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EVALUATING AND PROJECTING THE IMPACT OF LARGE-SCALE COPPER MINING OPERATIONS IN SOUTHERN ARIZONA AND NORTHERN MEXICO

A Multidisciplinary Team Field Study, Observations and Analysis

Submitted to

The AID 211(d) Management Committee

by

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EVALUATING AND PROJECTING THE IMPACT OF LARGE-SCALE COPPER MINING OPERATIONS IN SOUTHERN ARIZONA AND NORTHERN MEXICO

I. Introduction

During the summer of 1975 an experimental multidisciplinary field research project was conducted by a University of Arizona faculty team. This project was funded under the auspices of the AID 211(d) grant to the University, entitled "The Arid/Semi-arid Natural Resources Program."

II. Project Background, Project Goals and Project Organization

There were two basic intentions behind the formulation of the field research project. The first intention was to develop a set of guidelines to aid in the planning of a balanced program for the development of large-scale resource extraction operations and their support facilities in arid and semi-arid countries. The utilization of a multidisciplinary team for this project was to ensure full exposure through group interaction to a wide range of concerns and value systems in the process of achieving a final balance between resource development, human amenities and safeguards for the supporting natural environments. The second intention in the project formulation was to explore some of the facets of multidisciplinary team

interaction under field conditions, both in the United States and in Mexico. The ultimate goal of the project supported by both of the primary intentions was to increase the capabilities of the University of Arizona to respond to future requests for multidisciplinary assistance from developing countries.

As a means to increasing this response capability seven faculty members were chosen from six different disciplines across the campus to participate in the project and to gain experience in the multidisciplinary concept. These members were as follows: Professor Ken Clark from the College of Architecture, Dr. Jim DeCook from Water Resources, Dr. Ken Foster from the Office of Arid Lands, Dr. Lay Gibson from Geography and Regional Development, Professor Carl Glass from Mining and Geological Engineering, Professor Fred Matter from the College of Architecture (as Team Leader), and Dr. Edward Williams from Political Science.

As a means of observing the impact of Large-Scale Resource Extraction Operations under field conditions, a study outline was developed around the life-cycle of open-pit copper mining in Arizona and Mexico. A range of sites was picked in each country illustrating; long-established mining areas and mining

Similar phases in the development cycle were compared between Arizona and Mexico with regard to natural environmental impacts and social and economic impacts on supporting communities. The scheduling of the field work was organized so that the team spent the first two weeks visiting mining sites in Arizona as a breakin period without foreign language problems. The second two weeks were then spent in Mexico with a final wrap-up period at the University in Tucson.

III. Report Organization

Throughout the field work phase of the research project, the members of the multidisciplinary team worked as a closely-knit investigative unit. All individual observations were discussed during scheduled team review sessions, and strategies were developed in the field pertaining to the organization of information for the final report format. Following this basic outline, individual reporting tasks were assigned to team members for finalization after the field work phase of the study was concluded. These individuals' reports were then collected, reviewed and edited, and a final format was devised to emphasize the individual areas of expertise through separate chapter and subheading divisions within the report. Although these divisions were utilized for purposes of order and emphasis, it was also recognized that certain sections would overlap in content. These overlaps are indicative of the interworking of the multidisciplinary team.

Within the main body of the report the first basic division of information is a narrative section discussing the major problems and potentials for achieving balanced resource extraction operations in conjunction with desirable community environments, as observed in each of the mining areas visited by the team. (See "Map of Field Operations" on the following page and Appendix B for a "Complete Schedule of the Field Operations.") This section is divided into four major parts, the first three dealing with various aspects of the community environment and the fourth, an overview of a wide variety of problems associated with the natural environment as it is impacted by large-scale copper mining operations.

Following the narrative descriptions of these areas of concern are two sets of guidelines in outline form. The first set of guidelines abstracts the major points from the narrative as an aid in pre-planning the establishment of a new resource extraction operation with supporting community facilities in an undeveloped arid or semi-arid area. The second set of guidelines deals with the problems and considerations of establishing a multidisciplinary team research project. It is based on the experiences of the present team and is intended to facilitate the workings of future field projects of a similar nature requiring close team interactions.

Map of Mining Sites Visited During Field Operations

IV. Overview of Impacts

A. The Community Environment: Land Planning and Socio-esthetic Considerations

1. The Older Mining Town: Established Before the Advent of Modern Open-Pit Mining Methods (Examples Visited: Bisbee and Clifton, Arizona)

a. Land Use Resulting from Proximity of Town and Mine

A primary characteristic of many of these early towns is the proximity of the town to the mine workings. One of the causes for this was the need for easy access for the workers from their place of residence to the job site. At the time many of the first camps were founded, transportation was limited to animal or pedestrian means along undeveloped pathways. The early mines were of the underground nature and the amount of surface ground that they affected was limited in comparison to the more recent open-pit developments. As a result many towns were built immediately adjacent to the underground mine heads.

b. Safety Considerations

With the advent of open-pit methods of mining, generally in the early 1950's in the United States, this close relationship of town to mine became more of a problem than a convenience. (Figures 1 and 2). As lower grades of ore became more economical to mine, the open-pit expanded and the town

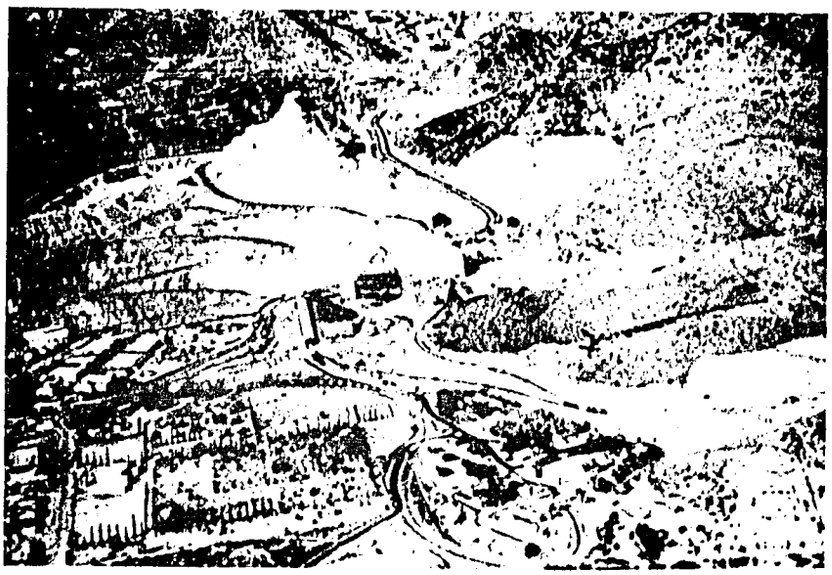

Figure 1 Bisbee and Lowell, Arizona; Lavender Open-pit Mine

Figure 2 Commercial district, Miami, Arizona

site in many cases was either moved or cut off from its natural expansion channels and transportation routes. Other negative factors also resulted from the same conflicting expansion pressures. Perhaps the most serious of these confronting towns that are still inhabited has to do with the safety of the residents from the possibility of large scale slides of waste materials. The competition for open land between town and mine frequently resulted in waste dumps and/or tailing ponds being located adjacent to or above inhabitated areas. (Figure 31) Although these dump structures have been carefully controlled in more recent years with regard to engineering safety they were objects of very little concern in the early years of mining, as evidenced by tragic examples of slide disaster from various mining regions around the world. A large part of the dump and tailing pond stability problem is associated with the possibility of water saturation resulting from prolonged rains bringing unnatural pressures to bear on the dump structures. In a semi-arid region like the southwestern United States or northern Mexico the possibilities of these occurrences are greatly reduced. Less frequency however does not alleviate severity of impact. It may in fact cause more damage being less prepared for and expected. In addition, the State of Arizona is in a moderate earthquake risk zone, the effects of which would be very hard to predict on many ancient dumping structures.

A lesser although real safety problem can also occur with the possibility of failures in the stability of the sides of the open pits or in the natural land forms that are adjacent to the pit. Some of these unstable conditions result from underground workings, especially in long abandoned areas, causing land subsidence and surface failures. In recent workings these conditions are monitored carefully and a certain degree of predictability lessens the possibilities of unexpected trouble. Constant precaution must be exercised, however, to avoid major inconvenience or worse. (Figure 26)

c. Visual Impact

Another effect of the close town-mine relationship stems from the visual impact of the mine workings on the everyday lives of the citizens. This impact takes many forms and varies considerably from individual to individual. Because of the personal nature of esthetic and psychological interrelationships, it is not easy to document in statistical terms exact responses. However, general tendencies are widely recognized and have a powerful effect on human psychology in the mining town. For this reason it is worth while to mention a few of the more obvious points. Perhaps the most startling characteristic about the workings of a modern open-pit copper mine is the gigantic scale of the earth-moving operations and the resultant man-made landscapes in the form of tailing ponds, waste dumps and the pits themselves. (Figure 3)

In the older mining town the relationship of the built-up area of the town to the gigantic residue of the mine is frequently very intimate. To the resident, a high pile of mine waste at the end of the street, or in some cases directly behind the house, is an ever-present reminder of the facts of company life. (Figure 4) In many of these towns there is no escape. The residents are employed by the company, housed by the company, they buy their supplies from the company store, go to the company hospital, and virtually live and die in the shadow of the company's waste dumps. Given the psychological mobility supplied via the electronic media in the 20th century, complete with all the illusory images of the good life for all, it is somewhat of a jarring sensation to be constantly reminded of a physical bond that dwarfs the individual by its overpowering scale. Such a continual reminder of work and of company control undoubtedly does not conform to the findings of industrial psychologists intent on improving working efficiency by means of happier employee home life. If these reminders of control are further tinged by an awareness of various forms of environmental pollution such as blowing dust, land erosion or air pollution, caused by the waste dumps, the attitude of the citizen stands an even greater chance of coming into conflict with company policies.

It would be well to point out, however, that not all the inhabitants of older mining towns share these same sentiments. It is not uncommon to find a miner who takes great pride in the

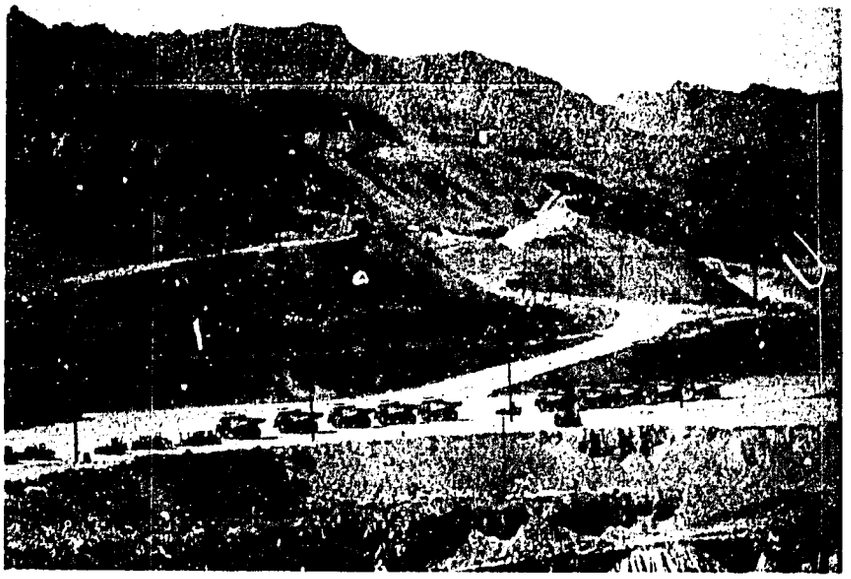

Fig. 3 Ray Mine, Kennecott Copper Company, Arizona

Fig. 4 Waste Dump and Residence, Warren, Arizona

scale of the man-made landscape, that enjoys a sense of the sheer physical power involved in the scene and that shares in the security created by being associated with that powerful force. For these people a tailing pond becomes a potentially beautiful land form and no amount of environmental disturbance can overshadow the convenience of staying close to the source of one's livelihood.

There is then, frequently, a split in an older town between the hard-core miner who has devoted his life completely to company and takes pride in it, and the younger generation of worker who needs the job but also is looking for other aspects of the good life outside of his work. A third party to this potential difference of attitude in town residents would be the independent businessman, who depends on the company payroll to stay in business but is also on the lookout for ways to establish his financial independence through expansion or attraction of outside interests to the community. From this group arises another possible conflict with the company in the area of land ownership. In order to understand this condition it is necessary to describe more completely the general physical setting of the older mining town.

d. Pressures of Physical Setting

Because of their proximity to the ore body, a majority of these towns are located in the foothills of a mountain range. In states like Arizona, New Mexico or Sonora, many of these

locations are quite remote from other significant urban settlements. The results of this combination of rough topography and remote setting are often quite striking. In general, the towns that developed before the start of the 20th century are rather chaotic in their pattern of streets and footpaths. Many of the houses are built up the sides of steep ravine walls with the major circulation paths following the natural drainage channels along the narrow valleys. (Figure 5) In some areas of these towns, as in Bisbee, Clifton or Jerome, Arizona, automobile access is an impossibility with long steep flights of stairways providing the only linkage from the upper to the lower portions.

The reasons for such a pattern of development are two-fold. The first reason is of course the natural topography. Available flat space is frequently very limited and used primarily for the location of major civic and commercial buildings. In addition, care must also be taken not to locate buildings too close to the drainage channels to protect them from flash flooding. Increased land pressures over a period of years often led to ignoring this safeguard with the eventual consequences as evidenced in Clifton, Arizona during its flood in 1974. As the original small mining town developed and new areas were needed for residential or commercial expansion, a second restraining pattern was also encountered. At the time of the foundation of the original town most of the surrounding land was bought or leased by the mining companies to safeguard

their ability to develop claims if additional ore deposits were found. Today, in an era when increasingly lower grades of ore are proving economical to mine, it is natural that the companies are not enthusiastic about releasing new ground for urban development, even when that ground is quite removed from existing deposits that are being worked. The result is a double squeeze on the urban organization, (caught between rough topography and company control of land), causing a crazy quilt of spotted developments stretched out where ever available open space can be found. In the case of Bisbee, Lowell and Warren, Arizona, partial developments are found in very close relationship to each other divided only by the mine workings or by inaccessible topographic features. The vulnerability of this type of partial settlement is further attested by the number of similar towns that have been completely removed by mining companies as their surface excavations expanded into the town site. The cost of moving the original town, as in Morenci, Arizona; Butte, Montana; or Cananea Sonora, reinforces the companies' desire to restrict future urban development in wider and wider circles from known ore bodies. (Figures 6 & 7) Thus the independent merchant seeking additional flat buildable land for commerical expansion is frequently frustrated by both topography and company land control.

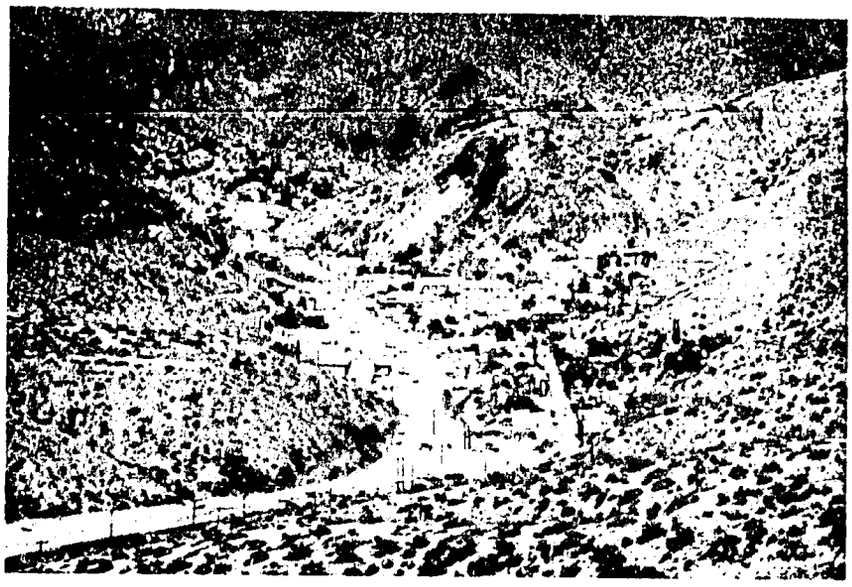

Fig. 5 Overview of Clifton, Arizona

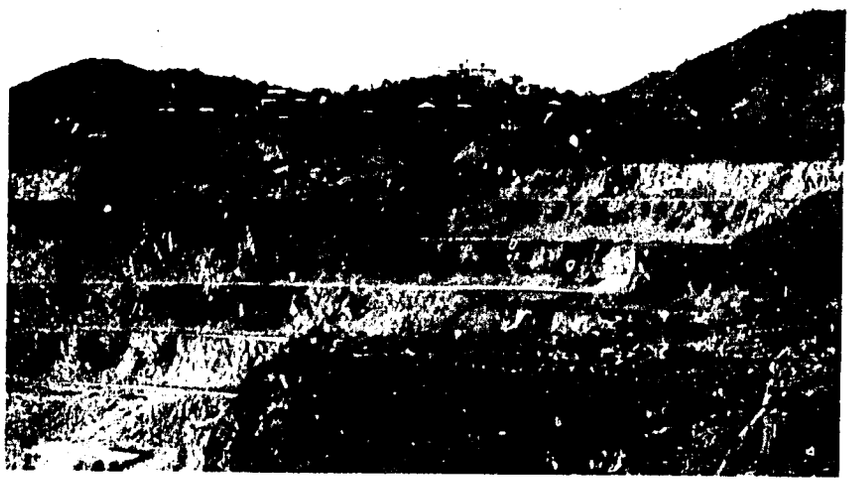

Fig. 6 View of Old Morenci and the Morenci Open Pit

Fig. 7 View of Remaining Residences in Old Morenci, Arizona.

Fig. 8 View of Central Business Area of Bisbee, Arizona

Additional competition between town and mine also can develop over water pumping rights and a variety of related environmental pollution problems. These latter potential problems are far more significant in areas where the town is economically independent of the mining company and resentful of its proximity to their chosen location. Such a case is well illustrated by the ongoing confrontation between the retirement community of Green Valley, Arizona and the adjacent mining operations in the Sierrita Range. In the case of the company town however, the mining company traditionally has aided development of an adjacent mining settlement by providing services to the municipality such as water, excess electric power from its converters or sewage disposal facilities that the community could not afford by itself. The towns of Cananea, Sonora or Santa Rosalia in Baja California serve as good examples of this type of interrelationship.

e. Picturesque Setting

The total effect of intimate town-mine physical proximity represents a mixture of good and bad effects. The following is a brief summary of some of the more interesting of these positive and negative effects observed during the field work of this study.

On the positive side, a curious outgrowth of the combination of remote location and rough topography is urban

picturesqueness. This quality of older mining towns is frequently compared to similar characteristics found in Medieval European hilltowns. (Figure 8). It is very attractive to visitors looking for something different than the automotive-dominated urban scenes of the major cities of the Southwest. Although such unusual siting qualities, as are found in Bisbee, make very interesting atmospheres for Sunday outings from Tucson; one wonders if the visual attraction is strong enough to outweigh the functional disadvantages created for fire protection or other services depending on a more accessible physical pattern.

f. Indigenous Architecture

Again, on the positive side, reinforcing the picturesque atmosphere is the unique quality of many of the individual buildings of the old mining towns. (Figure 9). The reasons for this uniqueness stem from the twin phenomena of rough topography and remote setting, causing the architecture to adapt itself to the particular characteristics of the terrain and limiting the types of building materials used in the "indigenous" architectural responses. Frequently missing are the more sophisticated 20th century methods of putting buildings together. The steel frame and glass curtain walls that have impregnated the less-remote towns of the region are clearily overshadowed in the typical old mining town by a pervasive handmade image. Buildings of wood and of unit

masonry attest to the skills of the resident work force and further reinforce the feeling of "local color" missing in many of the larger cities of the area.

g. Compactness

Another architectural response to local conditions that enhances the charm and the human characteristics of these towns has to do with the compactness of the central urbanized area. Within the confines of land available for building, the pressures for expansion over the years have caused the development of central areas that are quite dense. Older mining towns are frequently pedestrian towns. A walk through central Bisbee, Arizona reveals more level changes, more changing vistas and more visual excitement than can be found in most spread-out suburbanized desert cities. Compactness, indigenous architecture, security of place, social cohesion, pedestrian circulation -- these qualities sound like a typical description of a small 19th century town. Perhaps this analogy is not unrealistic. There is yet another side to the same picture, however, that counteracts the romantic image described thus far.

h. Social and Physical Decay

Isolation, lack of mobility and lack of exposure to outside influences also breed some negative responses on the part of the contained citizenery. High incidences of

alcoholism and divorce attest to the boredom generated in an inward-turned society. The number of bars and clubs in an older mining town offers a variety of excitement to the visitor but also suggests a more serious need for fulfillment on the part of the permanent resident. Part of this need can be directly related to the nature of working conditions in an older mining area. Mining has traditionally been a hard way of life. Exposure to risk, to harsh natural elements and to physical exertion all characterize the miner's job. Naturally, therefore, his needs for release from his labors and his working environment, being frustrated in the immediate physical surroundings, are more easily satisfied through a substitute form of escape. Interlaced then with this romantic image of setting as viewed by the visitor there is also frequently evident an underlying aspect of decay. Many older mining towns display a wide-spread lack of maintenance and a clear physical deterioration of many of their structures. It is interesting to speculate on the psychological connections between the nature of the basic operation of mining and some of these physical manifestations in the surrounding urban environment. A connection has been suggested, although never documented by testing, between the concept of an ore body gradually being removed from the earth never to be replaced or replenished, and the attitude of the miner, also foreseeing a limited duration of stay in one location, toward his physical surroundings. Older mining towns are boom and bust towns and the

western part of the United States is full of once thriving communities now ghost relics of the glory days. The sure knowledge of this eventuality undoubtedly plays a large part in the carelessness toward long-term concerns on the mining frontier. (Figure 10)

i. Community Survival

This condition is not, however, as simple as the pure frontier mentality of exploitation and moving on without worrying about what is left behind. In spite of the depletive nature of the ore deposit, a considerable measure of permanence is frequently built-up in the traditional mining town, particularly when the ore body has lasted over several succeeding generations of mining families working the area. Perhaps because of the intense nature of the work, mining seems to stay in families, passing from father to son over a number of generations.

Other factors also contribute to this phenomenon, including education, remote location and high minority representation among the work force. Over a period of of years mining camps develop into stable communities with a developed structure of social and ethnic hierarchies. The climax of this rather inward turned continuous quality of the community comes when the mine is no longer expanding and the work force feels the impact of a predictable number of days left on the company payroll. When the end is in sight, the paternal structure of the quality mining company provides for

Fig. 9 Buildings Along Brewery Gulch, Bisbee, Arizona.

Fig. 10 Residential Street in Warren, Arizona.

as many transfers of workers to new areas as is economically possible. It is not an easy time, however, and many are left by necessity or by choice to try to make do in the old community without the guaranteed payroll.

The final days of a long-established mining operation and its effect on community attitudes would provide interesting material for a number of sociological studies. Based on the limited observation time allowed in this study a few clear tendencies were apparent in the case of Bisbee, Arizona. Bisbee is a current example of a mining town confronted with a complete withdrawal of a long-term mining operation of considerable magnitude. In spite of the well-publicized intentions of the mining company and their considerable efforts in worker relocation, a persistent myth survives. Even though the mine is completely shut-down the citizens continue to believe that the former days of economic security will be revived by reopened or newly discovered ore deposits. This myth is symptomatic of a community structure that has been dependent on company patronage for so long that it has great difficulty planning ahead on an independent basis. With rather dreary survival issues at stake for many of the community's population, the most imaginative kinds of schemes are being discussed for future income production. These schemes propose to draw heavily on tourist attractions and other leisure-time activities, hoping all the while for a quick revival of the guardian angel mining economy. (Figure 11). In the face of a very probable prognosis of further economic decay and dislocation

it is interesting to discover that the community leaders remain quite loyal to the mining company, admitting readily that they were given warnings well in advance of the close-down date. In this type of a community it is quite possible that the older population will remain, supported by adequate retirement income from the company, while the younger, more mobile group will eventually have to find another setting for their productive years. Thus, once the primary dislocation has occurred, immediate to the closing of the mine, a period of relative stability will develop allowing the community to search for other means of long-term support before a secondary period of slower decay will begin to show its effects.

2. Pre-planned New Town Developments in Mining Communities (Examples Visited: Kearny, Arizona; Morenci, Arizona; Las Playas, New Mexico)

If the overall picture of a traditional mining town in the Southwest presents a blended picture of exciting human urban settings shadowed in places by evidence of decay and environmental deterioration, the various aspects of the physical environment of a new company mining town are no less contradictory. Included in the field work of this study were trips to three complete new company towns built by the mining companies for their workers. These were the communities of Kearny and Morenci in Arizona and Las Playas in New Mexico. The first of these settlements was sponsored by the Kennecott Corporation while the latter two were built by the Phelps Dodge Corporation.

a. Location

Although there are significant differences in the development of each of these communities, there are also some interesting similarities. In the case of both Kearny and Las Playas one of the primary criteria determining the location of the community was its removal from the immediate environs of the operating mine or smelter. In the case of Las Playas, the necessary distance was determined to be ten miles, far enough from the smelter that only the tip of the stack is visible from the town center. (Figure 12) This serves as a faint but ever-present reminder of the source of the town's livelihood. The distance is not too great to cause a serious inconvenience for the worker traveling between home and work. In the case of Kearny, the town is situated on the side of a river valley with gently sloping topography to the south and a view of the Gila River. The location is spaced between the Ray Division mining operations and a collection of smelters in the nearby towns of Hayden and Winkelman. Again, the spacing is just enough that the ever-present reminder of the mining operations is obscured from immediate view. A short trip in either direction, however, brings a quick reinforcement of the economic realities of the area. In the case of Morenci, Arizona a very different condition is present. The mine and the smelter at Morenci-Metcalf are situated at approximately 4,300 feet above sea level, in moderately rough

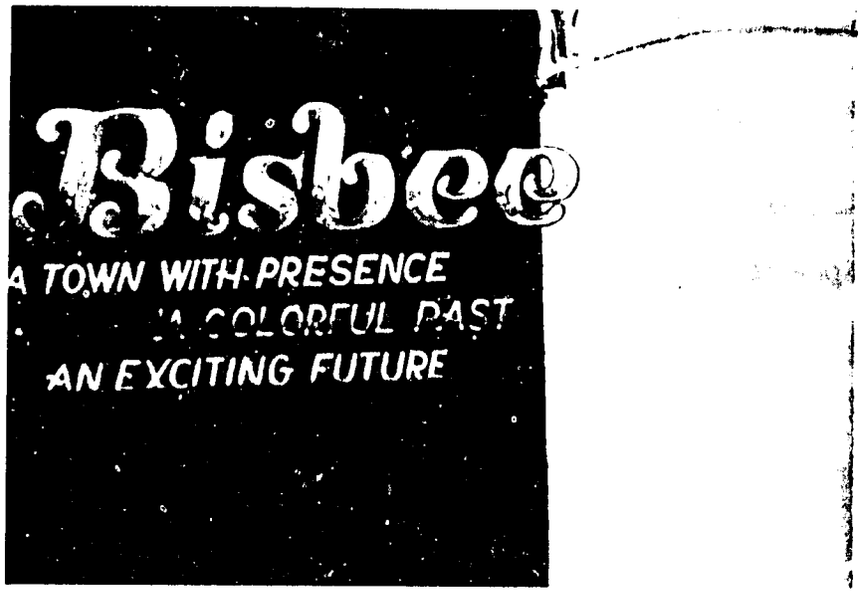

Fig. 11 Bisbee, A Town with Presence, A Colorful Past, An Exciting Future. Chamber of Commerce Sign on Edge of Lavender Pit.

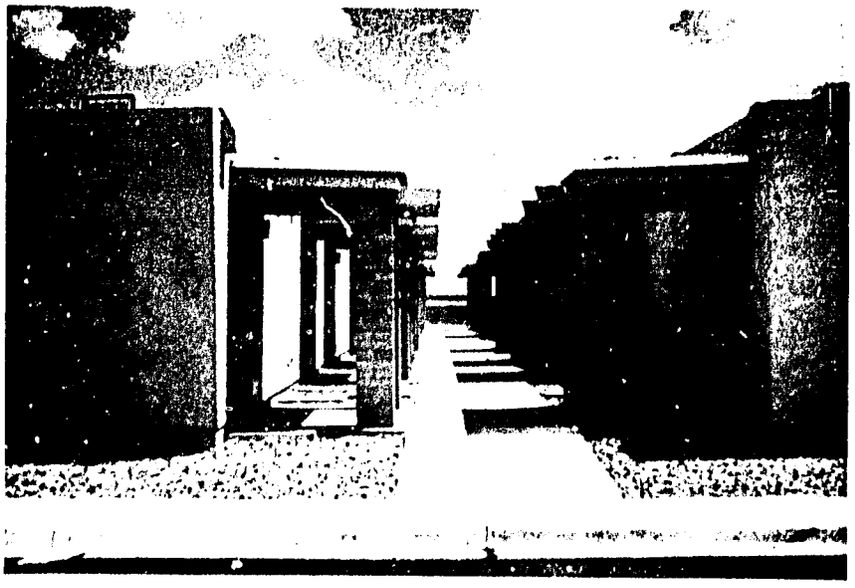

Fig. 12 New Apartments in Las Playas, New Mexico. Smelter Stack Framed at End of Vista 10 Miles Distant.

foothill topography, three miles from the older mining town of Clifton in the valley below.

Perhaps because the existing town of Clifton was in a state of partial decay, or perhaps because of land ownership problems, a decision was made by Phelps Dodge to locate the new community immediately adjacent to the plant site on the higher elevation. In fact, the central part of this new community, appropriately called Plantsite, is constructed on top of an abandoned tailing pond. (Figures 24, 25 & 26) Great care was taken by the company to landscape the areas immediately surrounding the new community and provide for a number of community facilities, in addition to housing, on the immediate site. The result is a new company town tucked into the ravines and on the hillsides directly adjacent to the mining operations, but shielded from the worst aspects of its disruptive qualities.

b. Company Management

All three of these towns manifest the clear-cut characteristics of a completely pre-planned community constructed over a relatively short period of time. Gone are the picturesque qualities of the old-time mining town with its dense central setting, its haphazard accommodation of topographical variations and its do-it-yourself building types. In their place are rationally laid-out street patterns, carefully graded building sites and selected flat open spaces for central community services. (Figure 13) Maintenance is better, clutter virtually outlawed

and a well-developed image of middle-class prosperity is cultivated. The advantages of such a development are numerous. The major community services, such as water, sewer, etc., are frequently subsidized if not paid outright by the company. The availability of a large amount of capital provided in the initial stages of construction means that a moderately complete town with at least a minimum of amenities can be provided from the start. In the cases of Morenci and Las Playas, totally owned company towns, highly subsidized housing is rented to the workers on a very short-term lease basis. All maintenance is company supplied. All shopping, recreation and service facilities are company owned.

c. Independent Management

In the case of Kearny, a somewhat different setup is used. An independent management firm was hired by the company to develop and run the town, backed with the financial security of company-provided mortgage funds. Individuals are allowed to buy their own homes and outsiders are welcome to settle in the town. Kearny has its own governmental structure. However, the management firm keeps strict control of the main shopping center. The problem of competition is virtually eliminated by a combination of remoteness of setting and tight ownership control of the land surrounding the town by the mining companies. Thus, to a lesser degree in Kearny than in Las Playas or Morenci, but still prevalent, is the

psychological reinforcement of both the security and the limitations of company control. Whether one argues the positive or the negative aspects of this psychology on the sociology of the community, the mental impact is not a consideration in the motivation of the company town concept. Most mining companies would rather not be in the development business. However, in an age of instantaneous need for inhabitable settlements, to accommodate large groups of mobile workers brought to new sites for mineral extraction, the alternatives are few. If the company does not fulfill the need, the enticement of private capital to a remote and undeveloped setting would be a drawn-out procedure causing all the inconveniences of an early day mining camp. Such an alternative is probably no longer acceptable to a 20th century worker.

Given the need, therefore, for a relatively fast-built community requiring company support, it is interesting to compare further the effect of the totally owned town concept to the independently managed arrangement. Given the impact of a fairly high degree of social isolation remaining as consistent for the new mining town as for some of the older ones, there are several additional tendencies in the totally owned company town that reinforce its inward turning characteristics. The typical new company town clearly expresses the hierarchy of the company's management in the stratification of the town's layout. Higher management personnel occupy the higher elevations of the town site. There is no over-lapping of social or economic differences.

Carefully controlled rational layouts mean similar materials, similar sizes and similar locations for each physical manifestation of the stratification of society. The ability of the miner to escape the status of his on-the-job role during his off-hours, as may have been possible in the clutter and jumble of the old mining community, has now been removed. Job status is clearly reinforced by physical community form. This tendency is not as obvious in the case of the more open and independent structure of Kearny, although natural economic stratification is, as always, present.

Another social group that seems to suffer somewhat uniquely in the new town is the teenage set. The neat, clean, orderly community leaves little room for the teenager to discover the variety of an historical urban conglomeration. In the current vernacular they have no place "to mess around," complete with all the physical implications that the term implies. Facilities providing for young peoples' needs are frequently overlooked in the capital outlay of a strictly functional town plan. In the case of Kearny this was a concern of the town's governmental body and ideas were being explored to remedy the situation.

Another interesting variation between the independently managed town and the totally company controlled type is in the handling of complaints by the citizens. The daily grievances, in the case of Kearny, are directed toward the management firm, not the mining company which is once removed from the operational scene. Kearny still suffers from many of the same problems as the totally controlled company town; citizen complaints

about lack of competition in the marketing outlets and lack of expansion space on company-controlled land to entice additional retial firms. The general reaction one hears about these problems, however, is directed toward the Galbraith Company and not Kennecott.

The situation in a Phelps Dodge town is perhaps clearer. Residents occupy their housing on a thirty-day lease system. Rents are highly subsidized and maintenance is company controlled. Company mercantiles can provide credit for company workers and many or all of the other services are also company owned. The result is a high degree of dependence by the worker on the company and a total lack of equity build-up by the individual in his private place of residence. When the worker retires from the company, he must also move from his company house. The social mix of the company town becomes, therefore, more restricted with the loss of all people of retirement age. Again, the company's intentions are well publicized in advance and the residents seem to be quite satisfied with the subsidized short-term lease situation. Perhaps the final realization for some retirees, who have failed to plan ahead during their high income days, comes only when faced with a new home purchase on a reduced income. The popularity of mobile homes and trailer parks for retired miners in Safford, Arizona, who have completed their tenure in the Morenci mines, may be partially explained by the lack of equity problem.

The final question concerning the completely company owned town has yet to be answered. That is, what happens to the physical investment when the supporting mine is eventually closed? Will the brand new town of Morenci become another southwestern ghost town? Will it simply be a tax write-off for the mining company when the last of the 30-day leases expires? Certainly it is an unusual situation when a community has no long-term roots, no life of its own to endure through changing economic scenarios. Perhaps the sure knowledge of such an ending is better than enduring the agonies of Bisbee trying to survive through the loss of its primary economic base. The decision in Morenci does not need to be faced for years to come, but when its time is due it will not be an easy matter to entice independent buyers for a community built on top of a tailing pond in a remote mountainous setting. Love for such a site can only be built gradually through the traditions and the routine of succeeding generations.

3. Impact of Renewed Mining Operations on Existing Communities with Limited Economic Bases (Examples Visited: Santa Rosalia, Baja California and Cananea, Sonora, Mexico)

Thus far two distinctly opposite types of mining communities have been discussed. They are the traditional mining town developed over the years from early camp days to fully expanded community, and the totally pre-planned packaged version of the

company town, built in a relatively short period of time. A number of other variations need to be mentioned, not as distinctly different types but as interesting mutations of the general extremes already discussed.

One such variation is the town of Santa Rosalia located in Baja California, Mexico. The history of this town is unusual and it has had a major impact on its physical characteristics. The supporting mine was developed originally by the French in the latter half of the 19th century. At that time a major portion of the supplies for the building and maintenance of the community was brought to Mexico by boat from France. The result was a French company town, in Mexico, built almost entirely of wood. (Figures 14 & 15) Subsequent political and economic events saw the town and mine change hands from French to privately owned Mexican. The final stages of change have occurred recently with the inclusion of the government in the management of the mine in an attempt to bolster the falling revenues of the company and the community. In this aspect the situation is quite different from similar cases in the United States. The Mexican government feels a strong and direct responsibility for the welfare of the town which if left to its own would probably be faced with large scale relocation. The government also has a tradition, stemming from original Spanish law, of guardianship if not outright ownership of all mining resources in the country. The action required for governmental intervention in the fate of Santa Rosalia was not, therefore, unusual.

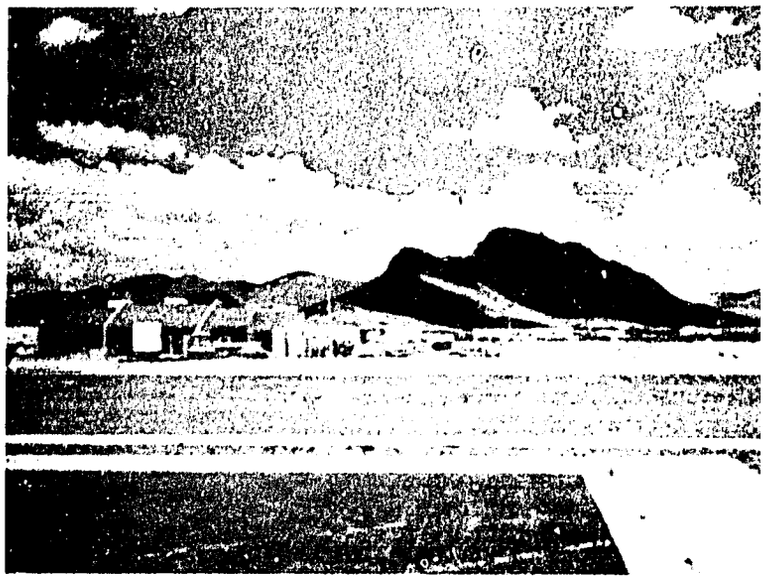

Fig. 13 New Town Center, Las Playas, New Mexico.

Fig. 14 Commercial Street with Wooden Buildings, Santa Rosalia, Baja California, Mexico.

The results are interesting although it is still too early to draw final conclusions as to the overall success of the undertaking. At the same time that new equipment is being supplied to the mines, the smelter is being rebuilt and government geologists are plotting new ore bodies. In addition, a large new section of masonry housing is under construction for the workers,to replace some of the inadequate wooden remains of the older town. Although the esthetic qualities of this new housing could be critized from both the building and the overall siting points of view, there is no question that its functional conveniences, in terms of mechanical equipment and sanitation, are considerably better than was available in the original dwellings. (Figure 16) What remains an open question is the long-term outlook for the town. If the mine revitalization is successful, how long will it last? Can other forms of industry be developed in the meantime, such as fishing or tourism, to take the place of the eventually depleted mine? Is it sometimes better to forego governmental support and let the remaining population look out for their own welfare?

Another variation on this same theme is occurring in the town of Cananea, Mexico. In this particular case the supporting mining operation is building to a major peak of activity with large-scale expansion plans in the process of being developed. At the same time a large section of new company housing is being provided for the mining workers.

Fig. 15 Mining Company Headquarters, Santa Rosalia, Mexico

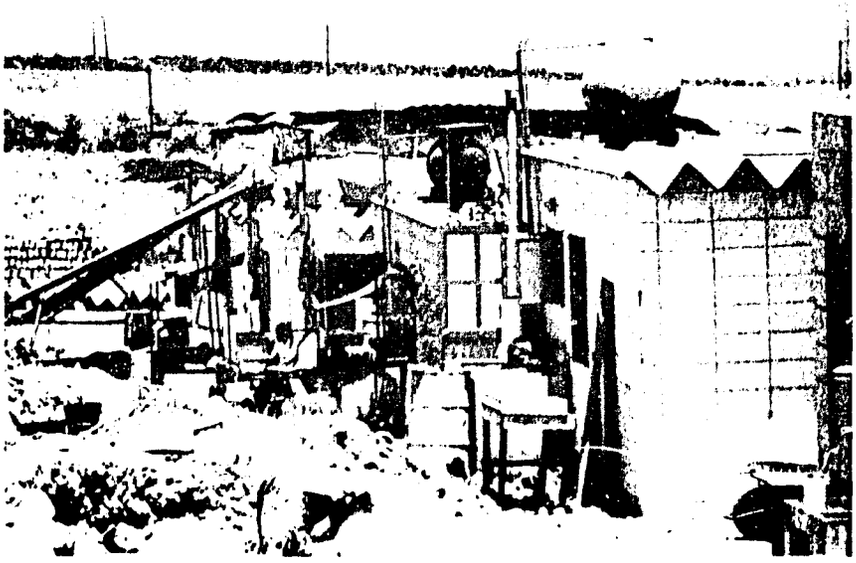

Fig. 16 New Housing, Santa Rosalia, Mexico

The town of Cananea also has a rich and varied political and eocnomic history, but it has endured the various changes to emerge with one of the highest average standards of living in the state of Sonora. The community is of course closely tied to the mining company for its economic base, but it does maintain a strong separate political organization, and it enjoys some advantage from the extra financial support of the ranching business in the area. The expansion of the mines means more income for the community. The provision of new company housing means a relatively high standard of living and services for a large number of workers. The use of local contracting for the new housing could provide extra stimulus to the town's economy. In addition, in both the cases of Santa Rosalia and Cananea, the mining companies supply benefits to the communities in the form of electrical power generation, a clean water supply and other forms of direct subsidy.

Again, in both cases, the subsidized housing promotes some ill effects as well as some good ones. The areas of the new workers' homes are set off from the older areas of the towns. The result is similar to that of federal projects in the United States. Social distinctions are obviously created by reinforcing the separation from other portions of the town. The rich density and the compact variety of the traditional Mexican town is lost within the logical pattern of a pre-planned mass-built section of new housing (Figure 17) Dependence in Mexico on a protective agency must

also have the same effect on the citizenry as dependence in the United States, it breeds lack of individual concern for the long-term future. Thus, the rising level of living standards must be considered against the very limited nature of the economic base, and questions must be asked about eventual diversification before additional government subsidy is required.

4. Impact of New Mining Operations on Existing Communities of Diverse Economic Base (Examples Visited: Green Valley and Florence, Arizona)

Another comparison considered during the field study period of the project was that of mining impacts on existing communities not dependent on the financial support of the operations. Two such cases were visited in the state of Arizona. The first of these was in the valley of the Santa Cruz River, just south of the City of Tucson, with the largest open-pit copper mining operation in the United States situated in the Sierrita Mountains above the town. This community called Green Valley, is advertised as one of the outstanding retirement locations in the country. Obviously there is no financial tie, no subsidy, no patronage linking this community and the mines. The relationship between retired people seeking quiet beautiful countryside with clean air, and mining people expanding to develop new ore bodies, is one of continual conflict. Both sources, that of retirement settlements and that

of mining operations, represent substantial income to the State of Arizona. It is both unfortunate and at the same time a monument to poor planning that two such diverse conditions could have ever developed in such close proximity. The attempts now being made to lessen or to cover up the most obvious aspects of the negative environmental conflicts are both costly to the mines and of questionable longterm value. Cosmetic surface treatment of massive-scale dumps and tailing ponds certainly lessens the immediate effects of blowing dust, but in the long-term radically different approaches will have to be taken to change these costly stop-gap procedures into self-supporting, income-producing developments. (Figures 18 & 19) Until such measures are proven effective a substantial number of conflicts will remain unsolved and a dilemma is presented to any community that faces the prospect of a similar mining development within close proximity.

Such a case is illustrated by the town of Florence, Arizona. Florence is one of the earliest American communities settled in southern Arizona. As a county seat it dates from the latter half of the 19th century. A small town of a little over 2,000 people, it has traditionally been supported by an agricultural and ranching economy, in addition to the state prison situated on its outskirts. Now it is confronted with the prospect of having a large open-pit copper mine established just a few miles beyond the edge of town. The impact of this

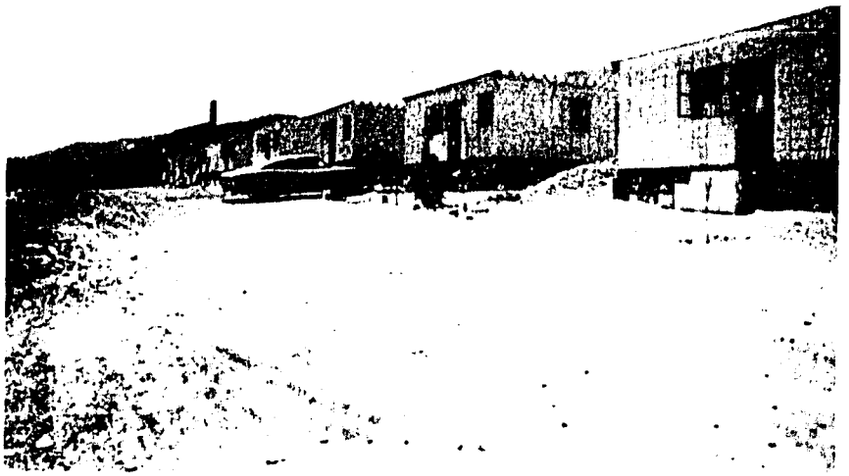

Fig. 17 New Housing Area, Santa Rosalia, Mexico. Smelter Stack in Background.

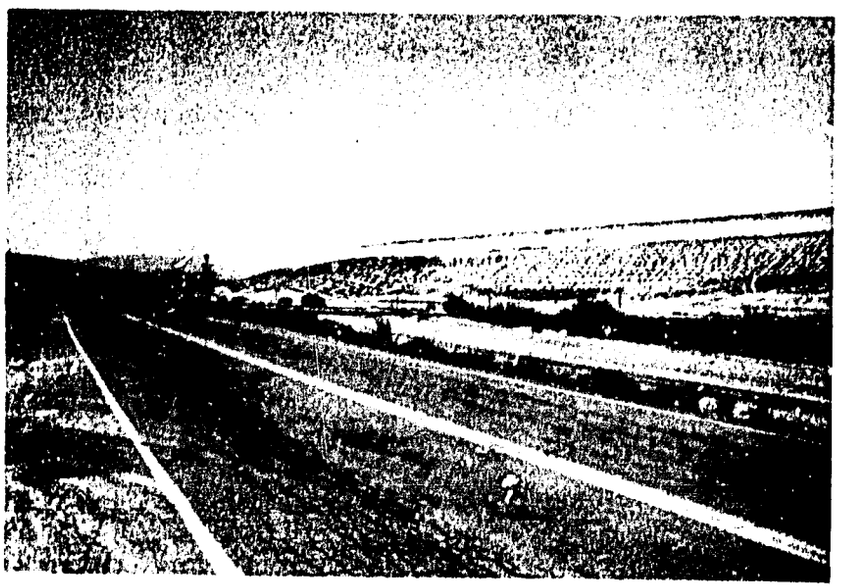

Fig. 18 Tailing Pond Revegetation, Hayden, Arizona.

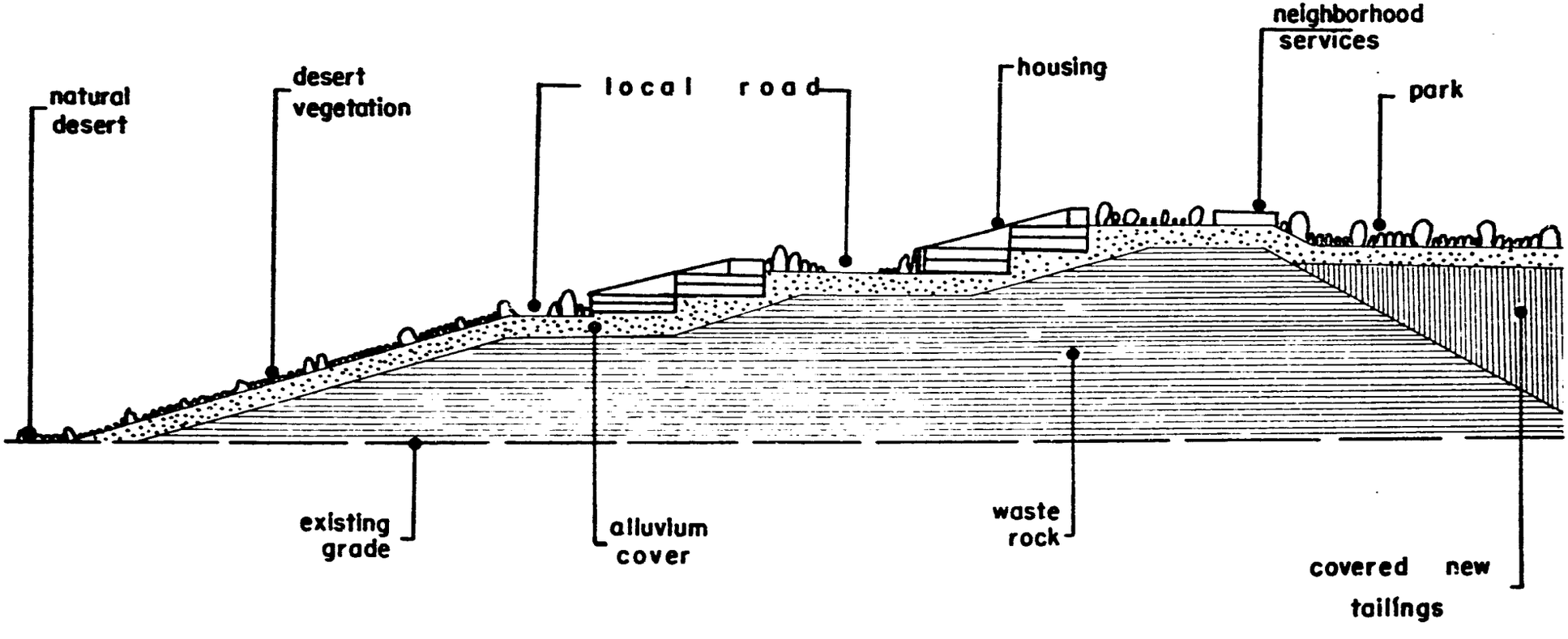

Figure 19 - Suggested Cosmetic Surface Treatments of Dump and Tailing Pond

From Clark & Matter (1974)

mine on the existing town in physical, economic and social terms will be very pronounced. The citizens are aware of this impending change but they are not sure of its specific characteristics and they are not unanimous in their support of its happening. There are precedents, as discussed previously, that reveal negative consequences if adequate advance planning is not instituted by the community and the mining company to control the [illegible]ts of the mining operations.

a. Advance Planning Problems

The problem is threefold: first, the townspeople must be privileged to a certain amount of confidential information from the mining company as to the nature of their eventual operations; second, they must agree as to the necessary planning steps well in advance of the development; and finally, they must find ways to implement their planning controls in areas that are untested in the previous history of the town. None of these conditions are easily satisfied. There are potential conflicts of interest already existing within the town structure over the question of large-scale growth. The problem of receiving information from the mining company is complicated by the necessary secrecy that surrounds a new mining development, and current zoning laws are not reliable instruments for long-term planning concepts. Within these three problem areas, the most promising possibilities for success

depend on the ability of the citizenry to act together. In order to agree, however, there is need for a better understanding of the possible impacts to be faced. Many of these impacts can be learned from a close study of existing mining towns, in various stages of development and dependence on adjacent mining operations.

b. Positive Impacts

On the positive side it is clear that the development of the operations would be responsible for increased business activity for the merchants of the community. In the long-term the capital investments of the mines plus the growth in population of the town would supply an increased tax basis for the local school system. In the short-term the use of the local work force for construction activities connected with mine plant development will create a boom for those in the building trades. Finally, the success of a strong mining operation in close contact with a town brings additional community benefits in the form of company assistance for recreation facilities and other worthy local projects. In all of these ways the businessmen of the city of Florence stand to benefit from the changes.

c. Possible Negative Impacts

There are also, however, a number of changes which need to be guarded against, or at least planned in advance, to

maximize the potential advantages and minimize the disadvantages. For example, the development of a new mining operation will create a short-term boom in construction activities in the area. If the need for workers is greater than the local area can supply and commuting distances are too long for a daily influx of trades, then the phenomenon of construction trailer camps will occur. These will have a short life expectancy and a probable residue of out-of-work citizens will remain after the initial building phase is over. In the long-term there is also the danger of the majority of a small town's work force coming to depend entirely on the payroll of the mining company. Although there is little that can be done to offset this problem, it eventually means that the town is tied to the economic cycles of the copper industry. This danger is further increased if the alternate economic basis in agriculture is in any way negatively affected by the mining development. Possible problems of this nature are generally associated with excessive water withdrawal from the underground supply forcing the mines and the farmers into a one-sided competition. The competition is one-sided because the greater capital resources of the mining company,or parent oil company, will outweigh those of the individual farmer, eventually causing him to sell to the mines as they safeguard their groundwater withdrawal rights. This possibility of large-scale land aquisition by the mining company can also cause problems with future community expansion,

as has been mentioned in other cases, unless long-range plans are made in advance by the concerned citizens. Another source of possible conflict with the agricultural interests can occur in the area of pay scales for hired helpers. A mining operation is strictly unionized and the pay scales of all the workers are above those of non-union agricultural hands. Thus, an already tenuous source of agricultural manpower could become even more questionable given competition with the mines.

In general, the existing social structure of the community will be changed by the impact of the new development. Older customs and relationships long established in the small town will feel the new pressure. This kind of change is inevitable and the judgment of its merits depends entirely on who benefits the most from its upheaval.

Finally, in addition to economic and social concerns, a general concern must be added for the immediate environment of the town. Problems related to this area include air quality as affected by blowing dust, water quality as affected by tailing pond seepage, noise from blasting and heavy equipment and visual impact from piling up huge mountains of waste rock and tailing materials. These are not insoluable problems; they do demand far-sighted solutions and they also demand a great deal of pre-planning. The conditions for success in this area again depend on the availability of information from the mines and the ability of the citizenry to work together toward mutually beneficial solutions.

B. The Community Environment: Socio-political & Legal Consideration

1. The Political Context

In the usual circumstances the mining town political system is a closed, paternalistic situation featuring intimate interaction between mine management and local political actors. The political relationships concomitant to that sort of overall political system are well-known, and even the neophyte has a good feel for the panoply of characteristics that come to mind with the concept of the mining town. The most important of those characteristics is the domination of the mine. The mine's predominance evolves from several factors including geography, a near monopoly of scarce resources and both conscious and unconscious management policies that tend to consolidate and buttress its natural advantage in the political system.

In a basic physical sense many mining/smelting operations are geographically located in remote areas far from the centers of government or large urban agglomerations that might imply the evolution of countervailing political power contenders. Of the eight sites investigated during this study, for example, fully half of them were located more than 100 highway miles from any urban center in excess of 10,000 people--the mine and smelter operations at Morenci, Cananea and Santa Rosalia and the new smelter at Las Playas.

Six of the locations, furthermore, were a considerable distance from the nearest interstate, or comparable highway in Mexico, and therefore removed from the sort of casual influences derived from large numbers of transients. Transportation and communication are obviously limited, and the mine-dominated political system exists in relative isolation far from the scrutiny of government or political actors independent of significant mining company influence.

The mine management's primacy is also enhanced because it enjoys a near monopoly of both economic and human resources. The mine operations directly employ most of the wage earners in the area and almost all of the independently owned service industries are overwhelmingly dependent on purchases from the mine or on the payroll of the mine's employees. The mine also controls almost all land in the area either through direct ownership or a seemingly infinite variety of leasing arrangements with private owners and state and national governments. The overall monetary resources of the mining companies, moreover, far exceed local governments and frequently are greater than intermediate governmental institutions like the state or province.

The most valuable human resources are also tied closely to the mines. The best educated and most sophisticated people in the community are overwhelmingly employed by the mining companies, including engineers, accountants, management people, lawyers and in some cases medical doctors and school teachers as well.

Nearly all of the formerly independent high-level human resources like the local bankers or businessmen who usually form the political elite of local communities are furthermore dependent on the mining companies for a large part of their income. In simple truth it is nigh onto impossible to identify even a small number of college-educated local citizens who are not directly employed by the mine or linked quite closely to it. The sons and daughters of the local citizens who leave to seek higher education usually do not return; if they do, they almost always find employment in the mines. Even the retirees frequently go off to other parts rather than remaining in the area where they might be a source of political opposition to the dominant local management. The migration of the retired folks is partially due to a natural urge to seek other climes, but in company-owned towns it is also influenced by the fact that they must move out of their company-owned houses upon the termination of their employment with the company.

In short there exists almost no employment possibility in mining towns that might provide a source of independently based political alternatives. Though admittedly only suggestive, some figures from the 1974 Arizona Directory of Manufacturers offer some idea of the situation. For the communities of Clifton-Morenci and Ajo, the sites of large mining operations, the Directory lists a total of five manufacturing firms employing a total of 22 to 24 persons. Total population of the three towns is nearly 17,000.

The policies and programs pursued by the mines (whether consciously or unconsciously) also tend to solidify their political hegemony. At the most basic level, decisions concerning location seem to quite consciously take into consideration factors like the proximity of large urban areas. All other factors being equal, that is, the mining companies are anxious to stay away from sources of countervailing power--well-organized and adequately financed local governments, independent business and agricultural enterprises, environmentalists, minority representation advocates and groups of sophisticated retired folks. The mines to the south of Tucson in the Santa Cruz Valley, for example, have engaged in almost constant controversy with governments from the city, county and Papago Indian Reservation as well as with agricultural organizations and more informal citizens' groups who complain about, bring suits against and launch investigations into a host of issues including water rights, tax assessments, employment practices and sundry environmental problems.

Although the ore bodies in the region are obviously rich enough to offer the opportunity for profitable mining operations, some mining people question the basic wisdom of the entire departure. The complexities implicit in attempting to undertake mining operations in close proximity to large urban agglomerations, that is, spell an array of irritating problems that come close to making the entire operation counter-productive. Even in Mexico where general political sensitivities and specific environmental

concerns are far less developed, the plans for a new smelter near Guaymas-Kino Bay has caused some concern within the mining community.

The paternalistic attention devoted to the problems of the local community also contributes to the influence of the mining companies. The mines are in a word good to the local people and very frequently cooperate in areas like housing, power and water, street improvement and recreational facilities. Every mining and smelter site visited by the team offered convincing evidence of those company policies. In company-owned towns like Morenci the company has created and maintained adequate medical and educational institutions, good shopping facilities, and, beyond those more basic necessities, attractive amenities like playing fields, parks and theaters. In other situations, like Cananea, the mining companies have made significant contributions to the local situation in the form of a first-rate water system, reduced energy costs and commodious housing for employees. In every situation, the mining company is an "easy touch" for all kinds of local initiatives from improving the town plaza to supporting the local baseball team.

All of those admirable examples of civic responsibility have significant impact and they certainly elicit a sense of gratitude from the local community. Those types of policies and programs also, of course, have a measurable political pay-off in garnering political support for the mining companies. None of

that is to question the sense of obligation and responsibility that obviously informs the mining companies but only to point out that the larger picture is composed of a panorama that connects civic generosity to good business and to effective politics.

In a much more direct way, the mining companies also tend to their political fences in the sense that mine personnel often hold political office with local school boards, town and county governments and various improvement districts. It is natural, of course, that those relatively highly educated and sophisticated people should emerge as community leaders, but it is also clear that they bring certain proclivities and attitudes that strengthen the position of the mining industry in local government. It seems, indeed, that the mining management cooperates with those office holders by permitting them occasional time off and facilitating the arrangement of work schedules.

Finally, the mining companies also maintain on-going contact with policy makers in the executive and legislative branches at the state and national levels of government. Both individual companies and the mining associations support lobbying efforts. Those representatives are concerned with a broad sweep of matters pertinent to the entire mining industry, but, more to the point of this analysis, they are also interested in policies and programs from the national and state level that impact on the local mining town political environment.

Given the disparity in resources, the mining company lobbyist is frequently a more salient and more effective local representative than the legislators sent by the respective district. Again, the policies and programs pursued by the companies tend to strengthen their position in the local political context.

2. The Socio-political Reality

The upshot of that context features an ongoing political stability, social cohesiveness and high standards of living and social services, but it also implies a certain immaturity that pervades the political culture of the system. From a political standpoint, in the first instance, mining towns tend to general political tranquility broken spasmodically by undisciplined, passionate (and sometimes violent) outbursts of unplanned activity that usually subside with little of substance accomplished for the ongoing political system. In company towns, of course, there are no formal politics and elections quite simply do not take place. Even in localities that boast a formal local governmental structure, however, elections and other manifestations of political activity do not assume the same importance that they do in the urban sectors characterized by larger populations and a multiplicity of contending positions reflecting a more pluralistic electorate.

Beyond the homogeneity of the socio-political and economic structures, political quietude also is enhanced because many issues are diffused by the cooperative attitude of the mine management in resolving local problems. To reiterate a point previously made--things are relatively good owing to high wages, adequate social services and comparatively low taxes. To propose a basic truism of the discipline of political science, politics simply do not exist where competing groups with differing ideas do not exist and, concomitantly, political activity tends to be low-key and relatively less important when the economic situation is good.

Socio-political stability in that sense reflects the social cohesiveness characteristic of most mining towns. Their geographic isolation reduces physical mobility and the entrance of new groups from differing areas and social backgrounds. Patterns featuring long traditions of father-to-son employment in the mining industry also contribute to the ingrown societies that predominate in most mining towns. Although mining operations certainly grow in overall activity, the introduction of increasingly capital-intensive mining methods implies that the labor force does not multiply in the same relative proportion as overall production. New jobs, therefore, are difficult to come by, and it seems that the employment policies of the companies combine with informal socialization to perpetuate the father-to-son tradition and, in the process, to foster relations within the communities leading to frequent

interaction and nurturing of common social and political norms and attitudes. The upshot of those several factors results in the evolution of long-term allegiances to mine and community. At the Mexican Cananea mine, for example, the average age of the employee is 53 years and the average company service is 23 years.

Combined with the relative social homogeneity of the typical mining town, its small size also contributes to its political stability. None of the towns visited by the team in Arizona, for example, counted a population of more than 10,000. In such contexts, the resolution of potential political disputes evolves in a more informal, personalized way than in larger, more socially diverse settings.

Bisbee was the only site visited by the team that displayed a vigorous political life and the exception quite clearly proves the point. Bisbee is the largest of the mining towns investigated; it has fallen on economic hard times as the open-pit mine was phased out; and, lastly, it has been invaded by new, younger people who have not been socialized into the values and decision-making procedures of the older, established community. Numerous stories in the Bisbee press quite clearly demonstrate that these younger migrants, many of them college educated, are, indeed, "trouble makers" in all kinds of ways. The larger picture over the longer run may well demonstrate, however, that their input into the community

may well have added an important dynamic quality that may contribute to fresh approaches and more vigorous resolution of outstanding problems.

In a more concrete political sense, the entire panoply of those characteristics and influences implies a sort of political immaturity usually found in semi-closed, paternalistic systems. Local political activity is stunted and ongoing intercourse with state and national government is not significant. Those higher levels of government are not usually so concerned with mining communities as they are with other areas because the mining community has a well-earned reputation for resolving its own problems in a context of political tranquility.

While the mine is operating at high levels and the local economy is vibrant in the shorter run, that political immaturity probably does only peripheral harm, but when the inevitable crunch comes with decreased mining production, it may well have profoundly serious ramifications. On the one hand, the local political machinery is in disrepair and not geared to undertake necessary petitions and lobbying for state and national support. The traditional paternalism of the mining companies combined with the informality of the local decision making process ill-prepares the usual mining community for hard times that necessitate effective political organizations and familiarity with avenues of influence to governmental agencies at other levels of government that may well be both designed and inclined to assist the mining town in the necessary readjustments.

On the other hand, the higher levels of government have grown accustomed to a policy of benign neglect toward mining communities and are frequently insensitive to the sort of unsophisticated political petitions which eventually are generated. They have had little experience with the general problem of mining communities and may be in a very basic sense quite unfamiliar with the local officials who have operated in rather isolated regions without ever being compelled to establish relations with appropriate agencies. The mining towns' political immaturity, in sum, leaves them ill-prepared to handle socio-economic crises and the political problems concomitant to such crises.

3. Legal-Political Problems

In addition to the crisis situation emanating from reduction in or termination of mining operations, several other key legal-political problems are integral parts of the mining town political system. At base they all evolve from the basic land tenure patterns of mining towns in which the mine owns or controls practically all property in the area.

At the most general level, overall community planning for the location, expansion or addition of new services and conveniences is profoundly limited by the land tenure system in force in mining areas. New housing projects, for example,

must be located where the mine wants them, sometimes with little regard for rational community development. In Kearny, an exemplification of the general problem centers on the community's desire to nurture a shopping area competitive with the existing business district, controlled by the Galbraith Corporation, under contract to the mining company. Although the Kearny town government enjoys the right of condemnation, there is quite simply little appropriate land in the area to condemn.

Water rights form another nexus for a series of legal-political problems, and water seems to concern every official in every community visited by the team. In Florence, for example, the new mine is destined to demand some readjustment of water distribution and the company has already been involved in a series of negotiations and plans to evolve arrangements with local Indian tribal governments, farmers and ranchers.

Another problem area reflective of the land control systems centers on home mortgage contracts and the ability of local governments to float bonds for infrastructural and civic improvements. The Phelps Dodge land tenure leases include a short-term notice for vacating the property. Mortgages at reasonable rates are impossible to arrange in many communities owing to the uncertainty of even medium-term predictability.

At the local governmental level the same sorts of problems exist. The land control situation inhibits the development of economic and recreational facilities and roads, sewers, water

systems and other types of large-scale undertakings that demand specialized financial arrangements. The governments of mining towns like the individual inhabitants face the same problems in raising monies owing to the lack of predictability concomitant to being located in juxtaposition to a large mining operation. When a new sewer system may be uprooted at any time, it is obvious that bonding agencies may be reluctant to handle the mining community's obligations.

In Miami, for example, the town council recently began negotiations leading to the potential purchase of the local water company. Among the many considerations discussed by the council was whether a bonding company would lend money for the system in the context of the adjacent mine's ownership of mineral rights in the area. During the council's debates on the issue, several of the councilmen made specific reference to individuals encountering problems in home mortgage loans and extrapolated that principle to the question of the town's purchase of the water system.

The peculiar nature of land tenure systems in mining areas in sum implies special legal and political problems for both individuals and governments. Again whatever the well-meaning intentions of the local company may be and however cooperative its position, the problems remain because the legal-political context is not easily revised.

4. Prescriptions

As the foregoing descriptions and analyses suggest, many of the difficulties (and advantages) of the mining town socio-political and legal systems are intrinsically connected with the very nature of the mining industry and really not amenable to dramatic, definitive solutions. So long as overall national values and priorities place empahsis on the extraction of minerals, the mining town, logically enough, must adjust itself to its role within the hierarchy and attempt to maximize the considerable benefits it enjoys and minimize the problems and difficulties.

With that contextual proposition posited, some partial solutions can be achieved by a series of measures including more perceptive mining company policies in both their own specific sphere and in cooperation with local government, initiatives undertaken and catalyzed by the local political systems, and more cogent input from formal governmental organizations and informal political groups external to the local system. At all three levels, both recent trends and future possibilities are mixed, but on balance the scenario is mildly positive.

In the first instance recent initiatives (in Australia and in the United States for example) demonstrate that the mining companies are sensitive to socio-political considerations and willing to make some adjustments to deal with those factors. The planning for the new smelter at Las Playas for example has

located the town at a distance of approximately ten miles from the smelter in an attempt to create a more attractive setting.

In Florence the officials planning the new mining operation have been cognizant of local concerns and have been receptive to the local community in establishing lines of communication looking to the resolution of problems. In Bisbee governmental authorities report a generally good working relationship with mining officials as the town attempts to maintain itself in the face of severe economic hardship resulting from the termination of open-pit operations. On environmental issues, finally, the mines have made a beginning in grappling with problems of air pollution and revegetation in several areas throughout the state of Arizona and even in some degree in Mexico.

However admirable those departures may be, they are still a ways from evolving a set of regularized and institutionalized processes that should be established. They tend to be ad hoc responses to particular problems or political pressures rather than the anticipation of and resolution of issues in a systematic, on-going, procedural framework. There are no panaceas, of course, but a fairly simple undertaking like regularly-scheduled, fairly formalized conferences between the mine management and local governmental officials might well provide a useful forum for on-going communications and problem-solving. The management seems on the whole to be receptive to the local governmental officers and needs only to evolve rather more formalized procedures to replace the ad hoc responses usually employed.

With references to the local community's government, much the same sort of minor initiative might imply some progress. The establishment of specialized organizations of mining town governments, for example, seems a logical undertaking. With 15 or 20 towns represented in annual conferences, mining town governmental officials and other interested people could compare experiences, generate information and offer mutual support for petitions to state and national governments, universities, research institutes and other groups and agencies concerned with some of the problems peculiar to mining towns and armed with resources that might be mobilized in support of such organizations. The list of possible linkages is almost infinite, but some obvious examples might include professional organizations, Indian tribal governments, sporting confederations and environmental organizations.

A rather more difficult effort centers on the pursuit of economic diversification. Some mining towns have explored those possibilities and experience seems to prove it both a complicated and unpromising alternative, but one that should not be abandoned. As a general rule the unpredictable land tenure system combines with tightly unionized and high-wage characteristics of mining towns to discourage new manufacturing ventures. Mining towns, as previously noted, are not poor, depressed areas like some in the South that have utilized reduced wage scales as an inducement to new enterprises, hence the difficulty in a program of diversification. With that understood, however, a few towns like

Douglas have succeeded in the beginnings of some degree of diversification On-going efforts should be maintained in that area. Cooperative ventures between both town and mine may be made more fruitful than past experiences.

At still another level of extrapolation, exogenous influences within the national socio-political context ought to be programmed into the mining town system to ensure the crystallization of cogent debate and the furtherance of productive discussion. That sort of high-level input, moreover, has the decided advantage of offering new information generated in other areas and from other perspectives.

The implementation of such procedures is, of course, more difficult than the postulation of their necessity, but the task is not impossible. National and state governments and/or political parties are the most obvious sources of outside influence, but their impact varies according to time and place. In the United States, interestingly enough, they may be less efficacious agents of outside influence than in some less developed nations. State and local governments in the United States tend to be more self sufficient than in other lands. Moreover, they tend to respond to local petitions and complaints and usually avoid problems unless they are catalyzed by local action initiated through local organizational structures. Much the same is true of the political party in the United States. It is essentially an agglomeration of local federations and state confederations

organized on the local level and seldom initiates action from the top down. Given the parochialism of many mining town governments and political party organizations, they cannot usually be expected to solicit on-going contact and intercourse with higher levels of government or political party organization. Hence, they tend to be weak conduits for input from outside of the closed political system.

In less developed lands differences in both reigning political theory and practice probably make national and state government and political parties relatively more fruitful transmission belts for exogenous input. The less developed nations place much store in governmental direction of the society, economy and polity; they look especially to overall regulation by the national government. Local governments, moreover, are not nearly so well funded and are therefore less independent. The result of those two factors is an environment conducive to continuing supervision of the local scene by national government. Governments in less developed countries are, of course, generally less effective than in the United States, but the long-range potential for modification of the closed political system may well be higher in those nations than in the United States.

Much the same situation pertains with reference to political parties. Less developed nations emphasize the organization of tightly-knit, nationally oriented politcal parties designed to

integrate the disparate regions of the nation. Again they are frequently not so effective as the theory or the intentions of the national elites would have them, but as is true of government the basic commitment exists and the long-term promise may be greater than in nations informed by differing political philosophies and traditions.

In addition to government and parties, labor unions offer some possibility as the conduits for outside input into the mining town closed political system. Unions generally (and particularly in the United States) tend to tighter organization than parties and union leadership frequently exercises significant authority on the local level.

Whatever the conduit, in sum, the essential task is to modify the closed political system in hopes of nurturing a more dynamic quality to long-range planning and short-range governing in mining communities. As noted previously, that is certainly no easy task, but both the local inhabitants and the more general political system should be healthier for the effort.

C. The Community Environment: Socio-economic Considerations

When a new mine is developed in an isolated and unsettled region, the developer will normally be responsible for both the capital investment required for the mineral extraction operation and the capital investment required to house and

advertise support the population which will be associated with the development project. The "new town" which is created will be built not because the developer is interested in experimenting with new and innovative forms or settlement but simply because the most efficient way to attract and hold labor in an isolated setting involves the development of housing and other community infrastructure.

A more common problem and the one addressed in this report, is that of evaluating the impact of a mining project in a settled region. There are three or four different situations where impact analysis is called for procedural and methodological considerations and essentially the source for analyzing each situation. The several "problem situations" have already been reviewed--what are the implications associated with:

1. the initiation of a mining project in a new region;
2. the discontinuation of mining activity in an established mining region;
3. the expansion of an existing mining operation;
4. and, in a relatively stable situation, the role a mining operation plays in the maintenance of a regional economy.

To answer these, and related questions, the researcher will be required to obtain a variety of data and follow through with several difficult analytical strategies. The process can be organized in three phases.

1. <u>Inventory of Infrastructure</u>

The first phase includes a complete description and analysis of the region's infrastructure. It is needed both where a resource development project is being initiated and in cases where an existing resource extraction project is being reduced in size or discontinued. The following items are typical of those that must be included:

a. Natural Resources

   i. locational resources

      proximity to markets

   ii. environmental resources

      climate

      recreational opportunities

b. Human Resources

   i. educational background

   ii. skill level and experience

   iii. employee performance

   iv. wage levels

c. Institutional Resources

   i. educational institutions

   ii. governmental organizations

   iii. research and development

The description of the items listed above and other similar items will provide the researcher with a better understanding of the region. Information of this sort will also provide inputs for a more detailed analysis using such techniques as economic base and especially input-output analysis. Results of input-output analysis can, as will be suggested shortly, be used to estimate the indirect and induced effects of the resource extraction project on the local economy.

2. Description of Project

The regional socio-economic environment has been described, the research can get down to the business of actually describing the proposed or existing development projects. If the research problem at hand is one where an existing project is declining, as in Bisbee, Arizona, the researcher will focus on the role that is played by the project in the regional economy with special attention given to the question of exactly how local governmental bodies and private businesses depend upon project payrolls, tax revenues and expenditures. These same questions are asked when estimating the potential impacts of a new project, such as at Florence, Arizona and Las Playas, New Mexico, but in this latter case the difference between long-term and short-term impacts is emphasized.

The economic impact of a new or expanded resource development project on a community might be thought of as occurring in three phases, as in Florence, Arizona. First, there is the construction phase. For a short period of time local businesses and workers benefit from construction expenditures. Second, is a short-run during which existing local business undergoes internal expansion to accommodate increased expenditures of personal and business income. The third is the long-run phase. It is here that new businesses are established to provide goods and services which were previously imported and to accommodate the general increase in personal and business expenditures. In any case, short-run and long-run impacts will certainly have a more lasting effect on a community than the transitory construction impacts, so subsequent discussion will focus on these two areas.

Impacts may be direct, indirect or induced. The direct income impacts come with the payment of wages, salaries, etc. Indirect income impacts are associated with wage, salary and other income payments to those local industries and suppliers who provide goods and services to the new enterprise. For example, a local supplier may hire additional employees or pay overtime to current employees. Finally, there is an induced income impact: increases in wage, salary and other income payments stimulate local demand for consumer goods and services. In the long-run, these impacts may increase both absolute economic growth in the region and the rate of growth.

More specifically, in the second phase the project must be described in terms that will allow the researcher to eventually estimate both direct and indirect impact on local and regional suppliers of both goods and services.

a. What public and private sector goods and services will be (are) required by the project itself, e.g.

   i. Will (does) the project demand water, sewer or fire protection services?

   ii. What local business services will be (are) needed?

b. What will be (is) the nature of demand for goods and services by new population.

Of the two questions, this is probably the most critical inasmuch as the project can probably "take care of itself," but this may be less so for the population associated with the project.

Although the development project may make some direct demands on local firms and governmental agencies, the most significant impacts will usually come from the new population which is drawn into an area such as Las Playas, New Mexico, because of increased employment opportunities. Employees directly and indirectly associated with the project will have varying degrees of influence on the demand for public and private sector goods and services within the community; the nature of the demand depends upon a) their length of stay; b) size of family; and c) level of income. Three employee types can be recognized:

Construction Employees. In addition to knowing how long this type of worker will be in the community we must also determine: the number that will relocate, i.e., move into the community with their families; that will commute weekly from a residence located elsewhere; and that will commute daily from a residence in some other portion of the impacted region.

Operating Employees. At some point during the construction phase, operating employees will move in and start their eventual takeover of the plant. It will be these operating employees and their families together with the supporting employees and their families that will create the long-term demand for goods and services within the region.

Supporting Employees. As the demand for public and private sector goods and services increases, local business and governmental units will need to expand. Using input-output analyses, we can estimate increases in supporting employment and from that, increases in associated population.

3. Estimating the Impacts

Once phases one and two have been completed, these findings can be combined for the purpose of actually determining what the impacts of the project might be on the study area. Three questions are asked now.

a. What activities are directly provided by the project, e.g., is there a company store, hospital, etc., such as in Morenci, Arizona?

b. What facilities are indirectly supported through taxes (e.g. local, school) or are supported by project activity (e.g. a local firm that sells mining equipment)?

c. To what extent are local merchants and governmental agencies dependent upon local spending by project personnel?

Attention should focus on:

a. schools

b. medical services

c. water, sewer, police and fire protection and other municipal services

d. consumer goods, other goods and services typically provided by the private sector

e. business services

It should be obvious that the vocabulary used when describing a particular project must conform to the local situation--for example, a sewer system is not considered a municipal service in many parts of the work. Nevertheless, we do assert that the strategy which we have just articulated is the proper one for evaluating the impact of a new or existing large development project on a local region's economic and social infrastructures.

D. The Physical Environment: An Overview of the Natural Environment As Impacted by Mining Operations

The natural conditions encompassing pre-development are documented to the greatest degree possible, however, in the case of all operations visited development has proceeded to a point whereby major changes in the local environment have or are already occurring.

1. Soils

In most environmental assessments, importance is attached to the three major processes affecting the soil environment: erosion, sedimentation and runoff. Additional importance is attached, however, to the soil in an open-pit copper mining operation. Two factors play an important role: (1) the utility of natural soil to form a dike or dam behind which mine tailings

can be dumped, (Figure 20) and (2) the fertility of natural soil and mine tailings to support plant life when revegetation of the tailing dumps occurs.

To successfully revegetate tailing dumps at the Cyprus Mine, three steps were conducted which may serve as a guide guide for future soil site preparation:

(1) chemical and physical analyses of the soil were made to establish a baseline of soil fertility. This was conducted in conjunction with qualified soil scientists who had access to laboratory equipment;

(2) organic material was applied to the slopes. Material such as straw is normally applied with a pneumatic mulcher or a hydroseeder. The addition of a mulch is expensive and is not always necessary to establish vegetation stands on sites with fertile natural soils. They are particularly important, however, in obtaining a satisfactory stand of seeded plants on sites where fertile soils are scarce. Mulches conserve soil moisture by reducing evaporation from the soil surface and help minimize erosion.

Where annual precipitation is between 250 and 450 mm, mulches are highly conducive to seedling establishment. This is particularly true on south and west facing slopes. In areas where annual precipitation is between 450 and 625 mm, mulches

Fig. 20 Dike Established From Soil Overburden

are not generally needed except perhaps on some extended south or west facing slopes. In arid areas where annual precipitation is between 200 and 250 mm. seedling success is variable even if mulches are used. Seedlings in areas receiving less than 200 mm of annual precipitation are subject to failure unless environmental conditions are considerably better than average during the establishment period or supplemental water is added.

Trials show that desert areas are almost impossible to seed artificially unless seeded along with mulches and watered frequently. In arid areas where precipitation is less than 200 mm, native vegetation will regenerate itself in disturbed areas if slopes are gentle. This may require from 10 to 30 years, unless supplemental water is added as needed.

Mulches conserve substantial soil moisture to a depth of 30 cm or more, resulting in a greater number of established seedlings and a denser herbage cover than areas sceded without mulches. Therefore, most mulches, when properly applied, give added benefits in obtaining a stand of vegetation on mined soils.

a. Surface Cover Mulches

Many mulches are applied uniformly on the soil surface by mechanical means. Such mulches are universally adapted to most soil and slope conditions.

b. Wood Fiber:

Wood fiber at 1,500 pounds per acre gives some consistently favorable results under all conditions except in areas where frost heaving or excessive surface water flow exists. If wood fiber is applied at rates less than 1,000 pounds per acre or on steep unstable slopes, little benefit will be obtained.

c. Straw-Asphalt:

Straw at 3,000 pounds per acre, bound with viscous asphalt at 300 gallons per acre, gives beneficial results, but this mulch is expensive and susceptible to being carried away by wind and water. Straw is often contaminated with grain and weed seeds that produce excessive competition with newly planted grass seedlings. Straw-asphalt mulch establishes better stands than wood fiber where winter and early spring frost heaving is a serious problem.

d. Soil-Anchored Mulch:

Either straw or hay can be distributed uniformly over the soil surface after broadcast seeding and held in place by punching it into the surface soil with either a mulch tiller, a modified sheeps-foot roller or a weighted agricultural disk. These methods adequately cover the seed so it is not necessary to cover the seed prior to adding mulch. The application of mulch occurs simultaneously with seeding operations.

(3) After seeding and mulch application have been completed field irrigation and fertilization occurs. Cyprus' irrigation procedure consists of a line of irrigation pipe at the top of the dumps from which water can be sprinkled over slopes.

Fertilizers consisting of nitrogen, phosphorus or potassium have given variable results. In some studies fertilizers have produced favorable results, but this response has not been consistent.

Fertilizers consisting of nitrogen, phosphorus or potassium alone and in combination, when applied at the time of planting, have shown only modest benefits to seedling establishment. Adding 80 pounds of nitrogen does produce some added benefits seedling size, but in most cases may not justify the cost. Phosphorus and potassium alone or combined do not appear to influence grass seedling establishment. Applying nitrogen in high quantities at the time of planting often increases weed growth and subsequent competition for soil moisture and nutrients. If fertilizer is applied on slopes, it is desirable to apply it at the time of seeding to work it into the soil, otherwise it may be blown or washed away.

Applying 80 pounds of nitrogen per acre in the fall, after the first growing season, or before the start of the second growing season, increases the total foliage cover over a shorter period of time when compared to areas not fertilized.

On most areas it is believed that phosphorus applied at 60 to 80 pounds per acre a year after planting is beneficial to rate of establishment of forb and shrub species. Combinations of phosphorus and nitrogen at 60 to 80 pounds per acre of each may be recommended when a wide variety of plant species are seeded and serious weed competition is not anticipated.

2. Topography

Topography is important in assessing possible soil erosion, landslides or soil creep. Most existing copper mining operations occur in the sloping foothills of mountainous areas. (Figure 21) Slope in these areas may approach 15 to 25 percent, hence large-scale excavation and dumping of alluvial material on these sites becomes an acute engineering problem.

Engineering input into a developing resource extraction program at an early stage will help ensure both short-term and long-term stability of the area. It will be assumed herein that the mining company responsible for the resource development will analyze and design the pit slope angles, bench set-backs, waste-rock dumps and tailing ponds (in the case of an open pit mine) or the pillar and support systems (in the

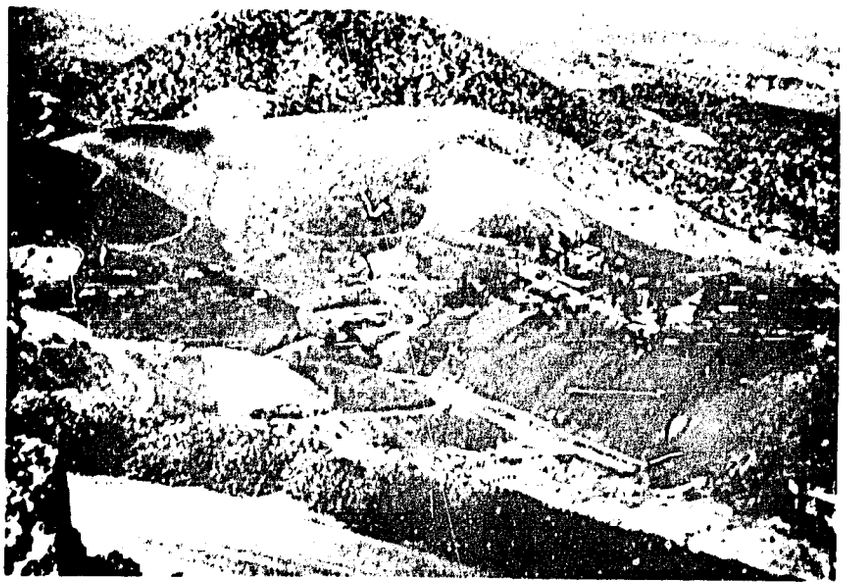

Figure 21 Example of terrain where copper mines may be developed. Old Cananea, Sonora, Mexico.

case of undergound operations) to an acceptable level of risk with regard to the safety and economics of the mining operation itself. Engineering input, then, is understood here to apply to analyses and design of a mine-community system only as they relate to each other.

Conflicts, in terms of hazards, between communities and mines occur as a result of close proximity of community structures to mining operations. In several of the "old mining towns" visited by the team, mine expansion has resulted in the relocation of entire townsites or has resulted in a hazardously close proximity between population and mining operations.

a. Morenci, Arizona

The old town of Morenci, Arizona has been evacuated as Phelps Dodge mining operations expand in scope. Eventually the old town site will be consumed by the open pit. (Figure 22) The town of Morenci has been relocated but is still in intimate contact with the mining operation. Portions of Morenci have been constructed atop old tailing ponds including company housing and commercial structures such as the company mercantile store and a bank. (Figures 23, 24, &25) Minor problems with differential settlement within Morenci, however, point out the necessity for adequate engineering studies and stabilization measures prior to construction on waste structures.

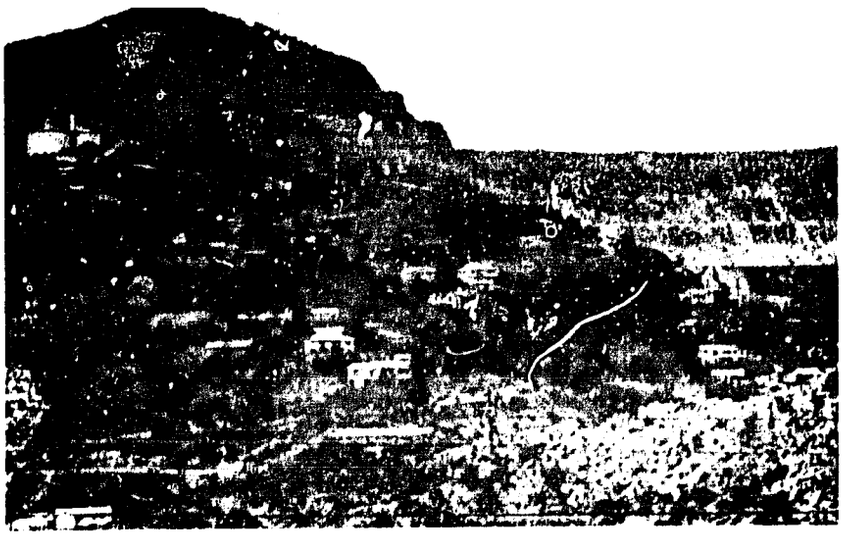

Fig. 22 Open Pit Encroachment on Old Morenci, Arizona.

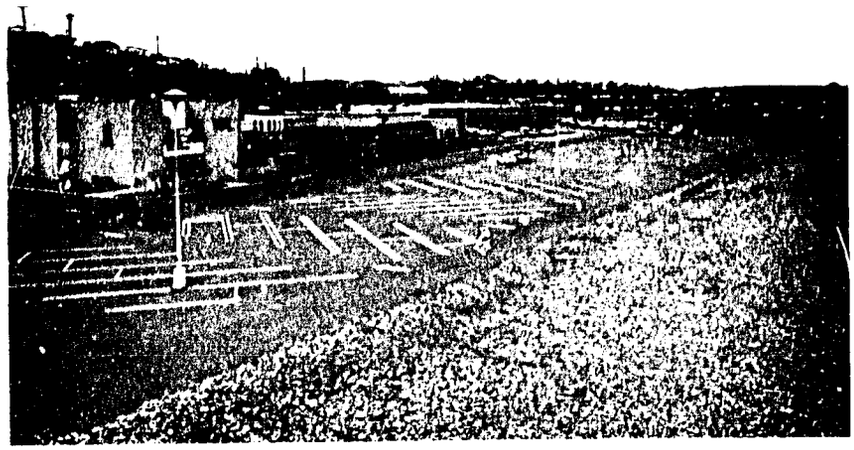

Figure 23 New Morenci shopping center

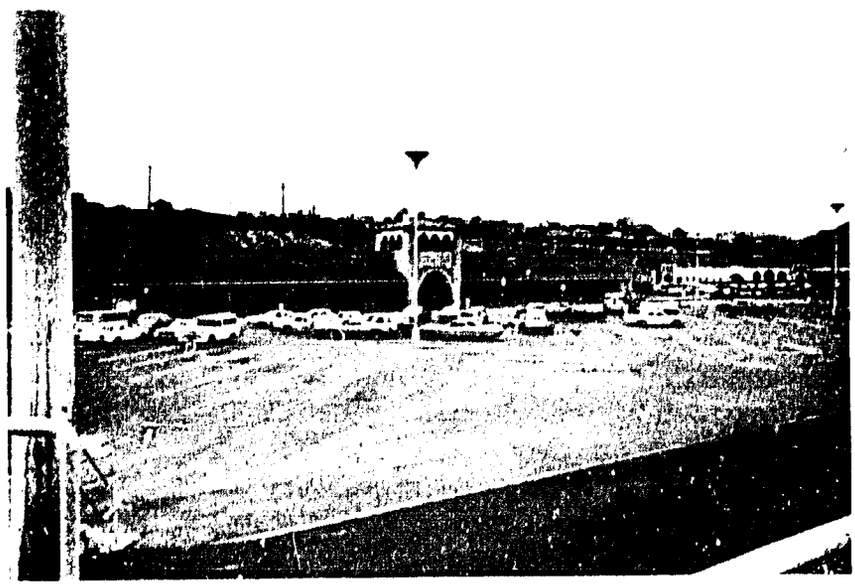

Figure 24 Company mercantile, Clifton/Morenci

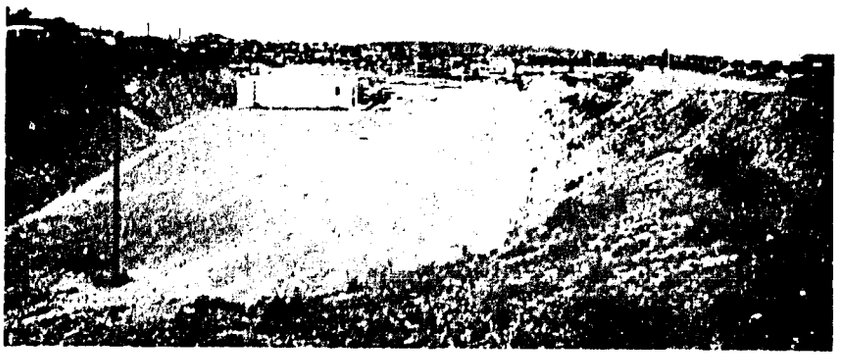

Figure 25 New Morenci shopping center, built on abandoned tailings pond

b. Bisbee, Arizona

Copper mining operations at Bisbee have ceased and there remains an unique example of hazards due to close proximity of mine and community. Both rock and soil slope stability problems will plague the community for some time to come. Final mining operations in the open-pit mine have resulted in a slope failure at the eastern edge of the Lavender Pit which currently jeopardizes Highway 80 between the downtown business district and Lowell, as well as several structures in the Lowell business district. (Figures 26 and 27) Modern attempts at resource extraction should avoid this type of juxtaposition of population and pit slope stability hazards.

Waste dumps and tailing ponds have also encroached upon the Bisbee community. (Figures 28 & 29) As in Morenci these structures pose a potential hazard to community development down slope.

c. Globe-Miami, Arizona

Tailing ponds in the Globe-Miami area are at the edge of the community. As future mining operations continue, blasting vibrations and other extraordinary loading conditions could conceivably produce slope failures, jeopardizing the nearby community. (Figures 30, 31 & 32)

Problems such as these can be avoided in future resource extraction programs by early planning. Adequate separation between the community and the limits of the largest anticipated ore

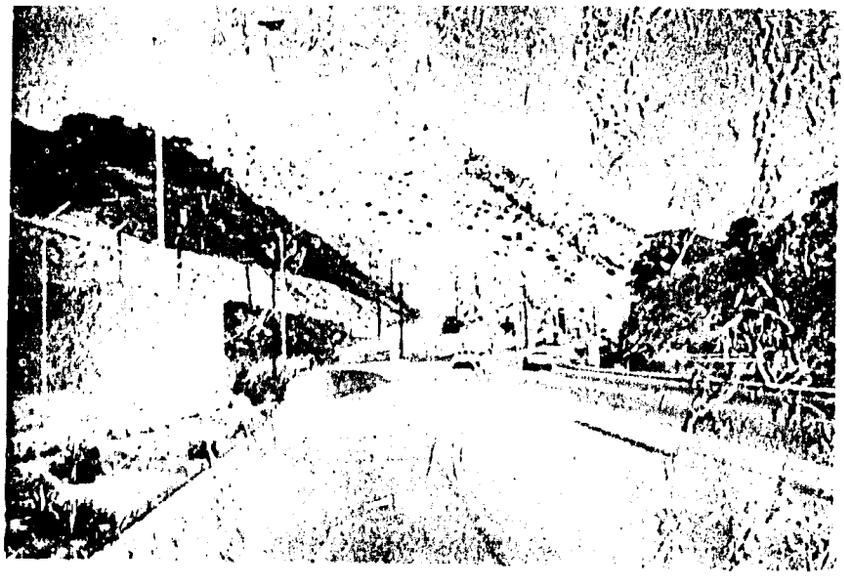

Figure 26 Pavement cracking, Highway 80, on edge of Lavender Pit, Lowell, Arizona

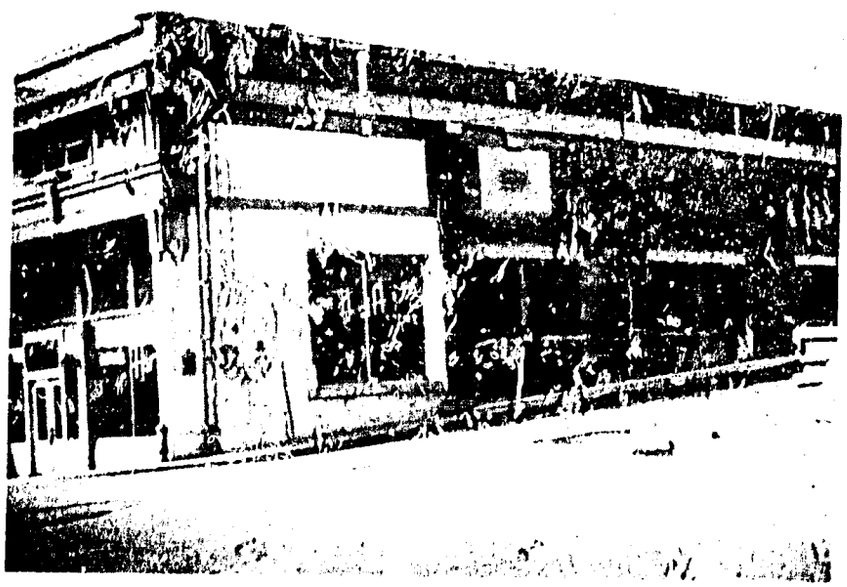

Figure 27 Building and pavement cracking on edge of Lavender Pit, Lowell, Arizona

Figure 28 Waste dump in Warren, Arizona

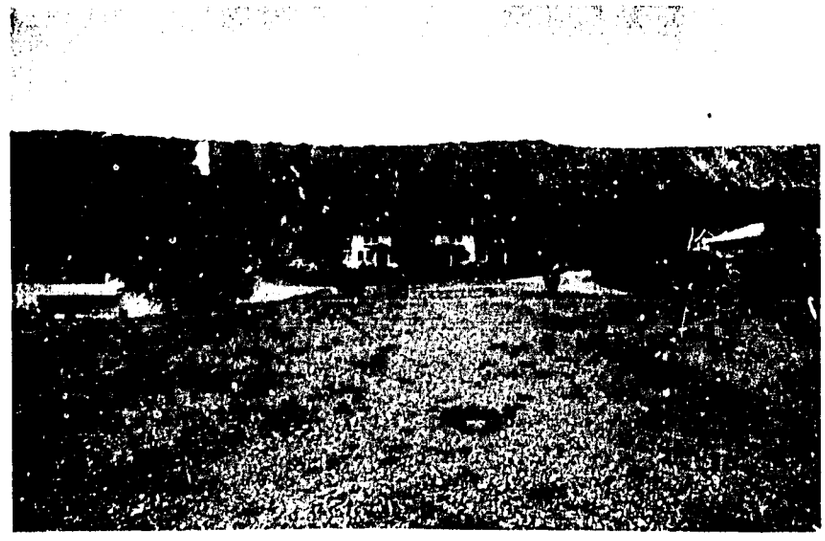

Figure 29 Waste dump in Bisbee/Warren, Arizona residential area

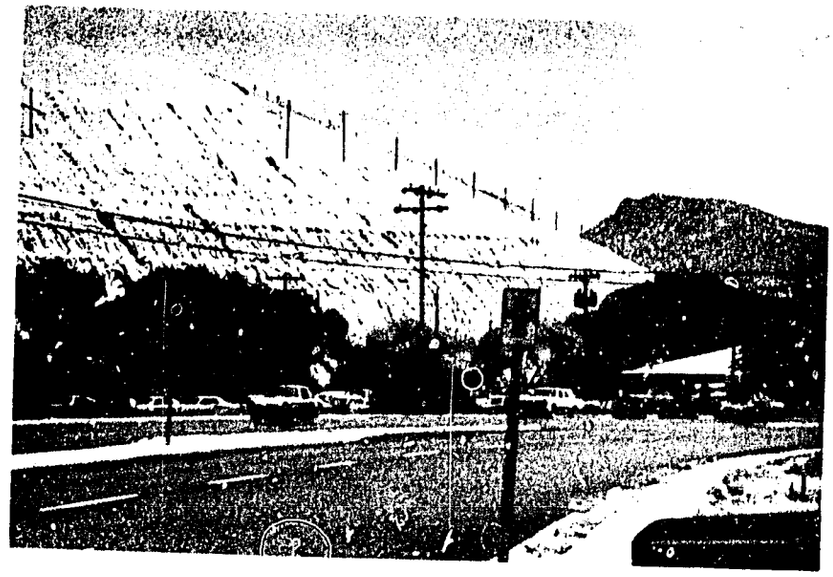

Figure 30 Mine tailings, Miami, Arizona

Figure 31 Mine tailings, as viewed from downtown Miami, Arizona

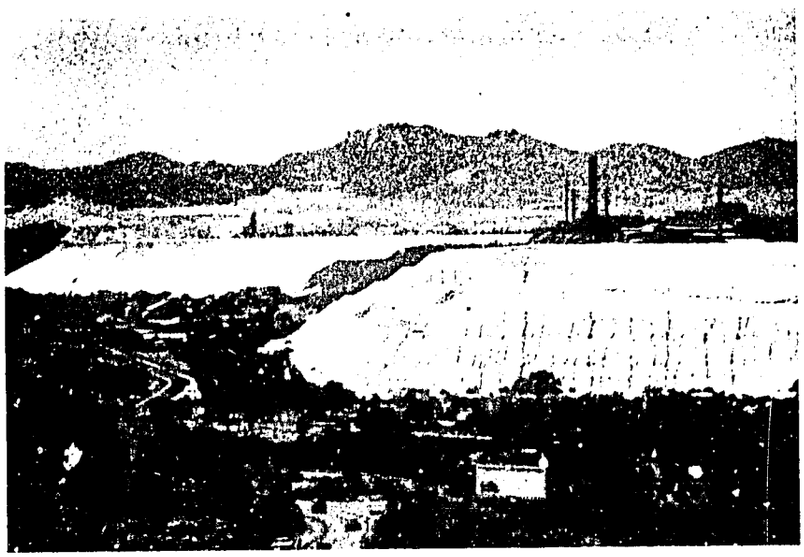

Fig. 32 Overview of Globe - Miami Mining Operation

reserves should be maintained. In addition careful planning and design of mine waste disposal sites should be conducted at an early stage to avoid future hazardous conditions. A good example of this type of early planning can be found at Phelps Dodge's new operation at Las Playas, New Mexico.

In addition to pit and dump designs topography must be accounted for when slope length and the resulting soil loss and runoff are to be calculated. The man-caused effects of large-scale open-pit mining and the surface features created which will affect the hydrology of the area are important in evaluating the impact of development on runoff and erosion from floods.

3. Subsurface Conditions

Subsurface conditions affect the ability of the development site to support structures, the provision of underground utilities and the ability of the rock to serve as a groundwater aquifer.

These aspects are of particular importance in today's method of open-pit mining. Most pit development is conducted in geologic areas impermeable o water movement; however, two components of the mining operation call for detailed knowledge of subsurface conditions. First, the mining operation usually calls for the removal of rock from the pit with a copper content not considered sufficient to merit crushing and routing through the milling process. This rock is stockpiled and leached by introducing water and a weak solution of sulfuric acid. This aqueous solution is

introduced at the top of the stockpile and is allowed to percolate through the rock and porous material. Stockpiles are usually located on sloping topography which allows the pregnant solution passing through the material to drain into holding dikes below the dumps. A common assumption for this practice, however, is that no seepage occurs at the dump-soil surface interface. Seepage losses of valuable water and more important the potential contamination of groundwater supplies make knowledge of subsurface conditions mandatory.

Second, mine tailings, the finely-ground residue or waste materials contained in the ore remaining after floating off the copper-bearing concentrate, are transported and dumped on areas which must also be impermeable to seepage. The tailings are commonly discharged to a thickener, where some of the water is recovered. After thickening, the partly dewatered tailings are sent to the tailing pond as a slurry. To date most water used in the slurry transport process is dispersed on the tailings and allowed to evaporate and seep into the tailings with potential groundwater contamination side-effects.

A common practice at some copper mines in Arizona is to drill groundwater wells around the periphery of dumps, tailing ponds and the open pit, which enables fresh make-up water to be pumped while at the same time recovering seepage within the cone of depression.

An extension of this kind of situation is illustrated by the CONOCO development near Florence, Arizona. There the ore body lies below the zone of saturation in the alluvium, so that open-pit ore extraction will require continuous pumping of peripheral wells in order to maintain a cone of depression approaching 70 m in depth. Although the mining company acquired several square miles of formerly irrigated farmland surrounding the site, problems arose regarding dispostion of the pumped water and possible long-term lowering of water levels in wells on irrigation project lands near the periphery of the cone of influence.

The description of a site for future resource extraction or development should contain at a minimum the following geological informtion:

a. bedrock type and characteristics
b. surface geology
c. geologic cross sections
d. presence and characteristics of geologic faults in the area
e. location of aquifers and recharge areas

4. Natural Drainage

Natural drainage occurring from resource development sites should be well mapped and known if any aqueous solutions from the overall development process might escape. For example,

several drainage ways in the Cananea, Sonora area leach water from the waste dumps. This water consists of sulfuric acid and large amounts of dissolved copper from the low-grade oxide ore. Normally this water is pumped back to pits loaded with iron scrap. The copper-bearing water is directed through a series of these pits where the iron chemically goes into solution and the copper is precipitated onto the scrap. This solution is then recycled to the dump. Such seepage may cause water contamination downstream for both human and animal consumption.

5. Climatic Conditions

Local climatic conditions can have important effects on the development of natural resource extraction sites, particularly if processing is to occur in conjunction with extraction.

An example of climate concern deals with the processing of low-grade copper (0.6% or less) from copper sulfide ores. The process for such an operation is shown in Figure 33. The process entails melting the copper concentrate in a reverberatory furnace, from which large quantities of flue gases are exhausted to the atmosphere.

Local climatic conditions can have important effects on development of smelting processes and the resultant location of housing and other mill operations. Major climatic characteristics included in a site analysis should include precipitation rates, temperature distributions and prevailing wind directions and speed.

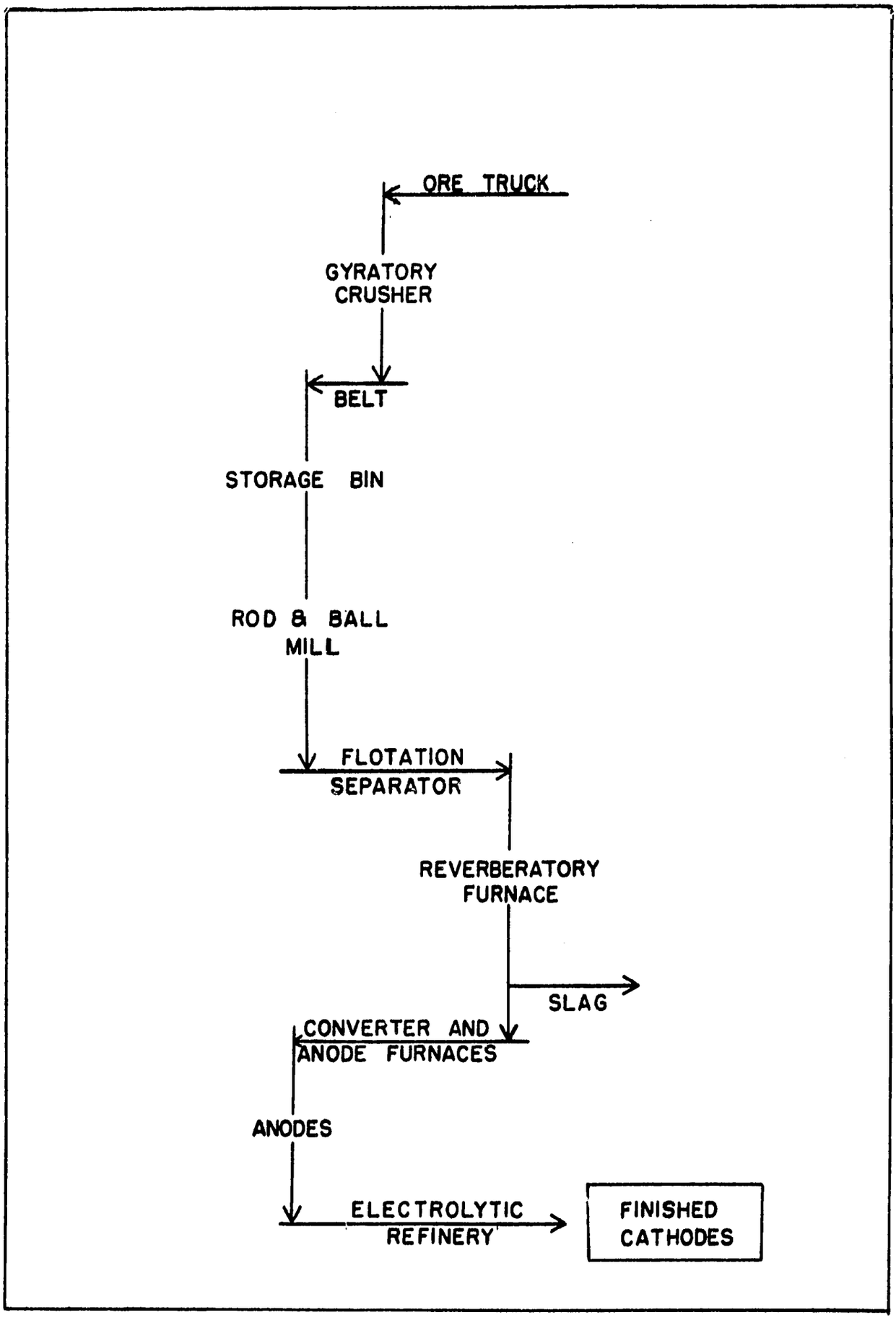

Figure 33 Processing diagram of low-grade copper sulfide ore

6. Vegetation and Wildlife

All mining operations toured in southern Arizona and northern Mexico are in the Sonoran desert zone. In Arizona the Sonoran Desert is most widely characterized by two shrub communities, the creosote bush communities and the palo verde communities. In addition the mining areas of Morenci and Bisbee (Arizona) and Cananea (Mexico) are located in the upper Sonoran Desert grasslands.

Of prime importance in mine rehabilitation is the re-establishment of native species in the disturbed areas. Copper mining and rehabilitation techniques used are similar to coal strip-mining operations, except that in the case of copper mining, rehabilitation is confined to the man-made soil of the milling process and soil overburden. In addition the unmilled waste rock removed from the pit holds little future for revegetation. It consists of rocks and boulders of assorted sizes which have little or no water-holding capacity or soil base on which to revegetate. To revegetate these areas successfully will require an artificial soil layer to serve as a plant base.

Procedures for rehabilitation should be specific for each situation within each broad vegetation type or zone. This will require a knowledge of the ecological structure and successional response that are characteristic of each site condition.

Characteristics fo identification of soil-plant response units or site conditions should include the physical and chemical properties of soils, the degree of slope and exposure and the dominant plant species present before disturbance. Most areas in the arid/semi-arid West are difficult to reclaim because precipitation is not only low but erratic. Without adequate and regular rainfall, vegetation rehabilitation from seeding experiences stress from intermittent rainfall, variable temperatures and evaporation.

Revegetation procedures should start with a good seed bed, and proper plant species to be seeded should be adapted to the site. Seeding on tailing dumps, as discussed earlier, is usually accomplished with a hydroseeder, which allows for the site to be seeded, fertilized and mulched in one operation. Table 1 provides a list of some common grasses, forbs and shrubs of possible utility in revegetating a Sonoran Desert type site. Most grasses would require a seeding rate of 10 pounds per acre or greater, assuming 90 percent germination.

Planting season can be variable in the Southwest. Mid-summer may be the best season to plant perennials because of the fairly dependable mid-summer and fall precipitation. In desert areas it may require as long as five years to establish new seedlings; grazing of such sites should therefore be delayed until the plants are well established.

TABLE 1

Common Grasses, Forbs and Shrubs

Common Name	Scientific Name
alfalfa	Medicago sativa
alkali sacaton	Sporobolus airoides
Arizona fescue	Festuca arizonica
blue gramma	Bouteloua gracilis
black gramma	Bouteloua eripoda
Canada wildrye	Elymus canadensis
four-wing saltbush	Atriplex canescens
needle and thread	Stipa comata
perennial ryegrass	Lolium perenne
sand dropseed	Sporobolus cryptandrus
sideoats gramma	Bouteloua curtipendula
western wheatgrass	Agropyron smithii
winterfat	Eurotia lanata

An example of revegetation of artificially created mine tailings was demonstrated at the Cyprus Pima Mining Company. Cyprus has emerged as the leader in southern Arizona for the revegetation of tailing dumps to enhance the local esthetics of the area. The need for this activity is especially critical in this case because of the nearness of mining activity to the resort community of Green Valley.

Revegetation of artificially created soils is not without specific problems. Mr. Ken Luedtke, a Cyprus agronomist, reported that the tailings upon which revegetation was occurring were alkaline because of the lime introduced into the milling process. In addition this material is contaminated with heavy metals such as copper, zinc, manganese and iron. Slope exposures and variations of the dumps create difficulties in selecting an uniform vegetation type that will prosper under all conditions. Stabilization of 1.5 to 1 and greater slopes is difficult prior to seeding, and lastly there is the purely operational difficulty of seeding large man-made structures which may extend from 20 to 30 meters in height and more.

The impact of wildlife was not assessed in depth on the mining tour; however, their impact on newly established reclaimed areas may be significant. Wild game and birds are attracted to the irrigated reclamation sites of remote mining areas. Browsing by deer and javelina account for the biggest stress on vegetation other than climatic factors.

7. Land Use

The overall regional land use of a potential resource development site should be described. Particularly attention should be devoted to the specific proximity of the site for existing land use, to avoid land use conflicts as earlier described for Bisbee and Morenci (Arizona). A possible classification scheme would include the following categories:

a. residential
b. industrial
c. commercial
d. public and quasi-public
e. open space
f. vacant
g. other

Proper planning prior to open-pit operations will be required to ensure the ore body delineated for mining, as well as dump sites, remains vacant of urban development. An example of such land use clash is in Morenci, Arizona where the entire town of Morenci was relocated to provide additional area for pit expansion. Waste material from the milling process and rock not milled must occupy large areas of open space. Projected dumping patterns and size must be accounted for to prevent company housing or other private developments from infringing on the area needed for orderly pit or dump growth.

8. Water

a. Water Requirements in Milling Processes

Water requirements for natural resource development is of prime importance in arid areas. In 1955 the Arizona copper industry used about 330 million gallons of water per day in the mining and manufacture of 500,000 tons of copper (Mussey, 1961). Assuming a linear correlation for water requirements, the State of Arizona utilized 388 million gallons in 1960 to produce 588,605 tons of copper (Gilkey and Beckman, 1963), and 600 million gallons in 1972 to produce 908,612 tons of copper (Bureau of Mines Minerals Yearbook, 1970).

Sulfide-copper ores, with copper content generally ranging from 10 to 100 pounds per ton of ore, are mined by the open-pit or underground method and are processed as shown in Figure 33. The various kinds of water needs in mining are shown in Table 2.

In flotation sulfide copper is recovered in a froth from a pulp containing suitable reagents and water in proper quantities. Optimum density of the pulp ranges from 15 to 40 weight percent solids. A 15 percent pulp contains 5.67 tons (1,360 gallons) of water per ton of ore and a 40 percent pulp has 1.5 tons (360 gallons) of water.

TABLE 2

Water Use in Sulfide Copper Ore Treatment

Mining:	Bank sprays
	Wet down haulage roads
	Leach and precipitate copper from waste dumps
Crushing:	Cool crushing machinery
	Collect and slurry dust
	Spray ore to minimize dusting
Concentrating:	Slurry the ore for grinding
	Particle size classification
	Manufacture milk of lime
	Flotation process
	Transport concentrates
	Transport tailings
Smelting:	Water jacketing for material protection
	Waste heat boilers for energy conversion and gas cooling
	Water sprays for gas cooling
	Water sprays and bosh tanks for copper product cooling
Acid plant:	Gas cleaning and cooling
	Process cooling

After Nebeker and Cooper (1973)

refineries outside the state. Water is mainly used in the smelter for cooling the reverberatory furnaces, converters and copper anodes.

Copper smelters generally utilize waste heat to produce electric power. The power plants require large amounts of water for condensing steam and smaller amounts for boiler feed.

Leaching, another method of recovering copper, is particularly applicable to low-grade oxidized ores. Three types of leaching are commonly used: (1) leaching in place, (2) heap or dump leaching and (3) vat leaching. Oxide-copper minerals are dissolved by a diluted solution of sulfuric acid. Some sulfide-copper minerals are soluble in a diluted ferric sulfate solution. Copper contained in the pregnant solution is precipitated by passing the solution over shredded scrap iron. The recovered cement copper is sent to a smelter. The copper may also be recovered by passing the solution through electrolytic cells, which have insoluble anodes. The product of the latter method is refined copper.

In leaching evaporative losses and seepage must be replaced by adding new water to the solvent. If ferric sulfate (formed by the action of water on certain sulfides) is present in the solvent, some of the solvent in the system may have to be removed to prevent an undesirable ferric ion build-up.

Table 3 illustrates the relative water requirements for the mining-flotation-smelting method of recovering copper and for the leaching-smelting method.

TABLE 3

Average Amounts of Water Required and Consumed

in

Producing Copper in Arizona, 1960[1]

	Total Intake		Consumption	
	Gallons/pound Copper	%	Gallons/pound Copper	%
Mining.....	1.1[2]	1.9	1.0[2]	11.1
Flotation concentrating	56.0[3]	96.2	7.5[3]	83.3
Smelting.....	1.1[4]	1.9	.5[4]	5.6
TOTAL.....	58.2	100.00	9.0	100.00
Leaching.....	29.7	96.4	15.1	96.8
Smelting.....	1.1[4]	3.6	.5[4]	3.2
TOTAL.....	30.8	100.00	15.6	100.00

[1] Excludes water required for power plants, domestic and miscellaneous purposes

[2] Based on average grade of ore mined

[3] Based on average grade of feed at concentrators

[4] Based on smelter output

From Gilkey and Beckman, 1963

Comparison of the figures in Table 3 reveals that the mining-flotation-smelting method requires about 80 percent more intake of water per pound of copper than does the leaching-smelting method but consumes only 58 percent as much per pound of copper.

Assuming a linear extrapolation of nine gallons of water consumption per pound of copper in 1960 to 1963 and 1972 production levels gives a consumptive use figure of 10,584 million gallons (32,460 acre feet) in 1963 and 16,344 million gallons (50,134 acre feet) in 1972.

Nebeker and Cooper (1973) have provided an in-depth overview of water requirements in a hypothetical 25,000-ton per day (tpd) grinding-flotation concentrator. The water balance of the concentrator is shown in Figure 34. An interesting point in the diagram is the water lost to evaporation and seepage, which accounts for 2,340 gallons per minute. This amount must be balanced by fresh water makeup. The largest amount of water loss (2320 gpm) occurs through mine tailing disposal and is the basis of most concern for potential water salvage at all mine sites.

Nebeker and Cooper (1973) provide an excellent narrative of the water balance, presented below as an explanation of Figure 34:

> "A typical ore received from the mine will contain about 5 % moisture which in our 24,000 tpd illustration amounts to 220 gpm of water. To the ore at the feed end of the rod mill is added about 1570 gpm of water so that the slurry in the mill and discharging from it will be at about 70% solids, by weight.

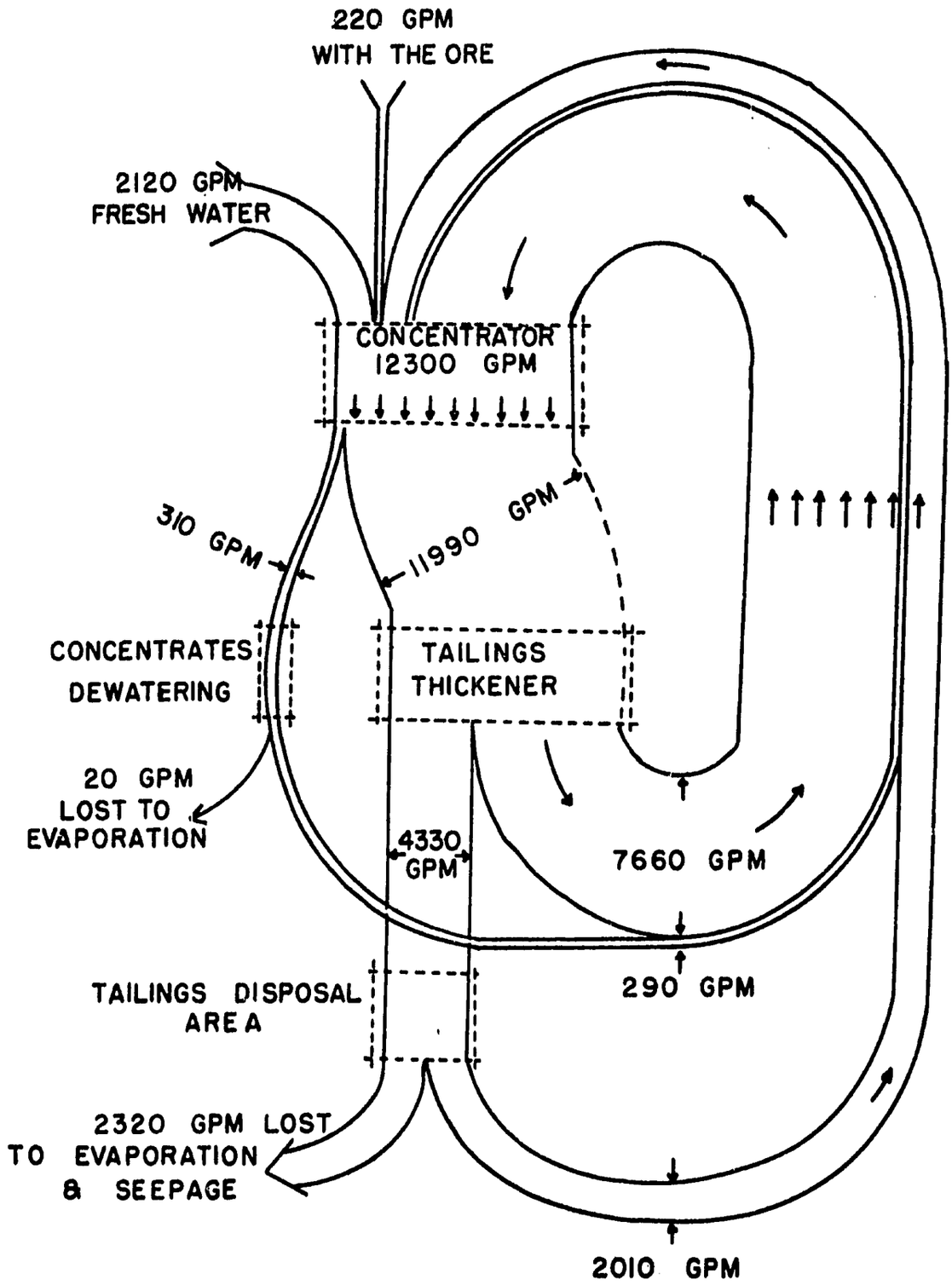

Figure 34 Water balance - 25,000-TPD concentrator

(After Nebeker, 1973)

"The rod mills discharge into sumps which also receive the discharges from the ball mills. To these sumps is added another 7060 gpm of water so that the cyclone classifier overflow which is the flotation feed contains about 32% solids, by weight. Miscellaneous quantities of water are added to the sumps and as washdown water launders in the flotation circuit, so that the concentrates will contain about 310 gpm of water and tailings from the flotation cells will contain about 8500 gpm of water. Clean up water, pump gland water, etc. will eventually reach the tail race so that the plant tailings will contain about 11,990 gpm of water. The total of all the process and cleanup waters put into the plant must equal those leaving the plant, and in this case they equal 12,300 gpm.

"A rough rule of thumb is that the total of all process and potable waters used in a concentrator will amount to about three tons of water or 720 gallons of water for each ton of copper sulfide ore processed.

"The tailing thickener consists of a large diameter, open-top tank in which the slurry is allowed to settle with clear water overflowing the perimeter for recycle to the concentrator and the thickened solids being raked to the center and drawn off at the bottom. The vacuum filters may be of

several types, but in general they consist of a cloth medium which deposits a filter cake or damp product containing perhaps 12% moisture. The water contained in the filter cake amounting to 20 gpm in the diagram is lost to evaporation in subsequent drying and smelting operations. The water drawn through the filter cloth joins the thickener overflow water to make up the 290 gpm of recycled concentrates water in the diagram.

"For the typical concentrator the tailings are thickened to about 48% solids, and 7,660 gpm of water are recycled to the process, leaving 4,330 gpm to transport the tailings to the disposal area. At the disposal area the final reclaiming of recycled water is accomplished by allowing the solids to settle in large ponds and the water to be decanted through decant towers, siphons or pumps for return to the concentrator.

"In the case of the typical concentrator, 2,010 gpm of water will be recycled, and 2,320 gpm will go to evaporation, assuming 100 acres of the disposal area is wetted down and 1,970 gpm will remain in the voids of the solids and cannot be decanted.

"Of the 12,300 gpm that the concentrator requires, 220 gpm or 1.8% of the requirement comes in with the ore, 9,960

gpm or 81% is recycled leaving only 2120 gpm (.4 ac. ft./hr.) of fresh water or 17.2% needed to make up for the losses. Assuming continual operation, 3500 acre feet would be needed per year as fresh make-up water."

b. Water Requirements in Electrical Generation Process

Mining operations in conjunction with a resident smelting capability usually allow for the generation of electricity through use of waste heat from boilers in the reverberatory furnace section of the smelter to generate steam for a steam turbine. Standard generating capacity for most power plants is approximately 30,000 kilowatts (kw). Consumptive water use of such a facility has been estimated by Durning (1975) to range from 17 to 20 ac.ft./ megawatt/year, or in the case of a 30-kw plant about 600 ac.ft./ year. This quantity is fairly insignificant when compared to the 2,300 gpm needed as fresh make-up water in the milling process. Yearly power plant requirements would provide about a 60-day supply of water in the milling process.

c. Water Requirements in Pollution Abatement Process

During smelting, dust, fumes and sulfur dioxide emissions are produced. Air pollution control regulations now require major reductions in emissions within the United States. Thus, smelters are being equipped with more particulate

removal equipment and plants are being installed to convert sulfur dioxide to sulfuric acid. Aqueous effluents result from such air pollution control devices. Smelter gases containing sulfur dioxide can be used as feed material for a sulfuric acid plant; however, the gases must be cleaned before use in the contact process. Each acid plant must be designed for the particular smelter-gas feed that is available. Battelle (1974) characterized the SO_2 emissions from reverberatory furnaces as having an SO_2 concentration of only 1 or 2 percent, which is below the three to four percent required for a contact acid plant. Thus, it is not feasible simply to add an acid to control all of the SO_2 emissions from a copper smelter. The SO_2 from the reverberatory furnace must be concentrated, or the furnace replaced by electric furnaces or the flash-smelting process, both of which produce higher concentrations of SO_2 emissions from a copper smelter. Concentrations of SO_2 from flash smelting are between 12 and 14 percent, which is suitable for acid manufacture.

The following problems were noted with respect to cost estimates:

1. The solids content of the water can vary from 200 ppm to 3 percent.

2. The amount of scrubbing necessary is a function of the efficiency of the gas cleaning device (usually an electrostatic precipitator).

3. The quantity of acid produced has only an indirect relationship to copper production. It is a function of the amount of off-gas treated and the SO_2 concentration in the off-gas.

Battelle handled these variables by the following assumptions:

1. Only the SO_2 in the converter gases is involved in sulfuric acid manufacture.

2. The quantity of SO_2 generated in the converting operation is about two tons per ton of copper produced.

3. Ninety percent of the SO_2 is converted to acid.

Using the above assumptions, Battelle (1974) calculated that a smelter producing 100,000 tons of copper per year produces about 513 tons of sulfuric acid per day. On the basis of data supplied by smelters on volumes of waste water produced by acid plants, an average value of 0.3 gpm/ton was calculated. This quantity represents an effluent volume of approximately 780 gal/ton of copper, which is approximately the same quantity of water required in the milling process.

Pollution abatement may double the water requirements of plant operation.

d. Water Supply

To meet these multiple requirements for water in the copper industry, available water supplies must be therefore assessed in relation to both immediate and long-term operational needs. In general, water supplies can be derived from one or more of three sources: surface water, groundwater or treated wastewater. Whatever the source, it must be evaluated in terms of its quantity, quality and availability (physical, economic and legal).

All these factors, along with the manner of water use during the life of the mining operation, will affect and/or be affected by some facet of the environment. Utilization of water from a surface-water source is illustrated by the supply conditions for the Phelps Dodge Morenci mine-mill operation in Arizona. In this instance water quality was not at issue, but problems arose regarding quantity and legal availability. The nearest apparent source of supply was streamflow in Eagle Creek --some seven miles west of Morenci. However, as mill capacity grew, this supply became insufficient. Development of additional water from this source was not feasible on a legal basis, because surface waters in Arizona are subject to the rule of prior appropriation. Priorities in the Gila River system (of which Eagle Creek is a tributary) had already been ordered under the Gila River Decree (1935) when the present operation at Morenci was begun (1937). The solution was to obtain water by pumping over a divide from Black River, a tributary to the Salt River, into the headwaters of Eagle Creek, through an agreement with the Salt River Valley Water Users' Association. Phelps Dodge constructed Horseshoe Dam on the Verde River, thus controlling additional quantities of flow for irrigation by the association. In return, the Morenci mine received credits for water to be pumped over to Eagle Creek.

After a period of years, however, this credit reserve also became inadequate to meet the mine-mill requirements. Similar augmentation was obtained, this time by diversion of flows in Show Low Creek, tributary to the Little Colorado River into the Salt-Verde headwaters, all of which inured to further water credits for the Black River pumping station. Yet another such trans-basin diversion, on East Clear Creek in the Little Colorado drainage, was more recently initiated.

This prolonged process of incremental development of water supply serves to illustrate the need for water resources planning in a time frame which considers the entire anticipated life span of the mining activity.

In arid or semi-arid regions such as those in southern Arizona and northern Mexico, the more common source of supply is groundwater. Evaluation and exploitation of the groundwater reservoir entail problems and considerations unique to this resource. Geologic and hydrologic field investigations commonly are necessary to define the nature and extent of the groundwater system and its relationship to the other components of the hydrologic cycle in the area of interest. Moreover, these factors must be extended through time to predict and evaluate the dynamic effects of pumping throughout the life of the mining operations.

A well planned program of groundwater exploration should yield sufficient data on aquifer characteristics and hydrologic conditions on which to base estimates of groundwater storage and permissible rates of pumpage. In the semi-arid Arizona-Sonora region observed in this study, two conditions commonly are encountered: 1) the rocks in the vicinity of the ore body are relatively impermeable and/or topographically high so that large supplies of groundwater can be obtained only from alluvial aquifers in the adjoining basins or river valleys; and 2) the annual rate of groundwater replenishment is relatively small so that heavy or prolonged pumping creates groundwater mining. These conditions are well illustrated in at least two districts studied: the Cananea (Sonora) district and the Tucson (Arizona) district.

At Cananea, two well fields have been developed in the basin-fill deposits near the headwater regions of the San Pedro River and the Rio Sonora. An average 6,000 gpm is pumped from these fields to the mining area where approximately 20,000 tons of ore per day is removed and processed. However, the mining company (La Compania Minera de Cananea) also furnishes domestic water supply for the community so that perhaps one-third of this pumpage goes to the public supply, the balance going to the mine at the rate of slightly more than 300 gallons per ton of ore.

The long-term capacity of the existing well fields near Cananea has become strained and development of new wells is not an easy matter because of the general lack of prolific production sites, but also because of competition for drilling permits. The Mexican federal government gives high priority to mining interests, but also grants high priority to water development by the nearby communal farms (ejidos) which are instruments of a long-range land reform program.

In the copper mining district south of Tucson, groundwater is pumped from the alluvial deposits of the adjoining Santa Cruz River Valley near Sahuarita for mine use. This aquifer is heavily overpumped because of multiple, competing uses in the same area. Large-capacity wells have been pumped for many years for crop irrigation and a well field also has been developed there for public supply by the City of Tucson. In 1969 a lawsuit was initiated against the mines by farming interests and the city later intervened on the basis of possible long-term pollution of groundwater supplies by return water from the mines. That suit is still pending at this time and the mining companies recently have taken an active interest in possible use of treated municipal wastewater from Tucson, as will be discussed below.

In the long run, another potential problem associated with groundwater mining is land subsidence and associated fissures. Where prolonged groundwater extraction occurs from alluvial materials subsidence is possible and if adequate lithologic data are at hand, predictions of amount of subsidence can be calculated and actual conditions should be monitored for verification.

In all districts where groundwater is produced, serious and expensive problems for the mining community can be avoided, resolved or at least predicted by the implementation of a continuing program of data collection or monitoring of rates of withdrawal, water-level declines, groundwater quality and other essential kinds of hydrologic information.

e. Sewage Treatment and Wastewater Reuse

In some instances, the assumed or inherited responsibilities of the mining company in a large, long-term operation have extended to providing domestic water supply and even to operating sewage systems for the surrounding or nearby mining community; in other places, the municipal agencies of nearby cities have undertaken these functions. In either case, if a sizable population exists, there will be a significant quantity of treated wastewater available which can be considered as an alternative water resource for mine use.

In urban areas such as Tucson, groundwater pumpage into the distribution system approaches 200 gallons per day per capita; roughly one-half of the input water is consumptively used by such activities as lawn watering; the remainder is returned to the sewage collection system and the treatment plant. In a quantitative sense, then, the significance of the treated effluent as a water source can be illustrated as follows: if wastewater is produced at the rate of 100 gpd/capita, and the mineral extraction and processing requires 500 gallons per ton of ore, for example, then each increment of 1,000 population yields enough wastewater for 200 tons of ore extraction. In the Tucson region, present wastewater production is about 40,000 acre-feet per year, approaching the total required annual pumpage for the mining complex south of the city.

This type of wastewater reuse has not received wide application, however, because of problems in wastewater quality and availability. Residual detergents and other materials in secondary effluent have posed an apparent problem with the flotation milling process. Recent research has been aimed at determining the type and cost of advanced treatment needed for general use by the mines. In regard to availability, there is economic competition among uses for wastewater, just as there is for other water sources. Existing irrigated crops near Tucson, for example, would receive not only their irrigation water requirement, but also their nutrient

requirement (available nitrogen and phosphorus) by application of secondary wastewater, and the cost of advanced treatment would be avoided.

Nonetheless, at any locality where mining activity is developing, it should be recommended in the planning process that wastewater be considered as a possible alternative source of water supply, at least for some uses.

9. Energy Requirements and Resources

Energy-availability (electricity, natural gas, oil, or coal) may serve to restrict natural resource development in many areas of the world. Energy demands in the copper industry, for example, have to date been predominantly met by natural gas and fuel oil. The scarcity of natural gas and the high cost of fuel oil, however, have forced recent attention to electricity as a means of maintaining production levels.

Most energy in the copper industry is consumed in the smelting phase of copper production. Here, 1500 ^{o}C furnace temperatures must be reached in order to melt the incoming ore. Air and fuel are blown in one end of a furnace and exhaust gases are removed at the other. Most of the heat in exhaust gases is recovered in waste heat boilers and used to produce electrical energy. Thus the electrical energy needed in smelting the ore is supplied as a by-product of the smelting process.

The U.S. Bureau of Mines (1975) conducted a nationwide survey of fuels and electrical energy requirements for mineral extraction and processing. The Bureau's findings in Table 4 provide the kilowatt hours equivalent per unit of production in 1973 for selected mineral resources. Copper production is broken into the mining and concentrating and smelting phases. Using four kilowatt hours (kwh) per pound of copper mined and concentrated and five kwh per pound of copper smelted, allows for an estimate of energy requirements for known copper mining production levels.

The 25,000 tpd mining operation of 0.6 percent copper ore as previously described has an energy requirement as shown in Table 5. These figures are based on pounds of copper milled and smelted, which in the case of the 25,000 tpd operation is 300,000 pounds.

Table 6 provides some factors used to compute kilowatt hour equivalents for other fuels commonly used; thus the energy requirements of the 25,000 tpd mill can be correlated with various fuel sources as shown in Table 7.

Table 4. Kilowatt-hours equivalent per unit of production in 1973, by selected mineral consuming sectors

Consuming sector	Production unit of measure	Kilowatt-hours equivalent per unit of production
Aluminum: (Largely estimated) 1/		
Bauxite (Mining and processing	Long ton.....	770
Alumina	Short ton	5,600
Aluminum	.....do.....	30,000
Blast furnaces 2/	.....do.....	5,400
Cement	.....do.....	1,760
Clays	.....do.....	900
Coal (bituminous and lignite)...	.....do.....	50
Coke	.....do.....	1,070
Copper:		
Ore and concentrate	Pound	4
Smelters	.....do.....	5
Ferroalloys	Short ton	12,800
Gypsum	.....do.....	750
Iron ore	Long ton	350
Lime	Short ton	2,200
Phosphate rock	.....do.....	190
Salt:		
Solar, rock, and brine	.....do.....	14
Vacuum pan	.....do.....	1,230
Sand and gravel	.....do.....	16
Stone (crushed and broken).....	.....do.....	14
Sulfur (Frasch)	Long ton	2,150
Zinc:		
Ore and concentrate	Pound	1
Smelters	.....do.....	10

1/ Includes estimates of fuels used by the aluminum industry to generate electricity as well as purchased electricity.

2/ Final data expected to be slightly lower when verified to eliminate duplicate reporting.

(From Mineral Industry Surveys, U.S. Bureau of Mines, May 7, 1975)

TABLE 5

Energy Requirements for a 25,000 tpd Copper Mine

Consuming Sector	Production lbs./day	Kilowatt hrs. equiv. per unit	Energy Requirement kwhr/day
Ore & Concentrate	300,000	4	1.2×10^6
Smelting	300,000	5	1.5×10^6

TABLE 6

Factors Used to Compute Kilowatt Hour Equivalents

Source of Energy	Units of Measure	Kilowatt hour Equivalent/unit of measure
Heavy fuel oils	Gallon (gal)	44
Diesel or light fuel oils	Gallon (gal)	41
Gasoline	Gallon (gal)	37
Natural gas	Cubic foot	0.302

TABLE 7

Daily Energy Requirements of 25,000 tpd Mill and Associated Smelter by Fuel Type

Consuming Sector	KW Hours	Energy Requirements: Heavy Fuel Oil gal/day	Light Fuel Oil gal/day	Gasoline gal/day	Natural cu ft/day
Ore, Concentrate	1.2×10^6	27,000	29,000	32,000	3.9×10^6
Smelting	1.5×10^6	34,000	37,000	40,500	4.9×10^6

10. Transportation

Transportation into remote areas assumes a high priority in large-scale resource development schemes. The necessity to convey large pieces of equipment and fuel to the site may create a heavy load on existing transportation routes. Narrow, winding dirt or gravel roads may have to be upgraded to ensure year-round access. In addition the resource product, whether raw or in finished form, must be moved from the site to the industrial centers where it will be utilized.

Basically the following transportation modes should be surveyed to determine their suitability and capability to meet estimated traffic demands:

1. Highways and feeder roads
2. Parking facilities
3. Rail service
4. Remote airstrips

11. Air Pollution

Air pollution levels in an area are related to the quantity of pollutants discharged into the air from various sources and the degree to which they are dispersed by mixing of the air. In defining the nature of air pollution in an area, the concentration levels for a number of variables should be described. Normally

these emissions are measured or are estimated using mathematical dispersion models. Table 8 provides an example of ambient air quality standards established within the United States.

TABLE 8

Example of Ambient Air Quality Standards

Pollutant	Annual Arith. Mean	Standards (micrograms per cubic meter) Max 24-hr. Concentration	Max 8-hr. Concentration	Max 1-hr Concentration
Sulphur Dioxide SO_2	80	364		
Particulates	75[1]	260		
Carbon Monoxide CO			10	40
Photochemical Oxidants				160
Hydrocarbons HC				160[2]
Nitrogen Dioxide NO_2	100			

[1] Annual Geometric Mean

[2] Max. 8-hour concentration

Code of Federal Regulations, Title 40: Protection of Environment, Wash 1973 U. S. Govt. Printing Office

The desirability of meeting these standards during plant design and subsequent operation may be tempered by energy availability, water availability, available technology and the design to maintain a higher plant efficiency.

The additional capital costs to "clean up" a plant's operation may well be outweighed by the need to keep these funds committed to full employment or other national needs.

In defining the nature of air pollution in an area, sources and quantity of emittents must be clearly defined. Sources commonly monitored in a mining operation are primarily the smelting emissions, and secondarily dust from the crushing and grinding of ore and from pit operations.

12. Summary of Unavoidable Impacts

The following section was taken from Clark and Matter (1974):

"For over 60 years Arizona has been the largest copper producer in the United States. Much of the economic growth of the state has historically been tied to the development of this mining industry. Over one-third of the dollar value of all nonferrous metals produced in the United States comes from Arizona's currently operating mines. At the same time large amounts of capital investment are being put into the location, testing and preparation for production of a number of new ore bodies within the state. There is no question that the people of Arizona and those of the entire country depend on the continuation of a

of a healthy mining industry in this area. Safeguarding this condition through careful planning and design becomes then a primary concern. At the same time it is also a concern of many of the residents of this state that the development of Arizona's mined resources be managed in a way that is in balance with a combination of other environmental pressures and demands on the areas surrounding the various mines. The extraction and processing of so valuable a natural resource as copper has not been achieved without paying a price in the disruption of certain aspects of other air, land and water resources. In short, a number of trade-offs have been made in the past in order to accommodate society's demand for a plentiful supply of copper. Today, however, we are confronted with a situation in which multiple demands are being made on all life-supporting resources. Many of these are non-renewable and many are becoming in short supply. It becomes apparent, then, that some of the trade-offs of the past are in need of re-evaluation.

In the category of land form and land utilization, the most visually prominent features of an open-pit copper mine are created by the disposal of immense quantities of waste rock and overburden in the areas surrounding the pit. The amounts of solid waste removed in search for copper ore can literally replace an area of natural mountainous terrain with a toally man-made landscape of equal dimensions and visability. Until recently the condition

of most of these waste piles has been regarded as a negative but necessary offshoot of the mining process and little has been done to modify or to take advantage of the effects of their presence on the surrounding areas.

Another element in the total land form with a visual impact similar to the waste dumps is that of the tailing ponds. One of the dams for these ponds can extend several miles in a horizontal dimension rising above the desert floor in an unbroken geometry that is emphasized by the grey coloring of the tailing material from form which it is built. The extremely fine sizing of this material when it is dry lends itself to problems of blowing grit over the surrounding areas. Considerable work has recently been initiated by various mining companies to study ways to stabilize this material through the establishment of vegetation on the slopes of the dams.

A third problem, not as visually apparent but perhaps with more long-term consequences than those of the land forms, has to do with the sizable quantities of fresh groundwater that are consumed in the milling processes of the mines and the eventual disposal of this water in the aforementioned tailing ponds. In the critical groundwater basins of Arizona, this is a resource that is under a multiplicity of demands. It is also a set of demands that frequently outstrips the natural recharge capacities of the region.

"These three areas of concern include some of the most significant environmental problems associated with the open-pit mine. They are generally responsible for a growing number of confrontations and restrictions that have beset the primary mining industry in Arizona."

V. Summary Guidelines for the Analyses of Community and Physical Environments: In Support of a Developing Natural Resources' Operation in Arid and Semi-arid Lands

A. The Community Environment

1. Land Use Planning and Socio-esthetic Guidelines

a. Land Use Planning Considerations

i. Advance preparation of a Regional Plan in conjunction with a Community Plan; in three dimensions

- Involve all pertinent parties in the planning process; town residents, mining company officials and all existing residents of the surrounding area
- Survey of all existing natural resources, air, land and water etc., and all social and cultural resources
- Project impacts of new development on all resources, social and physical

ii. New Community Location Considerations

- Distance of community from mining operations

  Safety of residents from pit and dump failure

  Adequate land for mine expansion

Removal of residents from the psychological impact of mining landscape

Removal from physical impact of mining, noise, air pollution, water pollution, etc.

Complete study of land ownership, land-leasing of the area to assure proper siting and expansion capabilities of the community

Moderate topography to allow automobile and other access

Relative flat area for large-scale commercial and industrial development

Some topographic variation for housing sites

Protection from natural elements: flood, severe winds, etc.

Adequate natural resources for both community and mining use, water, field construction materials

Good communications to other urban areas for both service and social reasons

b. <u>Socio-esthetic Considerations</u>

i. Physical Implications

- Encourage a diversity of regional building materials used responsively to local climatic factors
- Encourage competition in building contracting plus individual involvement in shaping the environment
- Discourage physical planning that reflects company management structure

- Discourage physical planning that separates new housing areas because of separate funding structures

- Provide for full community services at the earliest stages of community building

- Stage further community growth to allow for individual variations according to the changing times

- Plan from the start to redevelop mine waste areas with short-term vegetation and long-term plans for totally self-supporting reuses

- Protect the surrounding environment from potential pollution from tailing pond seepage and blowing dust by taking a positive view toward eventual multiple use of mined areas

- Exploit man-made mined landscape for tourism; recycled mine water for recreation, etc.

ii. Social Implications:

- Develop community governmental structure independent of mining company management

- Develop strong community planning agency, with adequate powers of implementation

- Develop good linkages with state and national governmental agencies (see section on political guidelines)

- Develop good company and town management communications

- Develop broad economic base for the town in anticipation of eventual mine depletion (avoidance of large scale relocation and upheaval)

- Allow residents to build equity in their own homes

- Encourage outsiders to settle in the community
- Plan facilities for residents of all ages, from the young to retirement age, to keep a balanced, self-renewing society
- Encourage independent competition in community commercial activities
- Encourage use of local work force for company-sponsored expansions of plant

2. Socio-political Guidelines

a. Socio-political and Economic Systems Considerations

i. The predominance of the mining company operating in a paternalistic, semi-closed political system

ii. A degree of political immaturity that diminishes problem-solving capabilities in the short-term and planning for the long-term.

iii. The mining town should be keen on keeping its political institutions and processes in good working order to ensure the existence of regularized problem-solving procedures and the nurturing of of information flows from exogenous sources.

b. The implementation of such goals implies several basic strategies

i. The establishment of semi-formalized and regularized meetings with mining company officials designed to involve both parties in the ongoing resolution of outstanding problems and also designed as a vehicle for continuing communication between the two groups.

ii. Ongoing and vigorous activity looking to the establishment and maintenance of linkages beyond the mining company on the state, regional and national levels with both formal governmental officials and agencies and other institutions and associations like leagues of cities and towns, universities and professional associations.

iii. The drafting and periodical revision of long-range plans involving a host of factors like employment patterns, projections of mine expansion or retraction, housing developments, educational projections, etc.

3. Socio-economic Guidelines

a. Inventory of Infrastructure

i. Description of the region's infrastructures

- Natural resources
  Locational resources
  Proximity to markets

- Environmental resources
  Climate
  Recreational opportunities

- Human resources
  Educational background
  Skill level and experience
  Employee performance
  Wage levels

- Institutional resources
  Educational institutions
  Governmental institutions
  Research and development activities

ii. Analysis of the region's infrastructures

b. Description of Project

i. Direct and indirect impact on local and regional suppliers of both goods and services

- What public and private sector goods and services will be required by the project itself

- Will the project demand water, sewer or fire protection services

- What local business services will be needed

- What will be the nature of demand for goods and services by new population

ii. Nature of the demand

- Length of stay, size of family, level of income and type of employee

c. Estimating the Impacts

i. By matching regional resources with estimates of new demand one can estimate new demand for:

- Schools
- Medical services
- Water, sewer, police and fire protection and other municipal services
- Consumer goods and other goods and services provided by the private sector
- Business services
- Housing

B. The Physical Environment

1. Environmental Assessment Guidelines

a. Description of the Project Area

i. General location

ii. Present ages

b. Description and Purpose of the Development

c. Probable Impacts on the Physical Environment

d. Probably Adverse Environmental Effects which Cannot Be Avoided

e. Description of needed Environmental Monitoring Prorams

i. Water quality

ii. Erosion

iii. Vegetation

iv. Air quality

v. Wildlife

f. Description of Alternatives to the Proposed Development

2. Relationship of Development to the Long-term Goals for Regional Development

VI. Summary Guidelines for Organizing an Interdisciplinary Team Field Study Project

A. The Conceptual Phase

1. Initial Identification of the Problem as It Is Conceived by Project Originators

   a. A clear statement of the overall goals of the project. This involves a sense of the scope of the problem and the level of detail and finality expected in the summary statement. Is it an open-ended or closed-ended project?

   b. Methodology of study best utilized to achieve the desired results. Should the project be conducted as a tight team effort or a loose framework of individuals?

   c. Identification of the cast of characters. In an interdisciplinary effort the participants should represent a balanced group of both hard and soft research disciplines.

   d. Identification of the type of support necessary for the functioning of the project team.

i. Space
ii. Equipment
iii. Funding
iv. Staff

2. Development of a Critical Path Outline, Interweaving Timing, Personnel and Support Systems

3. Development of an Advisory Group not Participating in the Field Study for Objective Consulation on Subsequent Decisions

4. Structuring Some Method of Final Evaluation and Utilization Plan for the Results of the Project

5. Structuring a Reward System for Project Participators

B. The Plan Development Phase

1. Research Team Organization

a. Definition of tasks and criteria for selection of the project leader and the team members.

b. Team Leader

i. Evidence of an overall understanding of the problem, its scope, needs and goals

ii. Freedom from prejudice to any one discipline in the conduct of the project; team leader should not try to be a discipline representative and team leader at the same time

iii. In a university structure the project and team leader should be free of allegiance to one particular department or college; they should answer to a larger group

iv. Must be capable of dealing with people and their problems and idiosyncrasies in an open and even-handed manner; be tolerant

v. Capable of allocating responsibilities for appropriate contributions from each member

vi. Initial responsibility for interpreting project objectives, ranking goal hierarchies and communicating these to all team members

vii. Comfort with his/her own identity and through good communications allow team members to establish comfort with their own role identities

c. Team Members:

i. Selection based on individual expertise and past experience

ii. Ability to communicate easily with others

iii. Open-mindedness to other ideas and value systems, willingness to learn from others

iv. Indications of personal sensitivity and respect for peers, tolerance of personal idiosyncrasies

v. Ability to adopt to unusual field conditions

vi. Persistence and motivation for interdisciplinary work; must be able to make a clear commitment to the project without allowing individual professional loyalties to interfere or subordinate project goals

vii. In many cases in a university structure younger members are better able to devote their time to an interdisciplinary project; are perhaps more adaptable personally and more willing to subordinate their own expertise to the project goals

d. General personality characteristics for all participants:

i. Personal and professional security

ii. Emotional maturity, objectivity

iii. Flexibility and open-mindedness

iv. Humility and sensitivity to others; willing to accept criticism

v. Desire to learn from other disciplines and to recognize the limitations of their own problem orientation; discovery-minded

vi. Creative imagination

vii. Likes to work with others

viii. Ability to adjust to unusual conditions

ix. Sense of humor

2. Research Team Procedures during the Plan Development Phase

a. Continued definition of the problem, its scope and needs; the project goals should be modified and sharpened by the team members as the team continues to be selected

b. Outline development for both long-range goals and specific objectives developed for short-term goals

c. Each team member should begin to understand his own purpose and his own output requirements

d. Outside consultants should be used to advise on team consolidation and goal modifications as additional information is gathered

e. Establishment of regular communication procedures between team members on an equal and open basis

f. Establishment of communication channels by each team member with outside sources on an individual basis regarding the project

3. Additional Comments on Development Phase Procedures Based on Current Experiences with the University of Arizona

a. Team selection within the University based on test of publications and experiences plus the verbal recommendations of peers. Due to the compartmentalized structure of the University prior first-hand knowledge of prospective team members is pratically impossible.

b. Generally the most active people are mentioned when recommendations are sought. Academically qualified but inactive people are overlooked. This tends to create academic jealousy.

c. Visibility and peer recommendation seem to be a fairly reliable method of personality selection for interdisciplinary work. Some caution must be exercised however in recognizing the potential difference between academic behavior and the ability to adapt to field conditions.

d. A University-wide organization to aid in the selection of qualified interdisciplinary team personnel would be of considerable help.

e. Adequate time will be allowed for a gradual selection process to modify personnel selections as the team is being molded. Including existing team members in the selection process facilitates better overall cooperation.

f. Final motivation for interdisciplinary work must come from the individual's desire to be exposed to new ideas and methodologies. Normal University reward systems will not offset team members' removal from the mainstream of their own disciplines. This could change with greater organization and recognition of legitimacy of interdisciplinary work.

4. <u>Management Organizational Plan</u>

a. All team members should be involved in the formulation of the management plan to assure a common understanding of the objectives and the methods used to achieve the desired results.

This also assures a better team understanding of the individual member's role in the process and a continuing understanding of the team's progress in the course of the project.

b. The plan should include an outline of the facilities and equipment needed, the supporting staff needed and the timing for the integration of all support facilities.

c. The plan should include methods for the control of project funds.

d. In a long-range project the plan should include methods for the control of salaries and promotions to assure continued loyalty to the project.

e. The plan should include methodology for the review evaluation and modification of project goals through the action of an independent consulting body to the project.

f. The plan should include methodology for determining when the final project goals are achieved. This is sometimes quite hard to measure and the objective advice of the consulting group could be helpful in this area.

g. The plan should include a methodology for evaluation of an individual team member's contributions to the project's success.

h. The plan should include a procedure to measure the methodology used in the project against the project's success in meeting its stated goals. Available time and support resources should be balanced against goal achievement for an accurate assessment of project success.

C. The Field Procedure Plan

Need for a Team-training and Break-in Period

a. Exposure of the team to the region of study, the specific industry or process involved and a general briefing on the social, economic and legal environment of the project area

b. Exposure of the team to the field operations for general acclimatization to the working conditions

c. Exposure of the team to each other, in small doses

2. Setting Up Regular Field Routine

a. Continued definition of each person's individual role

b. Scheduling of daily operations; important for individual security to anticipate certain routines

c. Important to estimate personal capacities and overloads; need to schedule slack time for relief from intensity of new experiences

d. Need to schedule time for both team effort and for individual effort and rumination

e. Need for mutually agreed upon team self-discipline not as rules but as personal goals

f. Both the team and individual members should be responsible for outside contacts during the field work phase.

g. Need to stay current during the field work phase in work interpretation and recording

Field work
Personal recording
Review and discussion session
Reinterpretation and recording (not necessarily reflecting total agreement)
Planning for new field work

h. The above should occur on a regular, perhaps daily basis, keeping the entire team informed on progress and generating new ideas in the process.

i. Full-time participation is required by the team during this phase; fieldwork is a growth process shared by all, full of error, evaluation and continual adjustment.

j. Careful planning should not be confused with rigidity, one of the worst traits in field work

k. A draft report should be compiled in the field; this ensures fresh insights and the ability to fill in information gaps while still on the site.

D. Information Interpretation and Assemblage of Final Report

1. Continued schedule of team meetings for review and evaluations

2. Presentation of individual report drafts by team members

3. Redrafting and final editing by the project leader

4. Submittal of the final draft to the consulting group and to the project sponsor

5. Draft approval and preparation for final printing

E. Printing and Dissemination of Information

1. Final form of the report should be directed toward the best format for potential users.

2. Identification and dissemination to all potential users

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APPENDIX A

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5. Mr. M. P. Scanlon, Assistant to the Senior Vice President, Phelps Dodge Corporation, Douglas, Arizona.

6. Mr. Alex Bissett, Project Manager, Continental Oil Company, Florence, Arizona.

7. Major J. F. O'Belka, Florence, Arizona.

8. Mr. Bob Winkle, Operations Superintendent, Ray Division, Kennecott Copper Company, Kearny, Arizona.

9. Mr. Len Judd, Smelter Superintendent, Las Playas Smelter, Phelps Dodge Corporation, Las Playas, New Mexico.

10. Compania Minera de Cananea, S.A. de C.V., Cananea, Sonora, Mexico

    a. Ing. J. Ruben Velasco

    b. Ing. Ramon Ayala

    c. Ing. Roger Stern

    d. Lic. Erasmo Lozano

11. Sr. Jesus Ahumada Barreda, Presidente Municipal de Cananea, Sonora.

12. Consejo de Recursos Naturales No Renovables, Santa Rosalia, Baja California Sur.

    a. Ing. Kapadia

    b. Ing. Santos Carlos Arechegui

13. Lic. Alfonso Molina Ruibal, Universidad de Sonora, Hermosillo, Sonora.

14. Ing. Juan Jose Cervantes S. Professor de Tiempo Completo Depto. de Ingeneria de Minas, Universidad de Sonora, Hermosillo, Sonora.

APPENDIX B

Schedule of Field Operations

WEEK #1

Monday July 14

AM Orientation meeting University of Arizona,
PM Pima Mine Tour, Cyprus Pima Mining Co.
Discussion with Dr. Ken Ludeke revegetation expert.

Tuesday July 15

AM Meeting and preparations for field trip to Morenci and Bisbee, Arizona.
PM Travel to Safford, Arizona.

Wednesday July 16

AM Meet with Mr. John O'Neill, Manager, Morenci Branch. Tour of Morenci and Metcalf mines and smelter, Phelps Dodge Corp.
PM Discussions with community leaders in Clifton, Arizona.

Thursday July 17

Meetings with community leaders in Bisbee, Arizona, City Projects Director and Cochise County Planning Director.

Friday July 18

AM Meeting with Pat Scanlon Assistant to the Senior Vice President, Phelps Dodge Corp. in Bisbee, Arizona.
PM Return to Tucson.

WEEK #2

Monday July 21

AM Open for individual work on field reports.
PM Leave for Florence, Arizona.

Tuesday July 22

AM Meet Mr. Alex Bissett, Continental Oil Co., and tour facilities with Mr. Roger Palmenberg, Environmental Engineering.
PM Meet with Mayor O'Betka and community leaders from City of Florence.

Wednesday July 23

AM Open for group discussion and report work.
PM Travel through Miami, Superior and Globe.

Thursday July 24

AM Meet with Mayor of Kearny and with James Maize, Public Relations Director of Kennecott.
PM Tour Ray Mine with Operations Superintendent, Bob Winkle of Kennecott Copper Company.

Friday July 25

AM Visit Office of company town manager
PM Return to Tucson.

WEEK #3

Monday July 28

AM Leave Tucson for Animas, New Mexico.
PM Tour Phelps Dodge smelter and new company town of Las Playas with Len Judd, Smelter Superintendent and Pat Scanlon, Assistant to the Vice President of Phelps Dodge for Public Relations.

Tuesday July 29

AM Meet with Roger Stern, Assistant General Manager of Cananea mine in Cananea Sonora.
PM Tour Cananea mine and smelter with Ing. Ramon Ayala. Meeting with Mayor of Cananea Sr. Jesus Ahumada Barreda.

Wednesday July 30

AM Talk with community leaders in Cananea and visit company housing area.
PM Return to Tucson.

Thursday July 31 and Friday August 1

Open in Tucson for group disucssion and report work.

WEEK #4

Sunday August 3

Travel to Guaymas, Mexico.

Monday August 4

Spend day in Guaymas, in group discussion and report work.

Tuesday August 5

Travel to Santa Rosalia with Ing. Salas
Meet Mr. Chapalya, Superintendent of Santa Rosalia Mine.

Wednesday August 6

Tour underground mine in Santa Rosalia.

Thursday August 7

Return to Guaymas and Hermosillo for discussions at the University of Sonora with Mining Engineering Department and Vice President of the University, Lic. Alfonso Molina Rubial.