for reclamation of land subjected to mining of metallic minerals, control of adverse environmental effects, preservation of natural resources, and wise land utilization while simultaneously promoting orderly development of mining, wise mining practices, and the beneficial aspects of mining. Furthermore, due consideration must be given to employment, the development of state-owned minerals and the economic benefits to mineral operators, land owners, local communities and the state.

This dual role of mineral resource management in Minnesota can be further explained by using the Department of Natural Resources as

GOVERNMENT	INDUSTRY
1) Geological and geophysical mapping through federal and state surveys.	1) Regional Appraisal(4) - locate geologic formation with high mineral potential.
2) Land is made available for exploration, on the basis of its resource potential and its natural and cultural resource value (ex. Leasing, Claims, etc.). 3) Develop potential mining models, depending on the types of orebodies that would be expected and the capabilities of the land to meet those requirements.	2) Detailed Reconnaissance(4) - locate target areas within a high mineral potential region - acquisition of land within the target area commences.
4) Develop planning techniques for the analysis of a potential mining district. 5) Pre-operational monitoring - regional data collection, necessary to determine water and land use capability, water and land use demand, socio-cultural impacts, environmental sensitivities and the character of the existing environment. This includes ongoing review of technical experiments regarding methods of processing, procedures for controlling impacts from processing techniques, and assessing impacts. 6) Determine capability of sites for mine facilities. 7) Develop an overall framework for land use planning in the potential mining district.	3) Detailed Surface Investigation of Target Area(4) - including both direct and indirect techniques such as: geologic mapping, geophysical and geochemical surveys,.etc. 4) Detailed Three Dimensional Physical Sampling of Target Area (4) - this stage generally involves all of the geologic sampling and testing necessary to determine if a mineral resource has the size, grade, processing and other characteristics necessary to make the exploration prospect an orebody. Additionally, new laws require the collection of considerable data necessary to determine, not only its economic feasibility but also the environmental and socio-cultural feasibility of a specific project.
8) Evaluate each proposal along with alternatives using the resource assessment, land use plan, specific company data and others. 9) Prepare the draft EIS: include the environmental, economic, and social impacts of the proposed project. 10) Hold public hearings on the proposed project. 11) Development the final EIS, and make a decision on the project. 12) Issue or deny necessary permits.	5) Mine Planning and Feasibility Analysis - this stage requires the development of a mining proposal. Alternatives examined should include those supplied by the agency for examination. 6) Submit the mining proposal and permit applications.
	7) Commence construction of the facilities.

ASSUMPTIONS:

1. Exploration information developed in each step warrants progression to the next step.
2. Although several steps may occur simultaneously, the separation lines denote comparative time frame for a general case.
3. Public involvement occurs throughout the entire sequence.

Fig. 1 Government and Industry Roles in Mineral Exploration and Development.

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an example. The Department is trustee for state and county owned mineral rights and in this capacity leases land for the purpose of exploration and mining. At the same time, however, it must administer through a permit system the mineland reclamation program, appropriation and disturbance of public waters, and utility crossings of public waters.

In order to illustrate the Department's various roles in mineral resource management three examples will be presented. The first example deals with the Copper-Nickel Leasing Program and illustrates a technique to 1) determine which lands should be offered for mineral exploration, 2) which ones should be explored only after special environmental considerations have been made and 3) those lands where exploration should not be allowed. A second example involves a computer assessment of land use capability and mine facility sites, plus a means of testing a mining proposal within the framework of an overall mining district. The third example illustrates a scoring technique for evaluating a series of alternative tailings disposal sites to determine which sites would result in the least environmental damage. While the last two examples relate to mining problems, the techniques utilized could be equally applicable to other major development projects.

Northern Minnesota Copper-Nickel Leasing Study

The mining industry has expressed concern that sufficient lands continue to be available for mineral exploration. On the other hand, public interest groups have expressed a legitimate concern that undue damage can result from mineral exploration, particularly in areas of high environmental sensitivity. To satisfy both concerns, a means of evaluating lands of mineral potential had to be devised. It was impossible to develop an environmental assessment of each individual tract of land to be offered for leasing, (the state owns or administers in excess of 10 million acres of mineral rights), therefore, an overlay technique was developed that could be used to screen out highly sensitive areas. This is a technique whereby clear acetate data maps are prepared. Several of these data variables can then be overlayed and the observer can get a feeling for the relationships between the overlayed characteristics. Generally, darker areas on the map represent higher environmental values than do lighter areas. Data was compiled for this study in the following resource areas:

Soils
Water Resources
Depth of Overburden
Forest Types
Geology
Mineral Resources
Exploration Leasing Data
Historical, Archeological, and Geomorphic Features
State and Federal Management Areas

This information is then used to determine which lands should be offered for leasing with the normal environmental constraints as contained in the Copper-Nickel Rules and Regulations, which lands require special environmental consideration, and which lands should not be offered. In the 1973 lease sale, this method was utilized. Thirty-eight tracts of land were removed and 67 tracts were leased, but with special constraints. These tracts do not represent a large percentage of the total land offered for lease (less than 1% of the total acreage offered). However, the overlay technique did provide an effective means of screening out those areas of particular environmental concern and these areas were not offered for lease.

"MINESITE" Study

The second example, the "MINESITE" study, is we feel, the most interesting and unique planning project ever undertaken in relation to mining. The Duluth Gabbro Formation, located in Northeastern Minnesota, is known to contain a major copper-nickel resource.(5,6) Although this is primarily a copper resource, it contains enough nickel to be considered one of the largest potential sources of nickel in the United States.(7,8) The area involved is also under growing pressure for alternative land uses and is extremely sensitive to environmental damage.

The area of primary interest, as shown in Figure 2, (contained within the "MINESITE" study area) is along the footwall of the Duluth

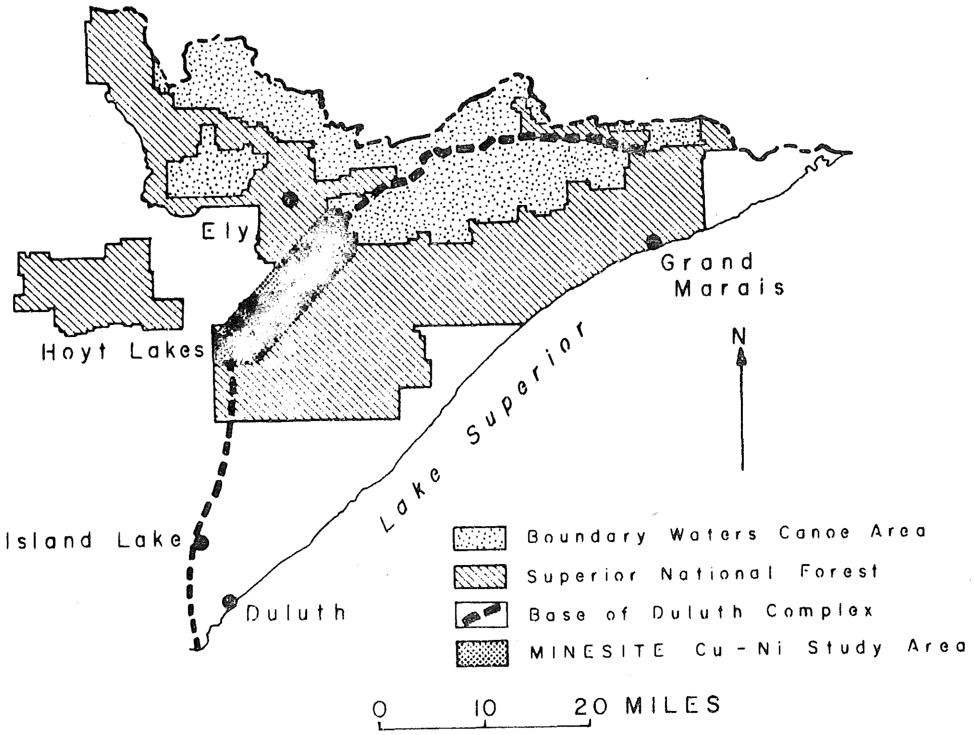


Fig. 2 "MINESITE" Study Area

Complex and runs from Hoyt Lakes to the Boundary Waters Canoe Area (BWCA) southeast of Ely, Minnesota. Extensive exploration has occurred in this area and two companies are presently considering development. The prime mineral potential area is located within the Superior National Forest, where existing land uses are recreation, (including hunting, canoeing, fishing, camping, hiking and scenic beauty), forest products (primarily pulpwood) and iron mining in several portions of the forest. The area is also environmentally sensitive; streams in the northern portion of the area flow directly into the BWCA (a part of the National Wilderness System), the lakes are primarily filled rock basins, and the soils are generally shallow or non-existent.

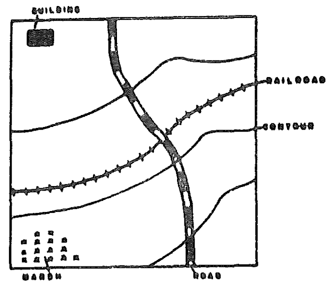
For this planning study, a computer technique, Environmental Planning Program Language (EPPL)(9), is being utilized. The study area, as shown in Figure 2, is composed of portions of 25 townships and contains approximately 635 square miles. The purpose of the study is to develop a technique which is capable of combining the existing land uses and environmental concerns into a framework that can be used to evaluate the effects of introducing a new industry, that of copper-nickel mining, into this dynamic environment. Recognizing that any change results in some impact, the objective would be to minimize negative environmental effects and land use conflicts and develop a framework for evaluating individual project proposals.

The general procedure followed, along with details of how the analysis techniques are utilized is the subject of a previous paper(10). Therefore, an abbreviated procedure will be presented here. Data is being collected for twenty-two variables. A list of these is shown in the first column of Figure 5. This data is being collected from a number of sources including USGS quads, Superior National Forest surveys, DNR data, and a number of contracts to develop specific surveys such as water availability and vegetation.

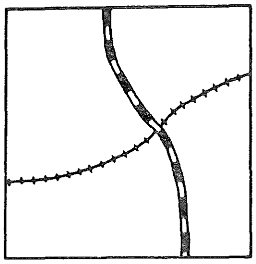
After data variables have been determined and information collected, the next step is computerization. Figure 3 is a generalized flow chart showing how the data is computerized. The next step is data verification. Since the results are only as good as the data utilized, the accuracy of the data collection, plotting and verification steps is extremely important.

The next step, data analysis, is undoubtedly the most interesting portion of the study. The analysis is made up of three sequential steps, regional assessment, land use plan and project evaluation. The regional assessment phase is designed to evaluate "the state of the land" in the study area and its capabilities. This assessment involves taking the original data and developing a series of environmental sensitivities, land use capabilities, feasible mine facility sites and the mineral resource potential.

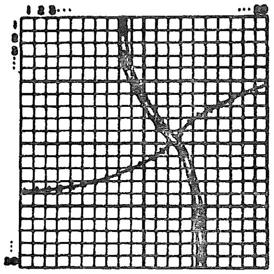
After completion of the capability assessment, a land use plan is



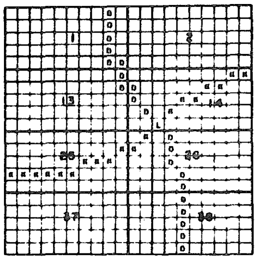
1. EXISTING DATA SOURCE (USGS Map)
Existing sources containing resource data (e.g. topographic maps, soil maps, plat maps, and aerial photographs) are assembled.



2. RESOURCE INVENTORY MAP (Transportation and Utilities)
A resource variable is obtained from an existing inventory map or data is transferred from a source to a base map of the study area.



3. GRID OVERLAY (20 rows and 20 columns = 400 cells)
The resource inventory map is overlaid with a transparent grid. Each cell is 100 meters on a side and contains approximately 2½ acres.

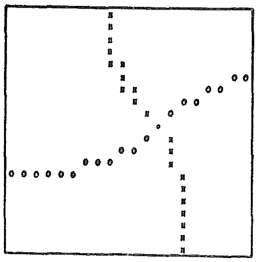


4. CODING FORM
D = Hard Surface - medium duty (good) road
K = Railroads
L = Railroads Adjacent to Road

Project personnel interpret the resource inventory map. The data value of the dominent category in each cell is entered on a coding form. For example, the first cell in row 14 is assigned the data value K. This represents a railroad as the mode of transportation occupying a portion of the cell.

5. DATA TRANSFER AND KEYPUNCHING
Data values are transfered to forms from which computer cards can be keypunched. A special shorthand transfer form was developed so that data can be transferred either as individual cells or, where the data is uniform, groups of cells.

6. COMPUTER INPUT - OPERATION - OUTPUT
(card reader to computer to printer)
The data cards are read into the computer (input). The data is stored and processed in the computer and a computer printed resource inventory map is produced (output).



7. COMPUTER MAP D = X K = O L = o
The computer map displays the resource base of a study area as it can be input into a computer for subsequent analysis.

Fig. 3 "MINESITE" Data Preparation

developed. The land use plan attempts to minimize environmental effects, land use conflicts and ownership conflicts, while at the same time maximizing compatible land uses and providing for mine facility site alternatives.

The last phase of the analysis is to evaluate a specific project proposal on a regional basis. The project evaluation phase looks back at the land use plan and the resource assessment to determine how well a project fits in with the other land uses in the area as well as the capability of the land for the proposed use.

From this very short description of the overall analysis procedure, the process appears very complicated. However, if each step is taken individually, the procedure is greatly simplified. Figure 4 illustrates the computer modeling technique for an example from the resource assessment phase. Each of these individual resource models is then combined with related models. The resource assessment stage is illustrated in Figure 5. Column 2 consists of titles for each resource map in the land use and environmental assessment areas. These are then combined in columns 3 and 4 as composite maps.

Reserve/Norshore Study

The third example deals with alternative on-land disposal sites in the vicinity of Reserve Mining Company's Silver Bay taconite processing facility. The purpose of this study was not to endorse a specific disposal site, but rather to prepare an environmental assessment that could then be incorporated into the economic analysis of tailings disposal sites. Four sites were evaluated.

The basic study involved a four-step procedure as follows:

1. Determine the major environmental and land use factors to be evaluated.
2. Select an interdisciplinary team to collect and review data requirements and evaluate resource factors.
3. Obtain available data, conduct field investigations and collect additional information.
4. Prepare resource data for analysis and presentation.

An overlay mapping system was developed and data was compiled for each variable. Two analysis matrices were then developed to evaluate and summarize the data. Figure 6 consists of the Impact Evaluation Matrix, which illustrates the gross and relative impacts of each proposal on the physical and cultural environments.

Under each tailings disposal plan are two columns of numbers. The left column of numbers represents the gross impact a proposal would have on each environmental component, such as number of acres of a particular component which would be destroyed by that particular proposal. The right hand column of numbers, those which appear in boxes, represent the impact unit assigned to each gross impact. The proposal that would produce the greatest gross impact on an

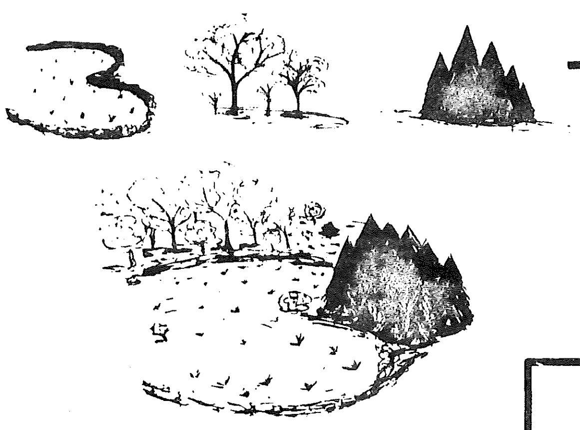
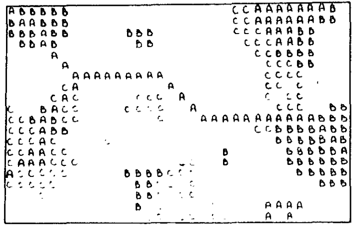
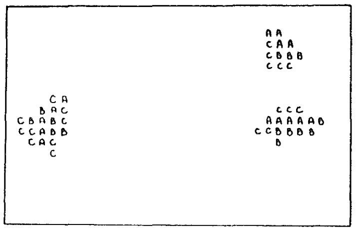
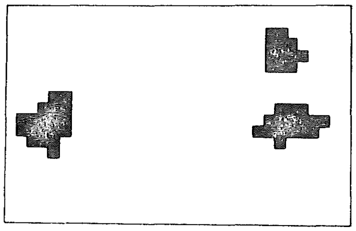
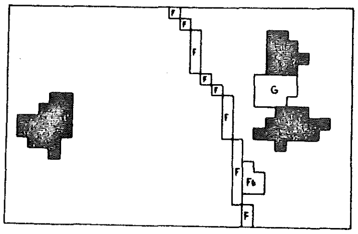
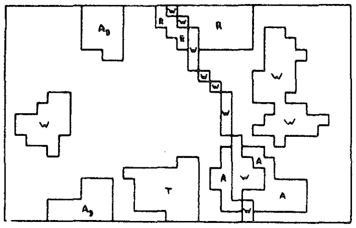
	GENERAL ANALYSIS	EXAMPLE
	1. Model Development Meet with resource specialists to determine essential requirements and how they should be evaluated.	1. Deer Habitat Model Essential Requirements 1. Forest Openings 2. Deciduous Cover 3. Conifer Cover Best habitat is a diversity of vegetation characteristics (species, age and density).
	2. Computer Model Simulation Analysis Techniques 1. Scoring 2. Flow or Logic 3. Process 4. Search 5. Cluster 6. View	2. Computer Model a. Group each essential requirement using a logic technique b. Search and cluster
 	3. Create a Series of Intermediate Maps These maps draw together the essential requirements through the use of computer techniques in order to obtain the model developed.	3. Intermediate Maps a. Composite of essential requirements A = Forest Opening B = Deciduous Cover C = Conifer Cover b. Search and cluster into small groups with all three essential requirements represented.
	4. Final Intermediate Map In Column 2 of Figure 5 map titles for each area of specific interest are shown.	4. Deer Habitat Map A printout of small clusters of areas suitable for Deer Habitat. SHADED = Deer Habitat
	5. Composite Maps Intermediate maps shown similar information are composited. In column 3 of Figure 5 initial composite map titles are shown.	5. Wildlife Habitat Map The Deer Habitat is combined with Furbearer, Fish and Grouse Habitat to form a composite of Wildlife Habitat. F = Fish Habitat (River or Lake) G = Grouse Habitat Fb = Furbearer Habitat SHADED = Deer Habitat
	6. Final Composite In column 4 of Figure 5 the final map is a combination of the composite maps necessary for a specific assessment.	6. Land Use Capability Map Wildlife Habitat is combined with Aesthetics, Recreation, Timber Production, and Agriculture and Urban composite maps to form a resource assessment of Land Use Capability A = Aesthetics R = Recreation W = Wildlife Habitat T = Timber Production Ag = Agriculture

Fig. 4 "MINESITE" Example Data Analysis

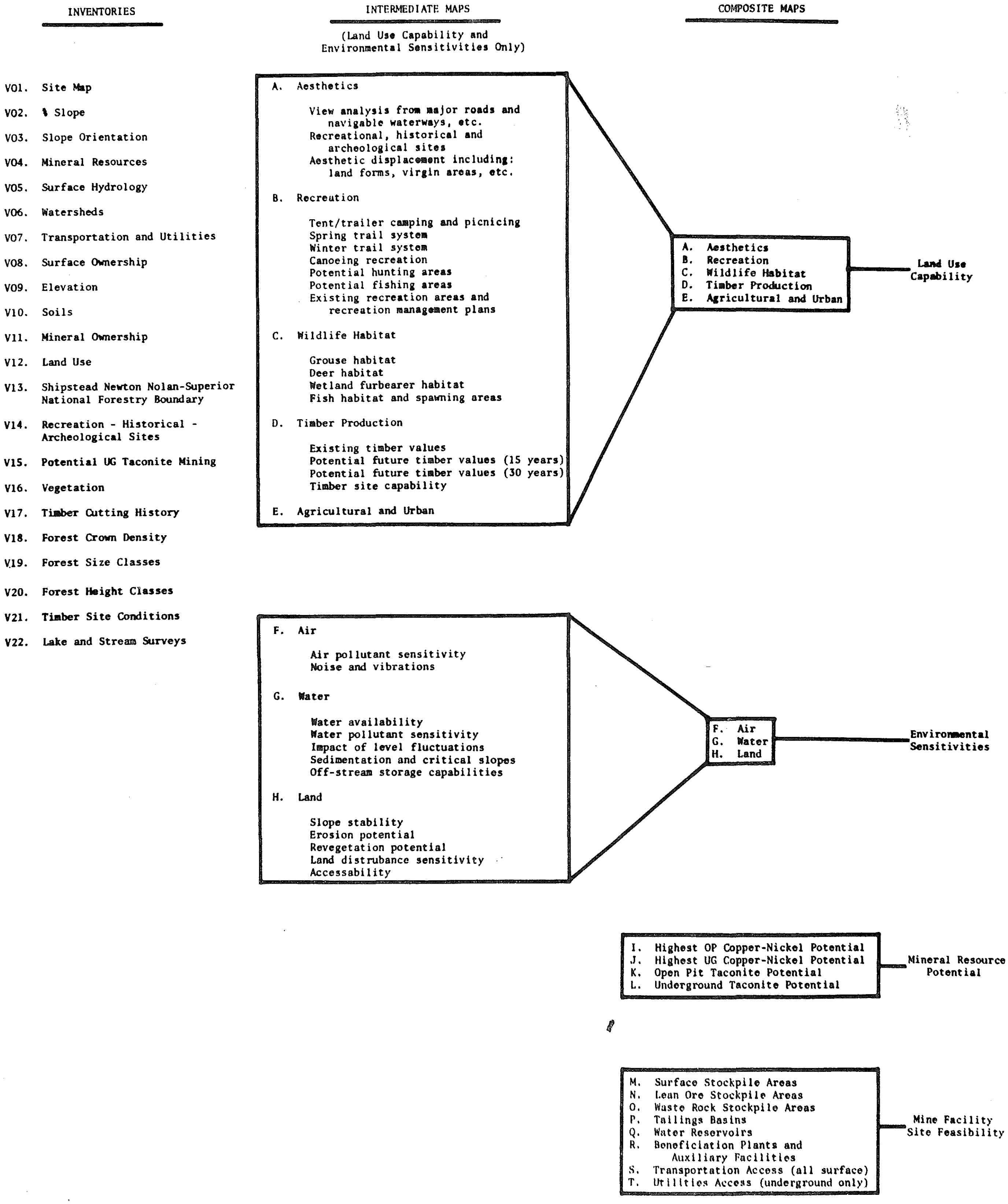


Fig. 5 "MINESITE" Resource Assessment Phase

environmental component is assigned an impact unit of 1.00. The corresponding gross impact of each of the other proposals is then figured as a percentage of the greatest gross impact, and is assigned the appropriate impact unit value. This assignment of impact units to gross impacts is a technique by which corresponding impacts of the four proposals can be comparatively quantified and ranked. For example, the Weston proposal would destroy 1,031 acres of lowland

CATEGORY	COMPONENT	MEASURE	PALISADE		WESTON		DNR		#3	
WATER SYSTEMS	Intermittent Streams	Miles destroyed or affected	2.6	.32	8.0	1.0	7.6	.93	5.3	.65
	Permanent Streams	Miles destroyed or affected	3.4	.12	27.8	1.0	11.2	.40	10.4	.37
	Lakes	Acres destroyed	225	1.0	0	0	0	0	0	0
	Watershed Flow: Beaver	% change in avg. flow	0	0	-45.0	1.0	-8.0	.18	-6.0	.13
	Watershed Flow: Palisade	% change in avg. flow	-75.0	.12	+642.0	1.0	0	0	0	0
	Contributing Surface Runoff Area	% of impoundment surface	23	.36	64	1.0	36	.56	42	.66
				1.92		5.0		2.07		1.81
VEGETATION	Lowland Conifers	Acres destroyed	59	.05	1031	1.0	1025	.99	1001	.97
	Upland Conifers	Acres destroyed	222	1.0	176	.79	80	.36	80	.36
	Aspen-Mixed Hardwood	Acres destroyed	2099	.64	3300	1.0	2555	.77	1730	.52
				1.69		2.79		2.12		1.85
HABITAT	Upland Game	Acres destroyed	0	0	32	1.0	32	1.0	32	1.0
	Designated Trout Stream	Miles destroyed or affected	4.6	.25	18.3	1.0	4.8	.26	4.8	.26
	Non-designated Stream	Miles destroyed	1.5	.41	3.7	1.0	2.0	.54	2.0	.54
	Lake	Acres destroyed	225	1.0	0	0	0	0	0	0
				1.66		3.0		1.80		1.80
UNIQUE NATURAL FEATURES	Unique Lakes	Acres destroyed	225	1.0	0	0	0	0	0	0
	Waterfalls	Number destroyed	1	1.0	1	1.0	1	1.0	1	1.0
	Unique Landforms	Acres destroyed	662	1.0	376	.57	264	.40	227	.34
	Vista Points	Number destroyed	3	1.0	1	.33	0	0	0	0
				4.0		1.90		1.40		1.34
TOPOGRAPHY	Bluffs	Inundated acres not used for confinement	425	1.0	291	.68	123	.29	123	.29

Fig. 6 "Reserve/Norshore" Impact Evaluation Matrix (Natural Environment)

CATEGORY	COMPONENT	MEASURE	PALISADE		WESTON		DNR		#3	
RECREATION	Scenic Highway	Miles destroyed	0	0	0	0	0	0	0	0
	Existing Recreational Area	Acres destroyed	150	1.0	0	0	0	0	0	0
	Potential Recreational Area	Acres destroyed	1180	1.0	0	0	0	0	0	0
				2.0		0		0		0
UNIQUE CULTURAL FEATURES	Ghost Town	Number destroyed	0	0	0	0	0	0	0	0
	Lumbering Site	Number destroyed	0	0	0	0	0	0	0	0
	Mining Site	Number destroyed	0	0	0	0	0	0	0	0
	Indian Site	Number destroyed	0	0	0	0	0	0	0	0
				0		0		0		0
VISUAL ANALYSIS	Urban Area	Acres with view of dam	459	1.0	0	0	0	0	0	0
	Recreational Area	Acres with view of dam	290	1.0	0	0	0	0	0	0
				2.0		0		0		0
NOISE	Recreational Area	Acres exposed to over 70 dBA	24	1.0	0	0	0	0	0	0
		Acres exposed to over 65 dBA	73		0	0	0	0	0	0
	Urban Area	Acres exposed to over 70 dBA	29	1.0	0	0	0	0	0	0
		Acres exposed to over 65 dBA	87		0	0	0	0	0	0
				2.0		0		0		0
TRANSPORTATION/ URBAN AREAS	Roads	Miles displaced	0	0	2.1	1.0	0	0	0	0
	Existing Urban	Acres displaced	11	.34	32	1.0	0	0	0	0
	Potential Urban	Acres displaced	53	1.0	0	0	0	0	0	0
				1.34		2.0		0		0
OWNERSHIP	State	Acres taken	34	.03	992	1.0	512	.52	406	.41
	County	Acres taken	1320	1.0	1286	.97	1188	.90	678	.51
	Village	Acres taken	502	1.0	0	0	0	0	0	0
	Small Business Admin.	Acres taken	67	1.0	0	0	0	0	0	0
	Private	Acres taken	875	.86	1023	1.0	415	.41	415	.41
				3.89		2.97		1.83		1.33

Fig. 6 "Reserve/Norshore" Impact Evaluation Matrix (Cultural Environment) conifers. Since this is greater than the number of acres which would be destroyed by the Palisade, DNR, or #3 proposals, the Weston figure was assigned an impact unit value of 1.00. The DNR proposal would destroy 1,025 acres of lowland conifers. Since 1,025 is 99% of 1,031, the DNR impact unit for lowland conifers is .99. The impact units of each proposal have been totaled for each category of components. For example, the sum of the impact units of the Palisade proposal relating to "Unique Natural Features" is 4.0, while the impact unit totals of the Weston, DNR and #3 proposals for "Unique Natural Features" are 1.90, 1.40 and 1.34, respectively. The impact unit totals are relative to one another within each category.

In order to arrive at a comparative measure for the total environmental impact of the four tailings basin proposals, a method using the relative values from the Impact Evaluation Matrix was developed. Figure 7 illustrates the Impact Summary Matrix. An impact level, low, medium, or high was assigned to the impact for each proposal from each resource category. The level of impact was assigned on the basis of the impact unit totals that were generated with the Impact Evaluation Matrix.

In each resource category, the impact unit total corresponding to the four impoundment proposals were averaged. If the impact unit

key: IMPACTS

-2 ● **HIGH**

-1 ◒ **MODERATE**

0 ○ **LOW**

	PALISADE	WESTON	DNR	#3
WATER SYSTEMS	◒	●	◒	◒
VEGETATION	◒	●	●	◒
HABITAT	◒	●	◒	◒
UNIQUE NATURAL	●	◒	◒	◒
TOPOGRAPHY	●	●	◒	◒
RECREATION	●	○	○	○
UNIQUE CULTURAL	○	○	○	○
VISUAL ANALYSIS	●	○	○	○
NOISE	●	○	○	○
TRANSPORTATION-URBAN	●	●	○	○
OWNERSHIP	●	●	◒	◒
IMPACT SUMMARY SCORE	-17	-13	-7	-6

Fig. 7 "Reserve/Norshore" Impact Summary Matrix total for a proposal fell above this category average, the proposal was assigned a high level of impact. If the impact unit total fell below the average, a moderate impact was assigned. Impact unit totals of zero were assigned a low impact. For example, as shown by Figure 7, the resource category "Water Systems" encounters a high impact in the Weston proposal, and a moderate impact in the other three proposals. The Weston proposal was assigned a high impact in this case because its impact unit total was above the category average. The remaining three proposals were assigned a moderate level of impact because each of their impact unit totals fell below the category average.

After impact levels were assigned in each of the eleven resource categories, a scoring method was used to sum these impacts for each of the impoundment proposals. This was done by assigning high impacts a value of -2, moderate impacts a value of -1, and low impacts a value of zero. By summing, the comparative impact scores for the four proposals are: Palisade -17; Weston, -13; DNR, -7; and #3, -6.

From the data and analysis presented, the Palisade proposal would be the least desirable from an environmental standpoint. The Weston proposal would result in nearly as severe an impact. Development of the DNR or #3 sites would appear to result in considerably less environmental impact.

SUMMARY

Mineral exploration and development today is much more than simply a process of finding the ore and getting it out of the ground. The public is no longer willing to accept the mistakes of the mining industry or any other industry. New laws require that environmental and socio-cultural values be given equal importance with economic values when considering any new project. These newly acquired functions result in a major change in the traditional roles in mine planning. As is required with an economic evaluation, a systematic interdisciplinary approach must be utilized in environmental and socio-cultural analysis. Three examples have been presented to illustrate this interdisciplinary approach to mine planning. Although this type of assessment is not as far advanced as is economic analysis, cooperation and a concerted effort by both the public and industry to advance these sciences can make mineral resource planning an important tool in total resource management.

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