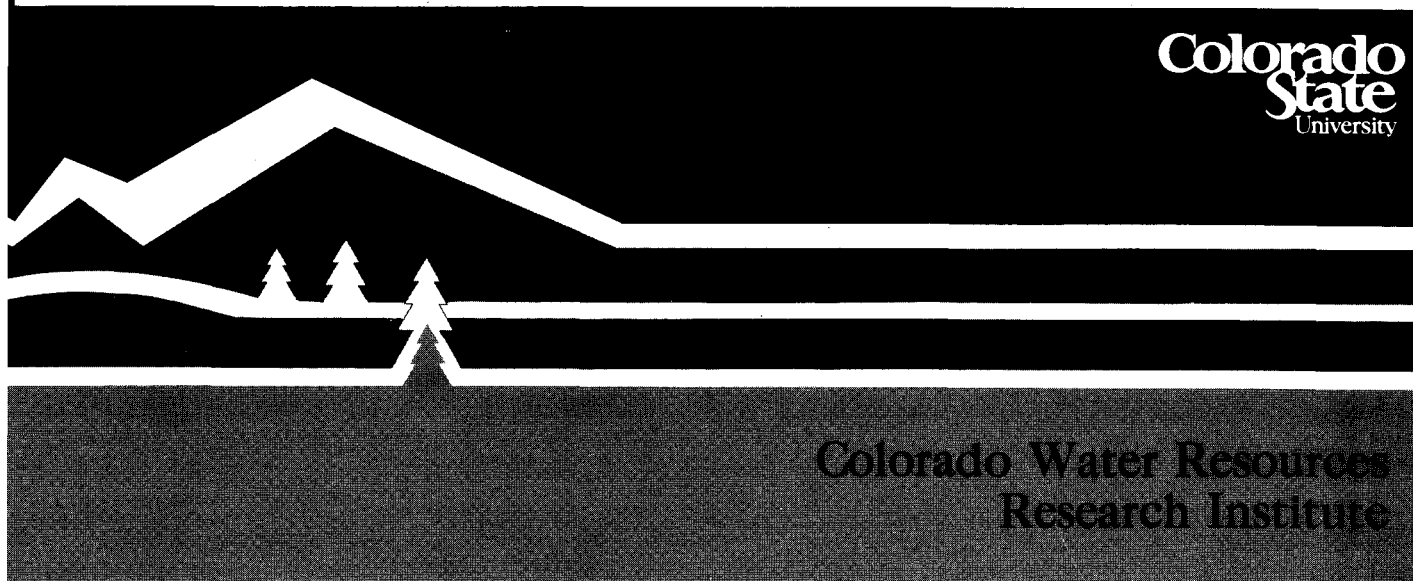


**PROCEEDINGS:  
HIGH ALTITUDE REVEGETATION  
WORKSHOP NO. 9**

**Edited by  
Warren R. Keammerer and Jeffrey Todd**

**July 1990**



**Colorado  
State  
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**Colorado Water Resources  
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**HIGH ALTITUDE REVEGETATION WORKSHOP**  
**NO. 9**

Colorado State University  
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Edited by  
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## **PREFACE**

The Ninth High Altitude Revegetation Conference was held on March 1 and 2, 1990 at the Marriot Hotel in Fort Collins, Colorado. The conference was organized by the High Altitude Revegetation Committee in conjunction with the Agronomy Department at Colorado State University. The conference was attended by a broad range of researchers, practitioners and government agency personnel from all over the country, and included representatives from four foreign countries.

Over the past 16 years, the High Altitude Revegetation Workshops and Conferences have focused on presenting information about research projects, case histories, new revegetation technologies, new equipment and innovative ways to reclaim disturbed areas in high elevation settings. The ninth conference followed this basic philosophy, and also included a session which introduced the ideas, concepts and practices of restoration ecology relative to high altitude revegetation.

The papers included in this proceedings are presented in the same order as they were given at the conference. In cases where final papers were not submitted, abstracts have been included. If you would like additional information about any of the papers, we encourage you to contact the authors.

We would like to thank all the speakers for participating in the conference. The time and effort they expend determine the value and success of our conferences.

Editors

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## Ecological Restoration: What and Why?

William R. Jordan III

I have two jobs here. One is to introduce the notion of ecological restoration into your ongoing discussion of land reclamation at high altitudes and to offer some ideas about what restoration is, how it is to be defined, and how it relates to other similar activities--such as reclamation, for example, or revegetation.

The second is to offer some comments on why restoration in a relatively narrow sense offers certain benefits that more generalized forms of environmental "rehabilitation" do not, and why this stricter conception of restoration ought to apply to work in environmental management--at least sometimes.

The first job is the easiest. The word "restoration" is a straightforward word that simply means to put something back into some prior condition, the connotation being that this represents an improvement over its present "degraded" condition. (It is perhaps worth keeping in mind that the word comes from the Latin word meaning to stand back up--as one might stand up a column that has toppled over, for example.)

Ecological restoration, then, is simply bringing an ecological system, whether conceived as an ecosystem, a community or a landscape, back into some explicitly defined prior condition following a period of degradation or deterioration.

The salient point, here is the explicit reference to a condition that prevailed at some time in the past. It is just this that distinguishes restoration in the broadest sense from other forms of land management, rehabilitation or reclamation, and it is also what distinguishes it from other forms of agriculture, which, though they may imitate natural or historic ecosystems in various ways, are by nature innovative and never aim merely to copy or reproduce them, as the restorationist does.

This idea is simple enough. But, as restorationists have learned, applying this idea to actual restoration projects in the field raises a number of questions. Of these, the one I want to concentrate on here is the question of defining the system for purposes of restoration: once you have decided to reproduce a landscape, say, exactly what about it, which of its features do you actually attempt to reproduce?

This question can actually be answered in various ways, with correspondingly various results. (Remember that when we attempt to restore any kind of system we are, in effect, cycling through

our consciousness--perception, abstraction, description, setting of specifications and development of a plan of action--and that the result is a test of that whole conscious process.) One can decide to reproduce function, for example, or structure, or dynamics--or even appearance. (One may, as Fred Turner has pointed out, aim to reproduce what the system is, what it looks like, or what it does. See "Restoration and Management Notes," 15(1)15, Summer, 1987.)

In general, these approaches vary in their level of abstraction. Function, for example, is a relatively abstract attribute. And in fact, you can restore certain functions to a system without getting any of the more concrete elements--populations of particular species, for example--back in place at all. Or you can bring populations of various plants and animals together to create the appearance of a natural system without attempting to recreate a functioning ecosystem or a dynamic community. (This is nowadays an objective at many zoos, for example.) Or one can try for the whole system: ecosystem, community and appearance.

It should be clear that all of these objectives are restorative at least in a broad sense, because all of them aim to reproduce an historic model. They differ only in which features of that model they aim to reproduce. Nevertheless, for our purposes in ecological management, I would suggest that the term "restoration" be applied only to projects in which the objectives are comprehensive--or at least as comprehensive as possible. In other words I think we should reserve the term "restoration" in ecological management to projects in which an effort is made to reproduce everything about the system that we can specify--all the functions we are aware of, all the populations, the dynamics, the appearance--and even, if you will, what British Ecologist Chris Barnes has called the "ghosts"--that is, the associations, the feel, the spirit of the place.

Projects with less comprehensive (and admittedly more realistic) objectives can go by other names with their various nuances: reclamation, rehabilitation, revegetation, reintroduction, and so forth, But I would prefer to see the term "restoration" reserved for those--perhaps often Quixotic--efforts that aim to reproduce--actually to copy--the whole system

(By this I do not mean, by the way, that the model system has to be rigidly or narrowly defined as it was at some particular moment in the past. Actually, the word "restoration" itself suggests such a narrow conception and is often associated with a sort of rigid purism as to model systems. What I have in mind, however, is quite the opposite; since the complete list of attributes the restorationist will be trying to reproduce includes dynamic attributes, the successfully restored communities will resemble their models even in the ways they change--in both the ecological and evolutionary senses.)



Now on to my second task, which is to offer some justification for insisting on this narrow conception of restoration, and for the contention that this form of restoration offers certain distinctive benefits, and that for this reason our reclamations and rehabilitations, our environmental management generally ought to be carried out in this way--at least sometimes.

Just what does restoration have to offer that other forms of environmental management and rehabilitation do not?

The obvious answer is it offers at least a commitment to a complete product (if not a guarantee of achieving it.) Projects with less comprehensive objectives obviously leave some things out--things that we judge to be somehow less important than those selected for reproduction, or perhaps things we are simply not aware of. Of course, even our best and most ambitious lists are incomplete, simply because we don't know everything. But at least the restorationist's lists are longer, and the restorationist is explicitly committed to checking the results against the model as best he or she can.

This, in landscapes dominated, or even influenced by human activities, is as close as we are going to get to the conservation of "natural" or historic ecological systems, with their relatively complex, highly adaptive function and structure and their relatively rich biodiversity. It is, in fact, the dynamic version of Aldo Leopold's often-quoted injunction to save all the pieces: don't just save them; see to it they get used--and so built back into the system, and so preserved.

This first reason, then, is purely "environmental." That is, it pertains to nature as an "environment," a collection of objects in the landscape, without reference to our relationship with them. And it is concerned exclusively with the product of restoration and not at all with the process, or with restoration as a human activity. To appreciate the other items on my list of reasons for placing a special value on the process of restoration in the narrower sense, it is necessary to go beyond a consideration of the products of restoration and to consider restoration as a process and--more than that--as a human activity, and to ask exactly what it signifies, or implies about us and our relationship with the systems we try to restore, and perhaps with nature in general.

When we do this, we begin to recognize restoration as a profoundly significant, richly rewarding activity with many values--so much so that I have come to think of it as nothing less than the basis for a healthy relationship between a culture or society and the rest of nature.

To explain, let me offer a list of benefits that we obtain from

our efforts to restore natural ecosystems--that is, constantly to be compensating for our influence on them.

1. Rehabilitation work has immense heuristic value--that is, it is a powerful way to raise questions and test fundamental ideas about the systems we try to rehabilitate. This is evident in the many lessons ecologists have learned about ecological systems directly or indirectly as a result of attempts to rehabilitate them. (This notion is explored in some detail in Restoration Ecology, a Synthetic Approach to Ecological Research, Jordan, Gilpin & Aber, Cambridge 1987.)

This value unquestionably applies to all sorts of rehabilitative efforts, including the most piecemeal and abstract. But it is only in attempting to reproduce the whole system that we confront in one way or another all the phenomena associated with it.

Restoration then, has a certain purely intellectual value that differs from and complements that of more general forms of rehabilitation.

2. Restoration, in contrast to other forms of environmental rehabilitation and management, demands a deliberate setting aside of matters of taste, creative impulses, costs, etc., that are extrinsic to the system in order simply and faithfully to reproduce the system--literally to copy it. This entails a measure of self-abnegation, whether personal or social, that is badly needed in a culture far too heavily weighted in favor of the individual, arbitrary manipulation, and perhaps in some sense even creativity. Restoration is an antidote to this--an exercise in humility, even in a sense a penitential act, a moral reparation for environmental abuse.

Obviously this is not true to the same extent of what I am calling rehabilitation, with the broad latitude it offers for selection, design, and invention.

3. Restoration, with its explicit commitment to historic models, provides a technique for the examination of change--specifically changes we ourselves have brought about in the past. It does this because it attempts to compensate for our influence in specific ways. This deliberate attempt to reverse anthropogenic change adds up to a kind of time travel, and an exploration of our relationship with the landscape. In this way it becomes a way of exploring and defining who we are in ecological terms--that is, in terms of our relationship to the system.

Thus the restorationist's rediscovery of the use of fire on our tallgrass prairies in the Midwest, for example, was more than the recovery of a technique, more even than the gaining

of a new insight into prairie ecology. It also added an element to our definition of ourselves both as a species (burners of the prairies in aboriginal times) and as a culture (we are the ones who ended the fires that maintained the prairies).

This obviously does not occur--at least to the same extent--in more general acts of rehabilitation.

4. In the same way, it provides not only the basis, but also the techniques for celebrating our relationship with the historic landscape. Again, our restorationists' fires are more than "prescribed burns." They are a demonstration of our interdependence with nature--a celebration of our emancipation from the role of observer of nature to that of participant--an active, influential member of the land community. What the burning means is that the system needs us just as we need the system. This in turn suggests that we do, after all, belong on this planet. And after a generation of doubt on this point, this is joyful, liberating news.

Ultimately this ability to reinhabit the natural landscape, to influence it in positive ways and to celebrate that relationship will prove critical to the conservation of these landscapes. Restoration, then, is not a marginal activity. It is fundamental--actually the key to conservation in any landscape, or on any planet, influenced by human activities.

5. In addition to providing us with ways to reinhabit the system ecologically, restoration provides us with ways of exploring and reenacting the history of our relationship with nature generally. Restoration entails not only the reversal of environmental influences (as in the case of the prairie fire), but the repetition of the phases of our relationship with nature that have occurred in the course of cultural evolution. The restorationist is hunter-gatherer, then farmer, then scientist. So restoration is reenactment, and a way of dramatically reexperiencing and reaffirming the broad range of human relationships with nature. In this way it provides a way of--as it were--coping with history, reconciling history and nature. This is something rehabilitation does only in a very loose sense.

In conclusion, what I am pointing out is that all acts are not only effective, but expressive. To achieve their full value, then, they must be read and interpreted, like a poem, a play, or any other expressive act. What this means is that the value of the act depends not only on what it produces, but on what it expresses or signifies, and we must consider this when evaluating--or inventing--such an act.

From this point of view, the act of restoration in the narrower

sense I am insisting on has a certain significance that other, more generalized forms of environmental rehabilitation do not have. For this reason alone, restoration deserves a special place in our repertory of strategies for environmental management.

Dr. Jordan is manager of broad outreach and publications at the University of Wisconsin-Madison Arboretum. He is editor of the journal, "Restoration and Management Notes," and a founding member and member of the Board of Directors of the Society for Ecological Restoration. His address is: University of Wisconsin Arboretum, 1207 Seminole Highway, Madison, WI 53711; phone 608-263-7889.

## LARGE SCALE USE OF WILD HARVESTED LOCAL SEED

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At a revegetation site where habitat restoration is a priority, the re-establishment of the original natural diversity is generally considered of fundamental biological importance. Additionally, restorationists often value diversity for at least three other reasons which may be shared by managers of other types of revegetation projects:

- 1) Diversity in the seed mix provides different species for the different microniches within a site. Within a central Texas site there is usually significant variation in topsoil amounts and type, depth to bedrock, moisture retention and shade, both in undisturbed habitats and at restoration sites,
- 2) The potential for good short term coverage is increased since a diverse seeding mixture is more likely to contain some species which respond best to which ever weather conditions occur during the first year and to possible variations in the seeding date because of construction delays. These two variables have caused significantly different growth and composition patterns from essentially the same diverse seed mixes at several restoration sites in central Texas.
- 3) Diversity usually provides a more aesthetically pleasing result with a much wider array of flowers blooming at various parts of a single growing season and a more permanent aesthetic appeal as a site shifts from annual to perennial flowers.

Because of the commercial unavailability of the many species which could be used on restoration sites, especially locally adapted varieties, harvested wild grown seed must often be an important component of a diverse restoration. The two most frequently utilized methods of harvesting wild seed, the combine and hand harvesting, will always remain important. However, combines are highly efficient, but very unmaneuverable, whereas hand harvesting has exactly the opposite characteristics.

A number of harvesting devices have been developed over the years with intermediate characteristics. Seed strippers, ranging from homemade wooden horse drawn boxes to manufactured modern tractor drawn pieces have been used primarily for the harvest of chaffy grasses. A simple box and reel stripper, front mounted on a jeep was developed and

used by the USDA in Utah. Harvest equipment developed and currently in use by Fred Faessler and Steve Apfelbaum of Applied Ecological Services, Inc. of Wisconsin is similar in principle. It consists of a street sweeper-style brush mounted on the front of an all-terrain vehicle which sweeps the seed heads into a bin. The height of the brush is adjustable. They have mounted the vehicle on half-tracks which reduces the ground pressure to 0.4 pounds per square inch. It is usable in rugged terrain and wetlands with minimum impact on the surface. Several other forage harvester devices have also been developed which collect all the material they cut, but which are designed for use on level cropland.

Environmental Survey Consulting (ESC), a small research and restoration business in Austin, Texas, has developed two mechanical seed harvesting devices, the Grin Reaper (U.S. Patent # 4,722,139) developed in 1985 and the Front-end Tractor Reaper developed in the fall of 1988, which have been especially useful tools for efficient harvesting of wild seed.

The Grin Reaper is a box-like attachment for a rotary line trimmer (weed-eater, etc.) which collects the material cut during operation. The aluminum box attaches to the shaft and surrounds the cutting head of the trimmer. The box is made by bending a 35 cm. by 180 cm. (14" x 72") piece of .1 cm. (.04") thick aluminum into an approximately triangular shaped box, which is open front and back and braced with aluminum tubing. The shaft of the trimmer goes through the top of the box, with the cutting head placed just inside the front opening of the box, near the center of the bottom. During operation the seed heads which are cut by the spinning string line are funneled by the box into the canvas bag attached to the back opening of the box. The result is a reaper that is highly maneuverable and fairly light, with the box and bag adding only 3 kg. (6 lbs.) to the weight of a commercial string line trimmer (approximately 6 kg. or 12 lbs.). The bag holds about 30 liters (one bushel) of cuttings, which are removed through a drawstring opening at the back of the bag. With this equipment, operators can harvest seed wherever walking is possible, even in steep, rocky or brushy terrain. This allows for selection in cutting, therefore avoiding unwanted species.

ESC's models have been improved with modifications inspired by hundreds of hours of field usage. Small-scale production of our latest test model has begun. This model will attach to most common brands of gas-powered trimmers, either straight or bent shaft.

The Front-end Tractor Reaper is a box 2.29 meters wide, 76 centimeters high and 1.52 meters deep (7.5' x 2.5' x 5') which is mounted on the loader arms of a tractor, replacing the loader bucket. A cutting bar from a sickle bar mower is mounted on the bottom front of the box, and a reel is mounted on the top front. The cutting bar and reel are powered by separate hydraulic motors mounted on the box. A hydraulic pump, with a 55 gallon reservoir of hydraulic fluid is mounted at the

rear and driven by the rear power take-off shaft. Hoses with variable flow control valves connect the pump to the hydraulic motors in front, allowing for separate control of the speed of the cutting bar and paddles. The Front-end Tractor Reaper is relatively maneuverable and is usable on land significantly rougher than crop land. In the central Texas hill country it can be used to wind between trees on the relatively level topographic benches. The height and tilt of the box can be constantly adjusted, lifting over rocks, stumps or patches of undesirable species. When the box is full it is unloaded by tilting the box vertically and releasing a trap door at the rear of the box. The cut material might be compared to a seed hay, but this device has the advantages of operating in habitat too rough for haying and also of collecting all the material as it is cut without the large loss of seed inherent in cutting, raking and bailing hay.

Both of these devices are efficient for the harvest of single species in large colonies, but their capacity to harvest an assortment of seed is perhaps even more useful for restoration. When used in a diverse habitat, the harvest can emulate the variety of species which are producing seed at that time of year. When this process is repeated at different times of the year in the same habitat, the seed harvest can mimic the seed production of the habitat. In our utilization of this equipment in central Texas on a typical day, one collection will often contain 30-40 species with large quantities of the dominant species, smaller quantities of the scattered species, and traces of the less common species.

The material collected by both these devices is made up of the tops and seed heads of the plants. We shred this material with a tractor-powered shredder to release the seed from the sheaths and heads and to create a mixture of manageable particle size for later seeding. No attempt is made to separate seed from the chaff and straw because of the wide variation in seed size and weight in a typical mix. This material has been seeded by hand and harrowed with a chain mat harrow. Preliminary tests indicate that a Truax drill seeder, which contains a picker wheel at the bottom of the seed hopper, can be successfully used to seed the shredded material.

Use of these wild harvested seed mixes, sometimes combined with commercial seed has produced significant diversity on restoration sites in central Texas. These sites have ranged from quarter acre residential sites to a 40 acre road side. More than 50 species have become established from seed at many of our sites. However, the utilization of these unquantified seed mixes has been primarily on sites where our firm has designed and installed the restoration or had significant impact into the design. While the common species in some of these mixes can be quantified, the better the mix in respect to diversity, the more complicated and costly it is to quantify. There is also a greater unpredictability as to the composition of the wild harvested mixes from year to year than there is with commercial seed. These factors make it difficult for engineers to develop specifications, for agencies to bid

contracts, and for inspectors to certify results with this type of approach.

Therefore, the most immediate applications for this process is where the design of a project and the harvest, processing and application of the seed are all performed by the same agency. Within this type of project, the utilization of wild harvested seed mixes is economically feasible. The formalization of this process, which would be required for many large scale projects, will have to be based on the quantification of these "green thumb" applications. The challenge will be to do this without unreasonably raising the cost or diluting the diversity of these seed mixes.

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ENVIRONMENTAL ISSUES OF SMALL UNDERGROUND  
GOLD MINING

by Thomas S. Hendricks  
President-Hendricks Mining Co.

A brief historic overview of Colorado's small mining industry will be presented; why men and women are attracted to it will be explored. Small mining presents many challenges, including physically demanding work, expertise in many areas and working at high altitude environments while producing raw metals such as gold, silver, lead, zinc and copper. The small mining industry is highly regulated by a number of permitting agencies, including the Mine Safety and Health Administration, the Colorado Division of Mines, the State Health Department and the Mined Land Reclamation Division and local and state zoning laws.

The economics of small mining are very complex and costly. The unpredictability of veins, and location and cost of exploring and developing them can be astronomical. Metal prices are cyclical and are based on supply and demand from world-wide economies. Compared to other mountain industries, small mining has become an almost nonexistent industry. However, the mineral wealth potential in Colorado is tremendous, particularly that which could be developed by small scale operations. Small mines are classified as those which produce 100 tons per day or less of ore and employ 25 or fewer.

Hendricks Mining Co. has been operating the Cross Gold Mine at Caribou since 1973. The Company has always maintained a strong commitment to both in-house and outside environmental issues. In 1988, the Company received an award from the Mined Land Reclamation Division and Governor Romer for designing and building a water quality treatment system. Future waste rock, which is high quality granite gneiss and quartz monzonite, will be crushed to road base material for use on county roads in the mountain area. This procedure will eliminate creating any additional mine dump areas and will save Boulder County money and reduce truck traffic by hauling similar gravel up from the Front Range. The Company is also designing and engineering plans for future construction of a plant to filter tailings sand, agglomerating it with Portland cement, making pellets and air-injecting them back into areas mined. This accomplishes many environmental procedures, including the elimination of a tailings pond and permanently stabilizing underground work areas and eliminating any water quality problems. The Company also maintains neat and clean facilities.

Several of the new veins located by high tech core drilling have been named after native American Indians. The Company recently made a donation to the Mescalero Apache Indians since mining has just recently commenced on our new Apache Vein system.

Concentrates from the operation are shipped to the most environmentally advanced smelter in North America which is located at Trail, British Columbia.

Worker safety and concern for worker's environment is also of paramount importance. Thomas S. Hendricks and Hendricks Mining Co. maintain memberships in a number of environmental organizations, including Greenpeace, the Cousteau Society and the Sea Sheperd Society. The Company also participates in community projects in the Nederland area, including help on the construction of the Nederland trail project. The Company has provided working mine tours for thousands of people from around the world, including education groups, a delegation from China, Argentina, several Pacific-rim countries, Russia and political figures, i.e., Senator Tim Wirth and Congressman David Skaggs.

Hendricks Mining Co. believes that we can emerge into a highly civilized advanced space age society during the twenty-first century where the production of raw materials and the environment can co-exist. The Company has seen several instances in Colorado where more money has been spent between major corporations and government agencies litigating existing environmental issues than

the actual cost of cleanup. This is absolutely unnecessary and could be eliminated by face-to-face round table discussions at the onset that would produce positive results.

## HISTORICAL PERSPECTIVES ON THE REGULATION OF MINE WASTES

Thomas E. Root  
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### I. Introduction

On January 9, 1990, the educational television series NOVA presented a program entitled Poison in the Rockies. Putting aside the technical and factual merits and demerits of the program, a matter over which there is continuing debate, there can be little doubt that the program hit upon a topic that is of widespread general interest - mine waste and its environmental impact upon life in the West.

At a time in the development of environmental law when the area continues in a state of flux - laws are proposed, regulations adopted, revised and reinterpreted, and cases are reported - it is appropriate to reflect upon the problem of mine waste currently before us, how we came to stand in our current position, and what methods to address the problem were in place prior to adoption of current structures. If we ask ourselves, "What does history have to tell us," I would reply that there might be experiences in the past helpful to us in solving our difficulties. If not totally adequate, we might at least find some help from how our forebearers thought about the problem. As Justice Oliver Wendell Holmes of the U. S. Supreme Court once wrote, " . . . A page of history is worth a volume of logic." (New York Trust Co. v. Eisner, 256 U.S. 245, 349 (1921))

### II. Reference Materials

A starting point for an historical review of regulation of mine wastes is identification of sources of information on the topic. One starting point is a paper which a colleague and I wrote for the Rocky Mountain Mineral Law Foundation last summer entitled "THE LAW OF MINE WASTE: A PRIMER, Mine Waste From Agricola to CERCLA and Beyond" (35 RMMLI 8-1 (1989) hereafter "paper"). That paper addresses, from a technical viewpoint, how waste is generated, identifies legal and technical definition of waste, and then proceeds to detail how mine waste was "regulated," first, under the common law of tort and real property, second, as addressed by legislative, judicial and administrative approaches from 1872 to 1976, and, third, under major waste/environmental statutes, such as the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) from 1976 to date.

A second source of information is the proceedings of an American Bar Association workshop, co-chaired by the author, entitled "COMPREHENSIVE WORKSHOP ON RECENT DEVELOPMENTS IN ENVIRONMENTAL ISSUES FACING THE MINING

INDUSTRY." The workshop was held in Denver, Colorado, on October 5-6, 1989, and the proceedings contain papers addressing mine wastes from coal and metal mining, air emissions related to mining, technical issues at inactive mines, Superfund issues at inactive sites, the Bevill Amendment to RCRA, and uranium mine and mill wastes. (It is available from the American Bar Association in Chicago. If anyone is interested, they should contact the ABA at (312) 988-5625, ask for Barb Smith, and request a copy of the workshop proceedings.)

Having addressed the reasons for studying the history of mine wastes and having identified information which is available on legal treatment of mine wastes, we move to the subject matter - historical perspectives on the regulation of mine wastes. Before doing so, however, it is worth mentioning that this paper will not be as exhaustive as the paper we delivered last summer. Rather, it will be a brief summary of how laws addressed mine waste prior to the time when the current framework was put into place. For details on the present statutes, the paper should be consulted.

### III. Common Law

The Common Law approached mine waste from the dual perspectives of tort and real property, a distinction in the early stages of which is best left to legal historians. The Common Law initially developed in the period of time before the advent of active government involvement in day-to-day doings of society. Consequently, its focus was upon the rights and responsibilities of individuals.

In the area of tort, it imposed obligations upon the owners or possessors of property upon which mine waste was to be found. If waste from one property did damage to another property, the owner of the first property was liable for those damages to the owner of the second, in an action for trespass.

In a situation where there was an invasion of one's property, which invasion was unreasonable, the action would be one for nuisance.

While these two major actions were Common Law tort actions, the difference lies in the relief one could obtain from a court. In the first action, that of trespass, one could obtain money damages for the damage done. In the second, nuisance, one could obtain an injunction against any further invasion, if irreparable harm could be shown.

This too brief review of the Common Law reveals, as noted above, that it involved a contest between individuals. One party, the plaintiff, needed to show injury or damage to person or property, or irreparable harm thereto, resulting from some action or circumstance attributable to another individual, the defendant.

Notions of the public interest did not occupy center stage at Common Law. While it should be noted that the Common Law did develop a complex

body of learning on requirements and obligations related to severance of minerals from the surface, obligations owed between owners of the severed estates, rights of title to ore in place and after severance, and liability in tort for escape or release of material from one's own property, it was not until legislation began to play a dominant role in lawmaking, replacing judge-made Common Law, that principles of public interest emerged.

#### IV. Legislative, Judicial, and Administrative Approaches to Mine and Mine Process Waste from 1872 to 1976.

##### A. The General Mining Law of 1872.

Although there was significant mining in the United States prior to 1872 (the lead mines in Illinois and Indiana, the gold mines in North Carolina, the Appalachian coal mines, and the rushes of Pikes Peak, Sutter's Mill, and the Comstock Lode of Nevada, to name a few), it was only with the General Mining Law of 1872 that Congress enacted a law of general application to the public domain, a land area of constant interest to those living west of the 100th Meridian. The reason for this interest is not hard to find: 36% of Colorado, 31% of New Mexico, 49% of Wyoming, and 30.5% of Montana are owned by the federal government (Denver Post, January 14, 1990, p.5-11). Given that in 1872 the United States had not yet completed settlement of the interior of the United States with states (not to be "accomplished" until admission of New Mexico and Arizona and 1912), the emphasis of national policy was upon occupation and development of the Interior, as that term was understood at the time.

Consequently, it is not surprising that the General Mining Law of 1872 contained no direct mention of treatment of mine waste. In fact, the '72 law was not a regulatory law as we understand the term today. It was a property disposal law governing how one could obtain mineral land from the United States. It did not "regulate" how mining activity was to proceed, except with regard to activity which would demonstrate that a property did, in fact, contain mineral values (which would justify the expenditure of time and money by a prudent man in developing a paying mine).

The 1872 law addressed mine waste obliquely, allowing one to patent a mill site claim upon which ores could be processed, but again, there was no mention of mine waste per se.

However, mine waste was not entirely ignored during the period of laissez faire government. Toward the end of the century, a number of cases were decided which seem remarkably contemporary both as to how issues were framed and how those issues were resolved.

## B. The Debris Cases

In Woodruff v. North Bloomfield Gravel Mining (18 F. 753 (C.C.D. Cal., 1884)), the plaintiffs wished to stop North Bloomfield from discharging mine waste into the Yuba River.

The case involved hydraulic mining, a technique which has passed into history but which is worth noting if for no other reason than to acknowledge the fact that concern with the environment did not begin with Earth Day in 1970, but had developed to such an extent that by 1898, opponents of this method had worked to achieve a de facto ban on mining by this method. (For a discussion of the activity at the time of Earth Day 1970 and the enactment of the National Environmental Policy Act, see Caldwell, NEPA Revisited: A Call for a Constitutional Amendment, the Environmental Forum, Vol. 6, No. 6, 1989, p.18.) This ban resulted from the inter-action of the courts, the legislature, Congress, and administrators in California.

In Woodruff, the court described hydraulic mining as a process by which riverbanks were excavated by jets of water. In that case, over 100 million cubic yards of riverbank had been jolted loose into the Yuba with over 700 million more cubic yards planned to be so mined. The streambed was filled with debris for 75 miles, up to a depth of 150 feet.

The state court enjoined North Bloomfield from its activities.

In response, North Bloomfield constructed cribs to contain the debris, and began to mine again by the hydraulic method.

Thereafter, the federal government brought an action to enjoin North Bloomfield (53 F. 625), alleging that the debris which escaped the cribs impaired navigability of the Yuba. (Note that navigability of interstate waterways was one way in which the federal government could get involved in those days of limited federal authority in state matters.) The federal court practiced such restraint that it refused to enjoin the activity, finding that the danger to navigability was " . . . so remote and improbable [given the construction of the cribs] that the court is not justified in enjoining the use of property." (55 F. 625, at 632 (1892))

By this point, a state court had enjoined mining under state law until the cribs were built, and then a federal court refused to enjoin the activity on the ground that navigability was not impaired. Note, historically, that there was no acknowledgement of the effect of the material on water quality or aquatic life as grounds for the injunction. Mining continued.

On March 1, 1893, the U. S. Congress became involved, in response to the federal court's refusal to issue the injunction by passing an act "to create the California Debris Commission and regulate



hydraulic mining in the State of California" (27 Stat. 507). The act established a commission over hydraulic mining within the Sacramento and San Joaquin River drainages in California, required a permit to mine by that method, and provided for penalties if such activities were conducted without a permit.

After passage of the statute, the United States went to court to enjoin hydraulic mining by North Bloomfield without a permit (U. S. v. North Bloomfield Gravel Mining, 81 F. 243 (C.C.N.A. Cal. 1897)). The court issued an injunction which was later upheld by the Ninth Circuit Court of Appeals (88 F. 664, 9th Cir. 1889).

As noted in the paper:

Thus the regulation/prohibition of hydraulic mining evolved from trial of rights between individuals, to application of a technological remedy to the problem, to enactment of a statute, to a constitutional clash between private parties and the federal government over the authority of the federal government to prescribe terms and uses of the nation's waters, and finally to the Federal Court of Appeals, which upheld federal regulatory authority.

The Debris Cases identified a weakness in the mining law which required attention, i.e., that a courtroom resolution of private property rights in conflict under a land disposal law was inadequate for resolution of public policy disputes. The resulting legislation (which required fact finding by a commission, granting of permits to act within specific limitations, and enforcement of administrative action by judicial power) addressed this gap.

Subsequent to the Debris Cases at the turn of the century, Congress did not continue to address mining waste on the public domain with the specificity of the California Debris Commission statute. Rather, it addressed problems from a general property perspective, given its role as owner and potential lessor of the public domain.

#### C. Coal and Oil Land Withdrawals; the Mineral leasing Act of 1920

Federal ownership of the public domain, with its treasure trove of minerals, forms the basis of control of federal lands west of the 100th Meridian. Concern about the misuse of those lands was voiced at the turn of the century by "conservationists," the ideological ancestors of today's "environmentalists." The concern of the conservationists was that the General Mining Law neither controlled how much land one could take up for mining nor did it control how minerals were to be extracted. This resulted in the general dual fears that we as a nation could run out of oil and that coal would be monopolized in

a few hands. Therefore, the critics of unfettered mining reasoned, resources should be "conserved." Under Theodore Roosevelt, this concern with "waste," in the sense of irresponsible exploitation, took the form of withdrawal of federal coal lands, and later, led President Taft in 1909 to withdraw over three million acres of land valuable for oil in California and Wyoming under Temporary Petroleum Withdrawal Order No. 5. The President's authority to make this withdrawal was immediately challenged in the case of United States v. Midwest Oil Company (236 U.S. 459, 1915). Before that case could reach the Supreme Court, President Taft, concerned that he had exceeded his powers as President, urged enactment of the Pickett Act thereby avoiding a constitutional clash over inherent authority of the President to withdraw public lands from entry, on the grounds that Congress had acted pursuant to its constitutional power to make needful rules regarding the public lands.

The situation, however, was not clarified because the question of inherent Presidential authority and the policy of "conservation" remained muddled. In 1920, Congress acted to clarify the situation somewhat by passage of the Mineral Leasing Act (30 U.S.C. § 184, et seq.). That act, among other things, eliminated applicability of the '72 Mining Law to phosphate, shale, oil, gas, and coal and some other minerals; limited acreage which could be held; provided for rentals and royalties as well as other lease terms; and eliminated the mineral patent for leasable minerals.

Thus, by 1920, concern with the waste of minerals had some statutory expression. Note, however, that "waste" was understood as a question of extravagant exploitation and was not understood as regulating to end product of the mining or drilling process.

The field lay dormant for the next 34 years - a period of the Roaring Twenties, the Depression, and World War II. Control of waste was, up to this point, not really a concern of Congress, if one is considering residue material rather than extravagance in over-production.

#### D. The Atomic Energy Act

However, at the end of World War II, there was very definitely a concern voiced in Congress with regard to certain types of material being mined. This material of concern, of course, was uranium. Under the Atomic Energy Act of 1948, as amended by the Atomic Energy Act of 1954 (42 U.S.C. § 2011-2246), Congress enacted a comprehensive statutory scheme for regulation of an entire industry. The act divided regulation into that of source material, by-product material, and special nuclear material. Of interest regarding mine waste was source material (i.e., ore containing uranium) which required a license for its possession, receipt, transfer, and ownership. The act did not directly address ownership of processed ore (i.e., uranium mill tailings) which was handled indirectly under the licensing provisions mentioned above. However, it should be noted that the Atomic Energy Act was the first attempt by Congress in peacetime to regulate an entire mining industry

in a comprehensive manner, and the statute was an attempt to place all authority for regulating activity affecting and affected by the nuclear fuel cycle in a single federal agency, the Atomic Energy Commission.

It is worth noting that the Atomic Energy Act was a federal statute which initially required a license to mine, although the statute did provide that a general license could be granted to uranium miners which required no formalities or written documentation.

It is also worth noting that the Atomic Energy Act regulated the nuclear fuel cycle not because of any environmental disruptions, but because of the national security interests involved with atomic power. Nevertheless, the comprehensive nature of regulation of the uranium fuel cycle is worth remembering as one considers the comprehensive environmental statutes passed in the latter part of the 1970's and early 1980's which address mining waste and waste generally.

#### E. The Environmental Movement - a Torrent of Legislation

Having mentioned mining regulation per se under the Atomic Energy Act, it is now necessary to jump forward to the late 1960's, an era which can be characterized as the beginning of today's Environmental Movement.

In 1969, the environmental movement did not possess the knowledge or political muscle to enact statutes which quantified environmental values. In fact, with the passage of the National Environmental Policy Act (42 U.S.C. § 4321-4347), the most that environmental lobbyists achieved was that federal decision makers were required to take a hard look at the environmental consequences of federal actions over which they held approval power.

As the NEPA Process (as it came to be called) focused attention on environmental impacts of man's activity within the environment, the mood in Congress quickened toward statutes which addressed individual components of the environment. Congress enacted statutes which addressed clean air, clean water, and the like. During this time, waste was viewed as a by-product of activity. These statutes did not focus upon disposal of waste, a development which took place later.

The statutes which specifically address mine waste, passed in the mid to late '60's and '70's, were the Surface Mine Control Reclamation Act, the Coal Leasing Act Amendments of 1976, and the Uranium Mill Tailings Radiation Control Act of 1978.

SMCRA is important for our study of the legal treatment of mine waste because it specifically addressed disposal of mine waste, tailings, coal process material, and other waste requiring stabilization. It also addressed reclamation, both in the sense of standards and in the imposition of a reclamation fee which could be used by the Secretary of

Interior to perform reclamation of abandoned mines and reclamation of surface impacts of underground or surface mining.

SMCRA went one step further than any prior statute in that it allowed for the prohibition of mining in the event that lands were unsuitable for reclamation after surface mining.

The Coal Lease Amendments introduced concepts of comprehensive land use planning and logical mining units to the coal lease process.

The Uranium Mill Tailings Radiation Control Act, passed in 1978, addressed one deficiency in the Atomic Energy Act of 1954, i.e., that uranium mill tailings (the waste product of uranium ore processing), had received no specific treatment under the Atomic Energy Act. The Uranium Mill Tailings Radiation Control Act contains provision for reclamation of uranium mill tailings piles, decommissioning of uranium mills, and transfer of property upon which mill and tailings were situated to the United States Government for long term care.

So far, this discussion has addressed major trends in the history of federal regulation of mine waste. It would be an incomplete picture, indeed, if one were to ignore the state mined land reclamation laws and the state permitting statutes addressing mining passed in the decade of the 1970's. In fairly short order, western states, such as Colorado, California, Idaho, Montana, Oregon, Utah, Washington, and Wyoming enacted state mine land reclamation statutes. These statutes addressed such matters as soil removal, storage, backfilling, grading, revegetation, surface water dispersion, water impoundment, and tailings impoundment. Suffice it to say that the local concern over mine waste was evidenced by a plethora of state statutes addressing mine waste, both in terms of extravagance of production (i.e., maximum economic recovery of the resource) and in the sense of residue.

#### V. RCRA and CERCLA - Waste Legislation Per Se

As the 1970's progressed, the environmental awareness, initially evidenced by the National Environmental Policy Act and developed by virtue of statutes addressing components of the environment, began to coalesce in the recognition that legislation was required to address waste per se. One consequence of this recognition was the passage of RCRA in 1976. As time wore on, it also became apparent that there was no specific statutory treatment for waste which had previously been deposited at the surface, RCRA addressing only newly generated waste. The result of this development was the Comprehensive Environmental Response Compensation and Liability Act known as CERCLA or Superfund, as well as amendments to RCRA known as SARA and HSWA.

CERCLA and RCRA closed the loop in the historical treatment of mine waste. There now are statutes addressing mine waste from exploration through development, operations, and abandonment either under the state reclamation acts, the specific federal acts which address coal, uranium,

and leasing act materials, or under RCRA, CERCLA, and their state counterparts. Thus, mine waste treatment under law developed from oblique reference in the 1972 Mining Law, through regulation under the property power of the federal government, on to comprehensive regulations which indirectly regulated waste generation, to today's statutes, which now regulate waste presently generated and waste generated years ago.

\* \* \* \* \*

I would like to close by saying that I hope you have enjoyed this all too brief presentation on the history of the legal treatment of mine waste as much as I did in preparing it. I would like to acknowledge the contribution of John Jacus of Bradley, Campbell, Carney & Madsen, who co-authored the paper referred to throughout. I would also like to thank Mr. Thomas A. Colbert, the moderator of this progrm, for allowing me to share this material with you. Thank you.

LEGISLATIVE DEVELOPMENTS  
AFFECTING THE MINING INDUSTRY  
IN SOUTH DAKOTA

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INTRODUCTION

The substantial increase in the price of gold during the early 1980's revitalized the precious metals industry world-wide. The gold mining industry in South Dakota was no exception. As gold prices increased, so did precious metals exploration activities which were usually centered around the historical mining districts located in the Northern Black Hills.

Discoveries of close-to-surface ore deposits were identified in the Lead/Deadwood area and eventually developed by utilizing new technological advances in surface mining, complimented by the less labor intensive heap leach processing of gold ores.

The Homestake Mine, located in Lead, has operated an extensive underground mine since 1876, producing over 1,000 ounces of gold per day from depths of over 8,000 feet below the surface. Ore continues to be mined by underground methods at Homestake. However, in an effort to offset the large expenses associated with mining at depth, Homestake has returned to the surface to rework an area where the original Homestake Claim was filed, an area known as the Open Cut.

Presently, there are five large-scale surface mines operating in the Lead/Deadwood area, including Homestake's Open Cut Mine. Of these, four mines utilize the cyanide heap leach process to extract gold from the ore. Homestake still relies on the vat leach process developed around the turn of the century and the Carbon in Pulp process developed at the Homestake Mine during 1972.

The recent increase in surface mining activities has brought about an increase in the concerns of the general public, focusing on potential socioeconomic and environmental impacts. Because of its visibility, large scale surface mining in South Dakota is very vulnerable to vocal environmental interest groups and anti-mining activists.

As the general public voices concern over the protection of our environment, new and more stringent laws and regulations are constantly being enacted by our lawmakers to address these concerns.

The following discussion will focus upon the evolution of regulatory development aimed at controlling large scale surface mining in the Black Hills of South Dakota and will discuss some bold measures being taken by the precious metals industry to meet these regulatory challenges head on.

#### Brief Background

The Black Hills of South Dakota have long been considered the "jewel" of the State, offering a variety of recreational, cultural and aesthetic qualities as unique as the ecology and geology of the area is itself. As home of the famous Mt. Rushmore, millions of visitors have made the Black Hills their summer playground for many years. The hills offer a rich and colorful history, of which gold mining has played a vital role.

The gold rush to the Black Hills began after the first major discovery in 1874. Since then, a number of mines and mills dotted the hills, finally culminating with the consolidation of many mining properties that eventually gave way to the only continuous operating underground mine since 1876, the Homestake Mine.<sup>1</sup>

Since gold was first discovered, nearly 40,000,000 ounces of gold have been produced from the Black Hills, with the bulk of this coming from underground mining.

Historically, mining has coexisted in harmony with many other uses and demands placed upon the natural resources in the Black Hills. With the advent of newer and more efficient technologies allowing to economically mine and process lower grade surface ores, mining returned to the area during the early 1980's as the price of gold suddenly increased. Although all of the present day mines are located in areas of past mining activities, a few are highly visible to the general public because of continued urbanization and widespread development of major recreational areas including ski slopes and other outdoor developments.

To date, approximately 2,048 acres of surface land has been affected (disturbed) by the five existing surface mines. This amounts to less than one half of one percent of the total five county area in the northern Black Hills where surface mining occurs.

However, mining and the associated processing activities by their very nature cause disturbance of land and environmental effects that make them a highly visible target for regulatory controls. The very nature of the mining business and its visibility to the public, including the uncertainties related to future expansion and development, have generated much debate over the past few years on the adequacy of existing regulations to control surface mining in the Black Hills of South Dakota.

## Regulatory Development

Mining and its associated activities are heavily regulated on the Federal, State and Local levels. Again, mining in South Dakota is no exception to this. Please refer to Attachment No. 1 for a listing of the major environmental regulations currently applicable to large scale mines operating in the Black Hills.

Of course, all states differ in the severity, comprehensiveness and level of enforcement of their mining regulations. These variations are, in part, a function of the type of minerals mined in the State, the importance of the mining industry to the State economy, the responsible State agencies, the general State philosophy on environmental regulation and the attitudes of the industry toward environmental controls, as well as past experience in environmental compliance.

It is the written policy of the South Dakota Legislature that mining and the public interest coexist in our State. The intent of State law is to strike a workable and necessary balance between the economic necessity of mining and potential negative impacts to the environment.<sup>2</sup>

In 1981 and 1982 the South Dakota legislature undertook a comprehensive review and update of the sections of South Dakota Codified Law dealing specifically with mining. An interim study committee comprised of some of the state's most experienced legislators met repeatedly in an effort to both strengthen and clarify the mining law. They reviewed and considered mining laws already on the books in such better-known mining states as Montana, Colorado, Wyoming, Idaho, New Mexico and Arizona. As a direct result of these comparative examinations, South Dakota lawmakers succeeded in compiling some of the best provisions from active mining states throughout the western U.S.

In 1983 the Legislature adopted the requirements of SDCL Chapter 45-6B, entitled "The South Dakota Mined Land Reclamation Act," which established the guidelines for reclaiming mined areas.

Section 45-6B-2 sets forth the state policy, "Every effort should be used to promote and encourage the development of mining as an industry, but to prevent the waste and spoilage of the land and the improper disposal of tailings which would deny its future use and productivity. Proper safeguards must be provided by the State to ensure that the health and safety of the people are not endangered and that upon depletion of the mineral resources and after disposal of tailings the affected land is usable and productive to the extent possible for agricultural or recreational pursuits or future resource development; that water and other natural resources are not endangered; and that aesthetics and a tax base are maintained, all for the health, safety, and general welfare of the people of the State."



In response to increased mining activities during the mid 1980's, another select Legislative Committee on Mining was organized during the summer of 1986 to study the socioeconomic impacts of large scale mining in the Black Hills.

The result of the study included legislation dealing with exploration, bonding requirements, local governmental controls over mining, reclamation plan development, and socioeconomic impact studies. Additional legislation gave the Board of Minerals and Environment authority to develop specific regulations.<sup>3</sup> Despite this strengthening of the laws, environmental and anti-mining activists continued to allege that South Dakota's mining regulations pertaining to exploration development, operation and reclamation were inadequate.

Interestingly, in late March 1987 a report commissioned by the Environmental Protection Agency (EPA) to evaluate individual state mining regulatory programs was published by Charles River Associates. The report compared and evaluated mining, waste disposal and reclamation laws on a scientific, state-by-state basis. The Charles River study and report ranked states' permitting processes, regulations on mine waste, mine reclamation requirements, groundwater pollution control, bonding requirements, closure requirements, mine waste testing, regulatory approaches and, most importantly, levels of actual compliance.

The results of this study were enlightening, especially when examined in the context of the environmental "objections" to the industry and its operation in South Dakota. The report, through a numerical rating formula, ranked South Dakota second overall (in a tie with California) behind only Wyoming in "Adjusted Average Rating of Regulatory Program". However, the report noted that Wyoming, while it was rated higher, had a high rate of compliance due to certain of the state's mining laws being "guidelines" and not enforceable by law. So, in terms of the "real world", the Charles River Report clearly indicated that South Dakota's mining law was in actuality the toughest and most enforced set of regulations in the industry along with those of the environmentally sensitive state of California.

In an effort to overcome irreconcilable differences among vocal opponents and the mining interests, in June 1987 Governor Mickelson declared a six month moratorium on the processing of mine permit applications to allow time for the staff of the Department of Water and Natural Resources to draft new regulations. In addition, he appointed a ten member Task Force consisting of representatives of the mining industry, environmental groups, state and local governments, and the public to prepare a draft set of regulations to be presented to the Board of Minerals and Environment as recommendations.

The Task Force held ten public meetings across the State during July, August, and September of 1987. The Task Force proposed rules on:

1. Requirements for reshaping lands to visually and functionally compatible contours, including mine pit backfilling if economically and technically feasible;
2. Restricting mining in certain unique areas; and
3. Requirements for water quality protection including treatment standards for neutralized spent ore from cyanide heap leach operations and heap leach facility design criteria.

The Task Force presented their recommendations to the Board of Minerals and Environment at a public hearing held in Rapid City in December of 1987. The regulations, entitled South Dakota Mined Land Reclamation Regulations, Title 74, Article 29 of the Administrative Rules of South Dakota (ARSD), were formally adopted on March 4, 1988.<sup>4</sup>

Even with a new set of regulations in place, opposition to mining continued to be voiced. Without even allowing for a true measure of the impact of the newly adopted rules, the 1989 Legislature adopted additional laws under the auspices of the Governor's Centennial Environmental Protection Act (CEPA) establishing groundwater protection strategies and mechanisms to fund programs to protect groundwater quality and quantity. Funding mechanisms affecting the mining industry included the filing of proof of financial assurance and assessment of a yearly fee of two cents per pound of cyanide used at each surface mining operation.

In order to evaluate the cumulative impacts of large-scale surface mining in the Black Hills, a cumulative environmental evaluation (CEE) was ordered to be conducted by an independent qualified contractor with the results to be reported no later than December 1, 1990. During the period in which the CEE is being conducted, no mine permit, amendment or combination thereof in excess of 200 acres of affected land for any one operator can be granted. Essentially, the Act imposed yet another moratorium on the processing of mine permit applications. The results of the CEE may be used in determining the environmental consequences of a proposed operation and in acting on future surface mining permit applications. Basically, the information is intended to help decide "when one additional mine is too many" for a given area within the Black Hills.

All five large-scale surface mines are located in Lawrence County. It goes without saying, as new mines were being permitted under state rules, local government could not ignore the potential land use conflicts associated with mining occurring in proximity to less intensive land uses. Therefore, yet another task force was formed, representing all interests including public officials, planning and zoning personnel, as well as the public at large. A very comprehensive ordinance was adopted from their efforts in late 1986 for the purpose of informing the public of the significant potential for the development of mining within Lawrence County and to minimize the adverse effects of mine development on public and private land uses. The ordinance requires

a very detailed application procedure requesting a Conditional Use Permit (CUP) for mining and related activities. The permit application also requires the submittal of a socioeconomic impact study and a number of performance standards, including a buffer zone which, at a minimum, will be 500 feet between the disturbed land and any adjacent or adjoining landowner. Since its inception, all five mine operations have obtained CUP's for new mine operations or amendments to existing operations. The ordinance, as adopted, is presently under review for possible amendments and/or revisions.

#### Initiative and Referendum

Pursuant to the Constitutional provisions of the State of South Dakota, any measure may be initiated or any law may be referred to a vote of the electors, provided a petition has been properly filed carrying signatures of not less than five percent of the qualified electors of the State.

Despite all of the joint task force reviews and all of the studies that eventually influenced regulatory reform resulting in the strengthening of mine regulations, petitioners were successful in forcing a countywide vote to invoke a temporary moratorium on the issuance of Conditional Use Permits for large-scale surface mines in Lawrence County. This proposal was strongly defeated by the vote of the electors on October 20, 1987.

Two additional initiatives asking for substantial increases in the state severance tax and a mandatory backfill requirement were also strongly defeated during a statewide election on November 8, 1988.

Presently, signatures are being collected on yet another initiative, requiring a mandatory 3100 acre cap on the total amount of acres to be affected at any one time by all operators of large-scale mines within the Black Hills. Petitions carrying 14,723 valid signatures of registered voters must be filed by May 1, 1990 to send this initiative to a statewide vote on November 6, 1990. This, of course, is approximately one month before the results of the CEE (as described above) will be reported on.

#### The Challenge

The concerns expressed by the general public for conservation of our natural resource and the demand for protection of our environment are real. Many concerns of the public are manifested in emotional reactions to change or the fear of the unknown. These types of concerns are not effectively dealt with by legislating new rules and regulations. In the long run, society will set the Standards of performance.

That is why the mining industry must recognize the sociological impacts of mine development and continue to make an honest attempt

to educate and communicate the nature of our business to the public at large. Once there is a general understanding of our business, then we must trust that the public will accept mining for what it is, an environmentally responsible industry.

### Meeting the Challenge

The mining industry in South Dakota understands the importance of gaining public trust and has, throughout its history, demonstrated its ability to change to meet the public needs.

Representatives of the industry have actively participated in the development of formal rulemaking that has strengthened regulatory controls to protect the environment.

A grass roots non-profit organization called "People For Responsible Mining" has been organized to communicate and educate the general public on the complexity of our business.

In an unprecedented move, the industry recently initiated and backed a bill proposed by the Governor during the 1990 Legislative session to impose a moratorium on new large-scale surface mine operations and to limit expansion of existing operations until January 1, 1992. This will allow time for a seven-member review committee to evaluate and make recommendations on the provisions of the on-going CEE.

During the next two years, the mining industry will continue to communicate and educate to overcome public diversity by promoting responsible mining in the Black Hills of South Dakota, thereby meeting the challenge head on.

By adopting such an active stance, the industry is hopeful to turn the tide of regulatory reform and gain the trust of the general public which is so important to the success of the mining industry in South Dakota.

### References

<sup>1</sup>With the exception of a brief shutdown by order of the U.S. Government in October of 1941-1945; (War Production Board Order L-208).

<sup>2</sup>Department of Water and Natural Resources Brochure "What Laws Regulate Mining in South Dakota".

<sup>3</sup>Ibid.

<sup>4</sup>Ibid.

## Attachment No. 1

ENVIRONMENTAL REGULATIONS CURRENTLY  
APPLICABLE TO LARGE-SCALE MINES  
IN SOUTH DAKOTA

Air Quality

- 1) Clean Air Act 1970:
  - a) Established primary nationwide air standards (National Ambient Air Quality Standards) or NAAQS to protect public health, and secondary NAAQS for the protection of public welfare.
  - b) Directed States to develop and adopt State Implementation Plans or SIPS with the goal of achieving NAAQS by establishing emission limitations, compliance schedules and other planning.
- 2) South Dakota Air Quality Act (chapter 34A-1, South Dakota Codified Laws), as implemented through Chapter 34:10, Administrative Rules of South Dakota, effective July 27, 1971:
  - a) Chapter 44:10:01: Air pollution requirements
  - b) Chapter 44:10:03: Control of Visible Emissions
  - c) Chapter 44:10:04: Open Burning Regulations
  - d) Chapter 44:10:06: Control of Particulate Emissions
  - e) Chapter 44:10:07: Control of Sulfur Compound Emission
  - f) Chapter 44:10:08: New Source Performance Standard
  - g) Chapter 44:10:14: Standards of Performance for Storage Vessels of Petroleum Liquids

Water Quality (Discharges)

- 1) Federal Water Pollution Control Act (FWPCA) of 1972 PL 92-500 Sections 302, and 303, 330 S.C. 1251
  - a) Requires that every discharger of pollutants into navigable waters of the United States meet certain effluent limitations.
  - b) The FWPCA established the National Pollutant Discharge Elimination System (NPDES) permit.
  - c) 40 CFR 112 - Requires a written, engineered spill control plan, response procedures, records and training for the prevention of discharges of petroleum products.
- 2) Dredge and Fill (404 Permit) - authorizes the Corps of Engineers to control the discharges of dredge and fill material into Waters of the United States, including tributaries and wetlands.

- 3) South Dakota Water Pollution Law - SDCL Chapter 74:03:02 effective February 19, 1981:
  - a) Governs effluent limitations based upon water quality of the receiving stream.
  - b) Establishes monitoring requirements.
  - c) Grants permits for discharges (NPDES).

#### Water Quality (Potable)

- 1) Safe Drinking Water Act PL 93-523 42 USC 201
  - a) Regulates drinking water contaminant levels
  - b) Establishes monitoring and analysis requirements
  - c) Requires reports and record keeping.
- 2) Mine Safety and Health Administration (MSHA) Regulations (30 CFR 57.10-2)
  - a) Requires mine operators to provide adequate supply of potable water in all active working areas.
- 3) South Dakota ARSD, Chapter 74:03:07
  - a) Provides for approval of public water systems

#### Land Holdings

- 1) 1872 Mining Act (30 USC 21)
  - a) Assessment work requirements (30 USC 28)
- 2) BLM Recordation Requirements (43 CFR Part 3830)
  - a) Evidence of assessment work/intention to hold
- 3) South Dakota Marketable Title to Real Estate Act (SDCL Chapter 43-30)
  - a) Severed Mineral Interests.
- 4) Lawrence County, South Dakota Comprehensive Plan
  - a) Zoning and Subdivision Regulations.
    1. CUP - Extractive Industry.

#### Mining Land Reclamation

- 1) U.S. Forest Service Surface Mining and Exploration Reclamation Requirements 36 CFR Part 228
- 2) BLM Mining and Exploration Requirements 43 CFR Part 3800
  - a) Regulate disturbances on public lands
- 3) South Dakota Mining Land Reclamation Act (SDCL) Chapter 45-6B
  - a) Regulates surface disturbances caused by surface and underground mining (Permits, bonding, and reclamation requirements).

- 4) South Dakota Mined Land Reclamation Article 74:29
  - a) Requires permit applications, reclamation of mill sites, minimum reclamation standards, concurrent reclamation and temporary cessation.

#### Solid Waste Disposal

- 1) Resource Conservation and Recovery Act (RCRA) of 1976
  - a) Protection of public health and the environment in relation to Solid Waste Disposal.
- 2) South Dakota Solid Waste Disposal Act SDCL Chapter 34A-6; ARSD Article 44:11 (July 31, 1980)
  - a) Establishes a comprehensive regulatory systems and permits for waste disposal

#### Hazardous Waste Disposal

- 1) Resource Conservation and Recovery Act (RCRA) of 1976
  - a) Protection of public health and the environment in relation to hazardous waste disposal (40 CFR 261.10 through 261.33 May 19th, 1980)
- 2) South Dakota Hazardous Waste Rules, Article 44:15 (January 11, 1981)
  - a) Applicable to Mining and Milling
- 3) Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) PL 95-510, 94 Stat 2767, December 1980 or "Superfund"
  - a) Provides funds from industry and government to clean up hazardous waste sites.
- 4) Superfund Amendments and Reauthorization Act of 1986 (SARA) PL 99-499
  - a) Major changes to CERCLA

#### Electrical Service

- 1) Toxic Substance Control Act of 1976 (PL 94-469)
  - a) Regulates use and disposal of polychlorinated biphenols (PCB's)

#### Environmental Protection

- 1) South Dakota Centennial Environmental Protection Act of 1989
  - a) Required preventative action plans for groundwater, additional surety and proof of financial assurance for remediating accidental releases of cyanide, assessed a two cents per pound of cyanide used and required accumulative environmental evaluation due December 1, 1990.

- 2) Environmental Impact of Governmental Actions (SDCL 34A-9)
  - a) Agencies may require an environmental impact statement on any major action they propose or approve.



Current Issues in Mining Regulation - the Good, the Bad and the Ugly  
(a pre-assigned title!)

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### INTRODUCTION

Whether any issue is good, bad or ugly is largely "in the eye of the beholder" or maybe it simply depends on what day it is. Regardless, the one thing that is certain is that there are several current regulatory activities that significantly impact Colorado's mining industry. This paper is an overview of the major issues under review and the direction that the state is taking through the programs of the Mined Land Reclamation Board and Division.

### THE MINERALS RECLAMATION PROGRAM

The Minerals Reclamation Program has rebounded in the last two years after having been briefly eliminated through state budget cuts and then restored. Since that time, the Division and Board have been challenged by a number of issues that have had or will have a significant effect upon the program, the public and the mining industry. The most significant issues are presented below.

Quarries: The public concern about the visual impact of quarry operations during and after mining has received considerable attention. The issues have been discussed for several years at the local level. However, projects proposed in Douglas and El Paso Counties came before the Mined Land Reclamation Board during 1989 and directed state attention to the visual impact issue.

During the development of quarries, the operations become visible as the area is disturbed. This raises citizen concern. After mining is completed, the appearance of the reclaimed quarry can be quite different from the original appearance. Where once there may have been irregular terrain, one sees long uniform benches that contrast to the natural topography of the surrounding area. Further, because of the harsh climate, the vegetation at some sites is sparse or consists mostly of grasses which do not hide the larger features of the reclaimed quarry.

Governor Romer took a personal interest in this issue. After inspecting the sites in Colorado Springs, he formed the Commission on Mountain Scarring. The commission was divided into two subcommittees. The first subcommittee examined state and local laws to determine whether existing law is adequate to regulate the development of quarries and to prevent future scarring of the mountains. The second subcommittee examined existing scars, particularly the Queens Canyon and Pikeview quarries in Colorado Springs, to determine what reclamation alternatives are available to achieve a visually acceptable reclamation at those sites. The final report from the subcommittee on laws is due at the end of March. The report from the subcommittee on existing scars was released on March 1, 1990.

One of the proposals of the subcommittee examining state and local laws was the endorsement of a bill introduced by Representative Renny Fagan that would have set up a formal process for a coordinated state/local review of a quarry proposal. Under the bill, the authority to review visual aspects of a quarry project would continue to reside with the county. The Mined Land Reclamation Division would provide advice regarding whether the proposal could be technically achieved in conformance with the Colorado Mined Land Reclamation Act. This proposal died in committee in the Colorado House of Representatives.

Although not directly related to the work of the subcommittee, another bill was introduced by Senator Tebedo of Colorado Springs which died in committee in the Senate. The distinguishing difference between the two bills is that Senator Tebedo's bill would have given the authority to conduct visual assessments to the state.

These two bills point to one of the issues that will continue to be discussed; the issue of whether visual requirements should be established at the state level or the local level. The authority to make decisions pertaining to visual impacts and land use compatibility has historically rested with the local governments. To those who continue to support this, the belief is that making decisions about visual effects is fundamentally a land use decision.

Others believe that visual assessments are a technical issue that may best be handled at the state level through statewide standards. Proponents of this concept are concerned that inconsistencies will arise between counties. Some fear that counties that are more concerned about visual impacts will make it difficult for quarries to be approved. Operators will move to counties that are more in need of jobs and are willing to allow mining without extensive visual consideration as a reclamation objective. Further, companies that have already invested in property in one county may find the mining potential of the property diminished as visual mitigation requirements are increased, thus giving properties in counties less concerned about visual impacts a competitive advantage.

Recognizing that there will be continued demand for quarry rock along the front range, the subcommittee examining state and local laws generally identified the following points which should direct public policy development on this issue.

- a. Visual concerns associated with quarry operations are legitimate and need to be addressed.
- b. There are various mining and reclamation methods which can effectively mitigate visual impacts associated with quarries.
- c. Local governmental authority over land use should be preserved.
- d. Coordination between local governments and the Mined Land Reclamation Board is important and should be strengthened.
- e. Populous counties, as required by statute, should develop and periodically update master extraction plans that balance the need for aggregate resources with other quality of life concerns.
- f. There may be certain open spaces along the Front Range which should be preserved in their natural state.
- g. Certain geographic areas are unsuitable for quarry operations.

The subcommittee on existing scars developed an analytical system to assess the different methods to achieve a visually acceptable objective, and based upon a cost/benefit analysis they recommended appropriate steps. The implementation of the proposed plans or elements of the plans at the Queens Canyon and Pikeview sites is still under consideration by the operator. The Pikeview is the more difficult of the two because of the long term nature of the mining plan and the current instability of the site.

This subcommittee, as well as the Commission in general, identified important considerations in the planning, development and reclamation of quarries that would mitigate visual impacts. The most noteworthy include proper siting, limitations on the size of the quarry or the extent that land can be disturbed at any one time, and the use of reclamation techniques that will mitigate visual impacts.

Quarries should be located and positioned on a site so as to reduce the visibility to the general area. Computer assisted techniques for conducting visibility assessments were reviewed by the commission and local governments, and operators are encouraged to use these analytical methods.

The visibility of quarries is also attributable to size. Large areas are disturbed to achieve the economies of scale in the mining process. These large disturbances occurring prior to reclamation make the operation highly visible. Reduction of the size of the quarries would reduce visibility, but the operator would lose the benefit of the economies of scale. This would result in higher prices for the product from a particular site.

The sequence in which a particular area is mined can affect visibility. Where possible, it may be prudent to delay mining highly visible portions until last if such areas cannot be reclaimed concurrently.

One aspect of visual impact is that much of the disturbed land may remain unreclaimed many years during the life of the project. Once mining is completed, it may take another 10-25 years for the reclamation to reduce the visual impact. Thus visual impacts may exist for decades. Even though final reclamation may not be practical in most cases, it may be practical to perform at least initial or partial reclamation at locations that are highly visible.

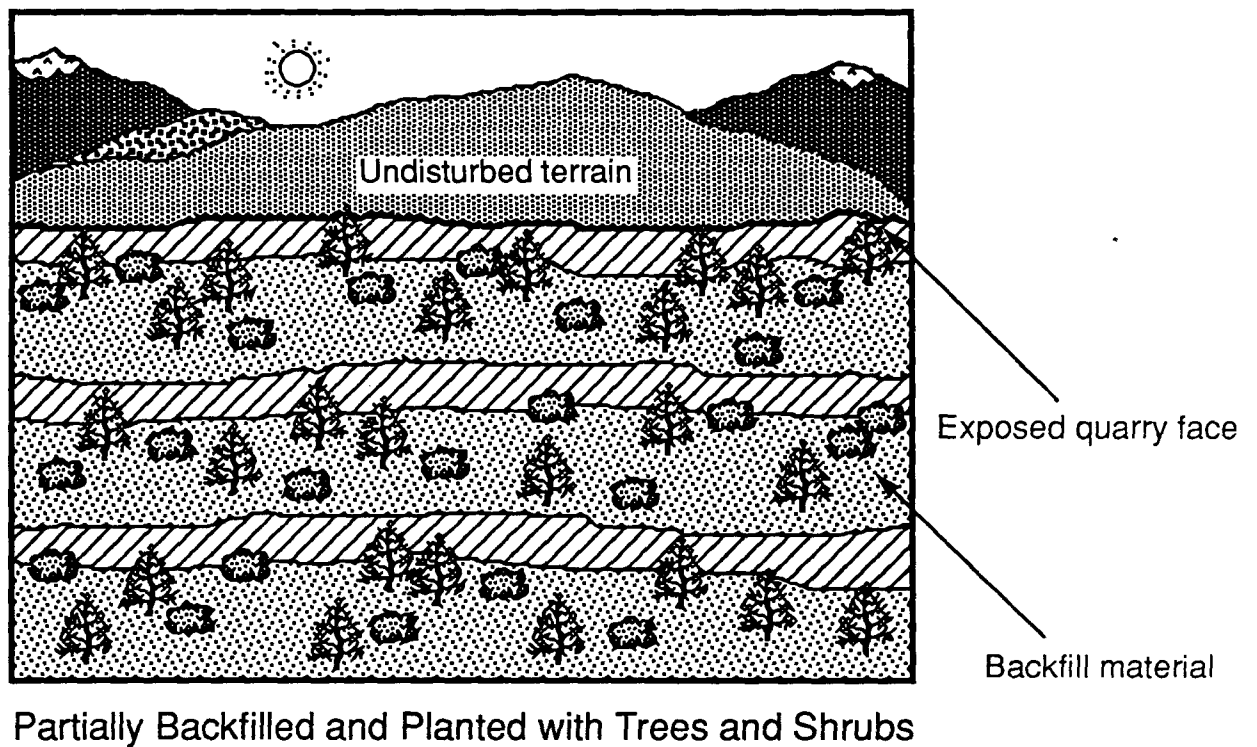
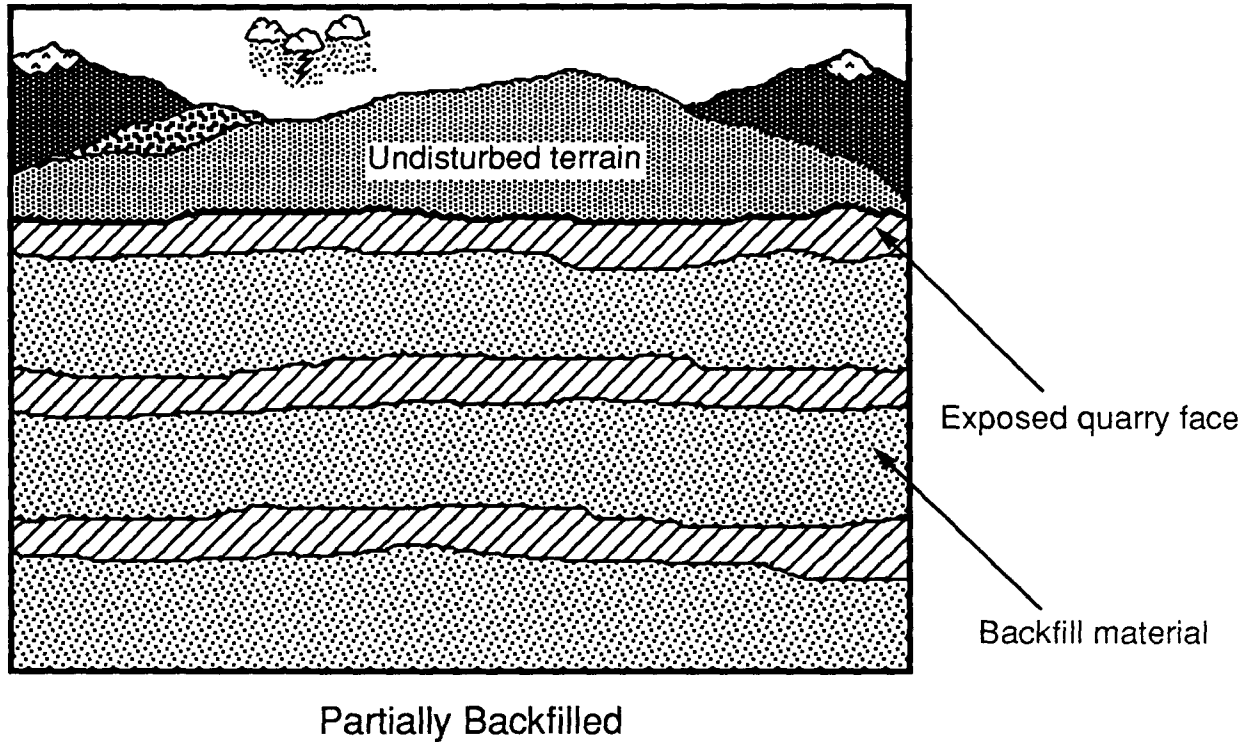
The traditional components of visual analysis could be applied to quarries to mitigate the post mining visual impact. These include consideration of form, line, texture and color. Efforts to develop shapes, to identify surface material and reproduce color that is compatible with surrounding topography and surface area will reduce contrast between the reclaimed area and undisturbed area.

The Division, through the permit review process, has identified a number of factors which could be considered in developing quarries that are more visually acceptable. Bench width and backwall height are significant factors in visual effects. Selecting appropriate ratios of backwall to bench width can enhance the potential for visually acceptable reclamation. As the ratio of backwall height to bench width is reduced, the geotechnical stability generally increases and vegetation establishment is enhanced. The potential for adverse visual impact from slope failure and barren surface is significantly reduced.

Typically, when quarries are mined the appearance during or after mining is a series of horizontally continuous lines. These lines are a direct result of the most efficient way to quarry rock. These continuous lines, however, may be partially removed through selective backfilling, selective blasting, construction of discontinuous benches, and some type of rock sculpting. An example of these techniques is the Vail Pass project. Figures I and II illustrate the results of these techniques. However, the employment of these techniques must result in a stable post mining topography.

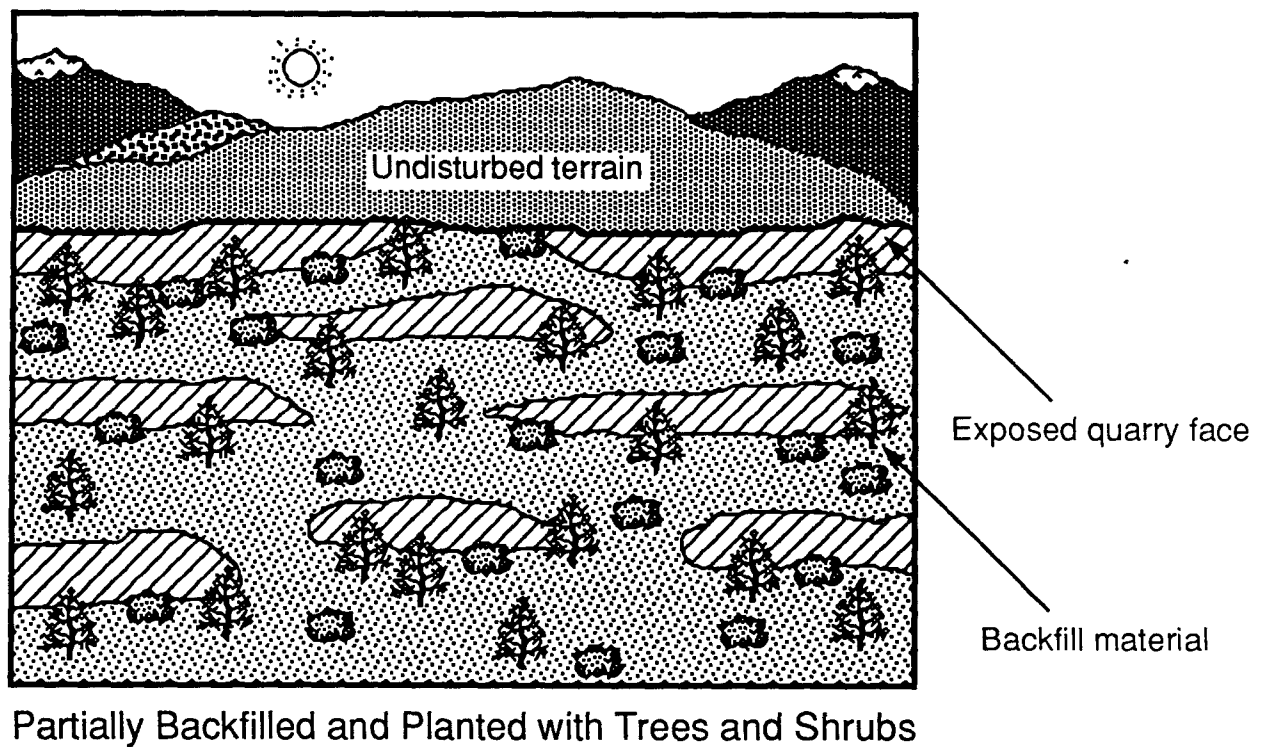
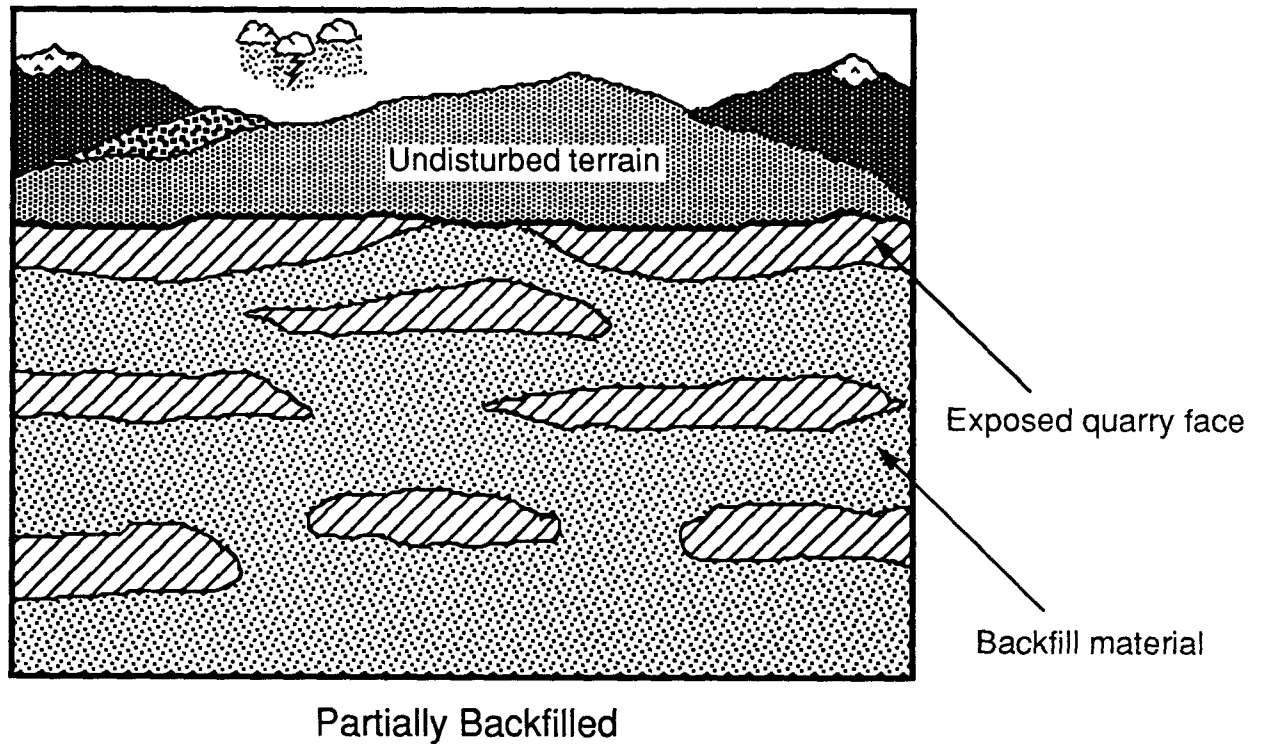
## Figure I

# Continuous Benches



## Figure II

# Discontinuous Benches



Quarry mining exposes faces of fresh cut unweathered rock which may contrast with the surrounding area. In general, the remedy to this problem has been to hide the exposed rock face by vegetation, barriers or berms, or staining the rock.

In summary, the issue regarding visual aspects of quarries has received significant attention during the past year. One can anticipate considerable activity at both the state and local level to develop public policy that will respond to community concerns about visual impacts from quarries.

Peat Extraction: The question as to whether the extraction of peat is mining which is under the jurisdiction of the Colorado Mined Land Reclamation Act has not been fully examined. In 1989, the Board directed the staff to investigate the issue from two perspectives. First, the Board wanted to know what existing regulatory programs govern the extraction of peat. Second, they asked for an examination of peat extraction in Colorado to determine the nature of the material being mined, the extent of activity and the uses that are made of Colorado peat.

The Division presented the results of its investigation to the Board in February, 1989. The Division found that there is no regulatory program that directly regulates the extraction of peat, although some counties are considering such regulation. Indirectly, the Corps of Engineers and the Water Quality Control Division can regulate some activities associated with peat extraction. Further, the Division found that peat could be considered to be a mineral under the definition of "mineral" in the Colorado Mined Land Reclamation Act. The Board, however, has some discretion in making a final determination with respect to the definition. If peat is a mineral, then it would be regulated under the Colorado Mined Land Reclamation Act.

There are approximately sixteen operators in the state who extract peat. The product is sold predominately as a soil amendment, although it has some other uses such as a material that assists in the clean up of acid mine drainage.

The Board will be reviewing the issue in coming months to determine whether peat extraction is mining and, if so, what are the appropriate mining and reclamation requirements under the Colorado Mined Land Reclamation Act.

Mine Waste: Currently, Colorado regulates the disposal of mine waste through the Colorado Mined Land Reclamation Act, the Water Quality Control Act, the Clean Air Act and other programs and statutes. As such, the state is very interested in the development of the national mine waste program under the Resource Conservation and Recovery Act. The state has focused most of its effort through the Western Governors' Association (WGA) Task Force on Mine Waste. Of

greatest importance to the task force is the development of strong state programs. The fundamental issue is providing states with the autonomy and authority to do an effective job while allowing for appropriate federal oversight to audit state program performance. One of our greatest concerns is that a federal permit by permit review will undercut state and federal programs, be duplicative and weaken the overall effort to regulate effectively mine waste.

The work of the Western Governors' Association Mine Waste Task Force is directed from the resolution put forth by the Governors. The resolution states:

The WGA believes that EPA should expeditiously propose and promulgate a regulatory program for any mining wastes found by the agency to warrant regulation as a solid waste under RCRA Subtitle D. However, the timing of the development of this program by EPA should be structured to allow sufficient time for meaningful state input through the WGA mining waste work group prior to proposing draft regulations. The regulatory program should establish a state based approach for protection of public health and the environment, taking into account site-specific, waste-specific and waste management specific practices that are in use. To the maximum extent feasible, consistent with this objective, the EPA program should allow reliance on existing state regulatory programs for mining waste.

The principle effort of the task force to date has been the review of the EPA Strawman regulations and development of an alternative to that proposal. The task force released the first draft of its proposed alternative to the public on March 21, 1989. Several comments on the task force's proposal were received and reviewed. On December 8, 1989, the WGA transmitted the task force's recommendations to EPA. The WGA proposal is divided into three parts which are based on the structure of the Code of Federal Regulations, as was the EPA Strawman; Part XXX, Part XXY and Part XXZ.

Part XXX describes the program development process and federal oversight for a state which intends to administer the mining waste program. The most significant concept within this part is "self certification". The main theme of the concept is that the state would develop its program and when the Governor finds that the program meets federal requirements in cooperation with EPA, the state would self certify. At that point, the program would be in effect. EPA would review the program further and acquire enforceability through federal codification of the state program.

Part XXY includes definitions and describes the technical criteria for mining waste management facilities and practices. Part XXY describes a multi-media approach to the management of mining waste. It emphasizes the need for flexibility to accommodate the diverse nature



of mining waste and the environments in which they are managed. There are two significant elements of the task force proposal. First, the program covers only existing and new mine waste units, and second, heap and dump leaching are recognized as a unique situation where measures are to be taken to protect against potential releases to the environment from the heap or dump during and after the leaching.

In regard to the first element, the states found it difficult to find an appropriate definition that would define inactive mine waste units. Defining inactive units such that they would be regulated means retroactive regulation of units. Retroactive regulation may not be appropriate since other laws, such as the Comprehensive Environmental Response, Compensation and Liability Act and the 7002 and 7003 provisions of RCRA, exist to address the problems with old units. As a result, the task force has initially decided that two universes of waste units will exist; those that are active or will be developed after a specific date and those that are inactive prior to the date of the program. An inactive unit that is reactivated would come under the requirements of the program.

The second element pertaining to heap and dump leaches is based upon the simultaneous nature of the extraction and waste processes. Because it is difficult to separate the two processes, the task force recommended that heap and dump leaching operations be regulated as a special process. The generation of waste is considered simultaneously with the mineral extraction process. The task force did not recommend that the mine waste program regulate any part of the ore recovery or extraction process, but only the waste that is generated from such processes. For example, as a dump leach is being constructed, it would be regulated under the mine waste program to the degree that the dump would need to be constructed in conformance with waste unit standards.

The task force proposed Part XXZ to describe the development and procedure of an EPA administered program where a state does not elect to certify for program primacy. It is similar to Part XXX in overall program concept, but provides the mechanism for a federal lead in the administration. It is recognized that in specific situations that federal authority to enforce a program would be appropriate.

During 1990 and 1991 the Division, as a member of the task force, will continue to work with EPA on the Strawman process and it will undertake three projects. The first project is a detailed review of Colorado's programs to assess the existing regulatory structure and needs relative to the proposed national program. Second, it will participate with the WGA in eight to ten special projects addressing technical or regulatory issues pertaining to mine waste. And third, the Division will participate in a reconnaissance survey of inactive and abandoned non-coal mines and a policy review of issues related to the reclamation of these sites. With respect to this third effort, it

is intended to provide information about the scope of the inactive and abandoned mined lands issue and the alternatives that could be employed to resolve the problems associated with such sites.

Mining Without a Permit (Illegal Operators): Considerable attention has been directed toward reducing the number of illegal mining operations in the state. In 1988, the legislature increased the civil penalty for illegal operations to a minimum of \$1,000 for each day the land remains affected without a permit. During 1989 sixteen illegal operations were brought before the Board where civil penalties up to \$25,000 were assessed. The Board and Division will continue to respond to citizens' complaints and other information sources to find illegal mining operations and reduce the environmental and economic problems associated with these operations.

Reservoirs and Water Resources Management as the Post-Mining Land Use: After the Colorado Supreme Court issued the opinions in Zigan Sand and Gravel and Three Bells Ranch Associates, sand and gravel operators that exposed groundwater were required to comply with state water law where mining and reclamation operations cause water depletions. The legislature followed up the Supreme Court decision with Senate Bill 120, passed in 1988, which provided a mechanism for operators to come into compliance with the statutes the State Engineer administers.

The decision and law have had an effect upon the types of applications being submitted to the Mined Land Reclamation Division and Board. The Division has received a number of applications for operations adjacent to rivers which propose a post-mining land use of a developed water resources or reservoir. The issues that arise pertain to whether sufficient water rights have to be available prior to approval of the reclamation plan, and whether the reservoir must be in use prior to financial warranty release. Relative to the financial warranty issue is whether the operator should post a financial warranty for development of a reservoir, including securing of water rights, or should it be for an alternative reclamation plan since the Division or landowner may not be in a position to manage a reservoir.

At the moment, the policy issue is still under review by the Board. The issue will be examined further through a Division and Board workshop and on a case-by-case basis.

#### COLORADO INACTIVE MINE RECLAMATION PROGRAM

The Colorado Inactive Mine Reclamation Program (CIMRP) is entering its second decade. It has accomplished much in those years: compilation of an inventory of the most hazardous mine sites in the state, development of a plan to address inactive and abandoned mines, safeguarding of over 2000 openings, and a growth of the program to address coal mine subsidence and mine drainage problems.

The Colorado Surface Coal Mining Reclamation Act, passed by the Colorado General Assembly in 1979, authorized a statewide reclamation program aimed at reducing hazards associated with past mining activities. Colorado's Inactive Mine Reclamation Program is funded by the U.S. Department of the Interior with reclamation fees collected under the Surface Mining Control and Reclamation Act of 1977. Operating coal mines are assessed 15 cents per ton of coal produced underground and 35 cents per ton if the coal is extracted using surface mining methods. The money collected is used to reclaim land mined prior to 1977 and for which there is no continuing reclamation responsibility.

Colorado conducted a survey of inactive mines in 1980 to determine the extent of serious safety and environmental problems attributed to past mining activities. Mine related features such as shafts, adits, portals, inclines, stopes, pits, structures and waste banks were evaluated and rated according to their severity of hazard. Surface subsidence associated with abandoned coal mines and the impacts associated with toxic mine drainage from inactive mines were also evaluated. Priorities for conducting reclamation work are established using this inventory data measured against the goals of the program. Three major goals have guided the program:

1. To assess the serious health, safety and environmental problems associated with inactive mines statewide and to abate those problems which result from past mining.
2. To preserve the historical and cultural values of these past mining activities.
3. To share information with local residents and governments and encourage their participation in all aspects of project work.

Policy issues affecting the program are formulated by the Inactive Mine Reclamation Program Advisory Council, a group of interested citizens with experience in mining, reclamation, local government, and education, and reviewed by the Mined Land Reclamation Board, a group which is appointed by the Governor.

The Colorado Inactive Mine Reclamation Program has completed to date 223 projects, safeguarded over 2000 openings and reclaimed over 1000 acres of inactive mined land. Several reclamation projects have been enhanced by the use of volunteers. Working with Volunteers for Outdoor Colorado, the program has staged three revegetation projects: 90 volunteers planted trees and shrubs on what was once a coal waste pile area at a park in Dacono, 150 volunteers helped revegetate at an abandoned strip mine in Fremont County, and 100 volunteers made park

improvements along the south shore of Trinidad Lake State Park, also an area which had significant coal waste material. CIMRP employees organized 30 volunteers to plant trees and shrubs as part of the reclamation of a glory hole at the town of Alice.

Contracts for reclamation projects are awarded to private contractors through a competitive bidding process. Various mine closure techniques, determined on a project by project basis, are used to safeguard mine openings. Some methods permanently seal the hazardous opening, while others only prevent unauthorized entrance into the workings. Some methods allow landowners and program personnel access for sampling and investigative purposes that could lead to the sale or development of the property. Drain pipes are installed in mine openings that discharge water to prevent hydrostatic build-up and eliminate potential water rights conflicts. Closures are marked with an identifying monument or brass cap, and areas disturbed by reclamation are revegetated.

Reclamation of Non-Coal Mines and Federal Legislative Initiatives (H.R.2095): One of the issues that faces the Colorado Inactive Mines Land Reclamation Program is the number of non-coal sites that remain unsafeguarded and unreclaimed at this point in time. The CIMRP inventory contains approximately 6500 sites that are considered hazardous to life and property. A conservative estimate of the cost of safeguarding those sites is \$32 million. This is based upon the actual costs incurred to date. The number of hazardous sites could be larger than the inventory indicates. This is because the inventory focussed upon populated or heavily traveled areas and was conducted in the early 1980s with a limited amount of funding. Changes in demographics or tourism patterns could increase the number of sites that pose a threat to life and property. An inventory needs to be conducted periodically to identify unsafe sites.

Old sites that are causing environmental degradation or that have an adverse visual impact are not included in the CIMRP inventory. Some of those sites are identified in other state and federal inventories, but no comprehensive inventory exists. Projection of the number of such old sites is upwards of forty to fifty thousand. This is because of Colorado's mining history where mine sites were abandoned or left inactive without consideration for the adverse environmental impacts they could cause.

The most significant issue before the CIMRP program is the debate regarding whether the collection of the AML fee under SMCRA should be continued. Several Congressional hearings were held in 1989 to examine this issue, which culminated in the passing of H.R. 2095 in the House of Representatives. Colorado's position on the bill is to be opposed to the extension of the fee placed upon coal operators and consumers because in Colorado we will be finished with the reclamation of our

abandoned coal sites by 1992. However, we recognize we have a substantial number of inactive and abandoned non-coal sites and believe that an appropriate funding mechanism needs to be developed to safeguard and reclaim those sites.

The only source of revenue at this time for doing the non-coal work comes from the fee placed upon coal producers and consumers. It seems appropriate that another source should be found or developed. Funding could be generated at the state level, or could include sources such as the unspecified mineral royalty receipts that are submitted to the federal treasury.

For this reason we were supportive of an amendment to H.R. 2095 that was put forward by Colorado Representative Ben Night Horse Campbell. The Campbell amendment proposed a new program under SMCRA for the safeguarding and reclamation of inactive and abandoned non-coal mines. The weak part of the Campbell proposal is that no real source of revenue was identified to support the program. However, the amendment did bring the issue to the table and further examination of developing a viable non-coal abandoned lands program is anticipated in the Senate when it takes up the bill.

Mine Subsidence Hazard Investigation and the Mine Subsidence Protection Program: The CIMRP has been involved in five community-wide subsidence investigations since 1980. Subsidence hazard investigations for the cities of Colorado Springs, Louisville/Lafayette, Dacono, Frederick, and Firestone and two neighborhoods in Jefferson County have been completed. Extent of mining/land use maps for all other coal fields in the state have been completed or are under development. The CIMRP also provides a "Subsidence Information Center" through an arrangement with the Colorado Geological Survey.

The CIMRP has been involved in an intensive effort to address mine subsidence problems in the urban areas of Colorado since 1985. Approximately 25,000 people are directly affected by mine subsidence hazards along the Front Range. The Mine Subsidence Protection Program (MSPP) offers an opportunity to manage the risk and finance repairs for damages to private property from inactive coal mine subsidence. The MSPP allows up to \$50,000 per occurrence to repair damage, after a \$1,000 deductible. Up to the fair market value of the home can be received if there are multiple subsidence events. The inspection fee of \$100 is included in the first year enrollment fee of \$135. Continued participation in the MSPP requires a \$35 fee per year. Currently there are 325 homeowners participating in the program. Additional efforts to increase community awareness will be undertaken in 1990.

Mine Drainage Abatement Projects: Significant discharges of toxic mine water are found in widely varying environmental situations in Colorado. Over 1300 miles of streams in Colorado are adversely affected by toxic heavy metals incorporated in drainage from inactive mine adits, tunnels, and waste piles. The principal metals of concern are lead, zinc, copper, and cadmium. The primary concern resulting from metals concentrations is the chronic or toxic effect on aquatic organisms. Most discharges are remote and not easily accessed nor served by electrical power, yet such discharges may adversely effect public and private water supplies. The need for low cost water treatment which can be used in these environments is great. Three experimental systems have been constructed and are periodically maintained.

The CIMRP has a contract with the Department of Health's Nonpoint Source Program to treat two mine drainages and is the lead sponsoring agency for mining drainage projects in that program. Activities include the installation of a demonstration treatment system at the Pennsylvania Mine on Peru Creek in Summit County and construction of a multi-tier wetland using locally available forest products at the Perigo Mine on Gamble Gulch in Gilpin County. Both involve cooperative funding efforts with the CIMRP.

Other activities addressing nonpoint source problems in Colorado include reclamation of a large glory hole at the town of Alice in Clear Creek County using old mine tailings and waste rock with an attendant improvement of water draining from a mine adit, installation of passive mine drainage treatment systems at the Thompson #2 Mine in Pitkin County and the Marshall #5 Mine in Boulder County, completion of several erosion and sediment control projects associated with old coal mines along the Purgatoire River west of Trinidad, and diversion of highly saline water at the Walsen Mine west of Walsenburg from a nearby irrigation ditch.

Plans for 1990 and 1991 include initiation of demonstration projects on Chalk Creek near Buena Vista, Mosquito Creek near Fairplay, and East Willow Creek near Creede to demonstrate a variety of best management practices for addressing abandoned mine problems. Several additional problem areas have been identified for future work as funding becomes available.

Revegetation Feasibility Projects The CIMRP has sponsored a cooperative agreement with the Upper Colorado Environmental Plant Center since 1982 to evaluate a broad range of new plant materials suitable for use in solving revegetation problems associated with Colorado's disturbed soils, mine waste, and climate extremes. The Plant Center has conducted various test projects for the Program at the

Osage and Curtis Mines in Routt County, the Moore Mine in Jackson County, and the Thompson Creek Mine in Pitkin County. An annual report submitted by the Plant Center summarizes their seed selection, increase, and release activities supported by the CIMRP.

Historical Cultural Research and Evaluation Projects: The CIMRP has been involved in a variety of historical projects throughout the state including: National Register nominations for the towns of Cokedale, Louisville, Gold Hill, Eldora, Marble, Redstone, and the Ludlow Monument. Other projects have included a rephotography project of coal mining areas around the state. The collection includes historical and contemporary photographs. The extensive compilation of historical information required for the Program's grant applications have also been incorporated into the Colorado Historical Society's files.

Mine Safety and Education Program: The CIMRP has actively participated in the Operation Respect Program, started by the Bureau of Land Management and Women in Mining (a non-profit service group). Operation Respect provides a poster and an educational calendar that focuses on mining hazards. The CIMRP has recently produced a warning poster for use by landowners and schools. The Program is also expanding its educational efforts to high schools and the tourist industry. Both of these groups, as evidenced by four of the five inactive mine deaths last year, require increasing efforts to spread information about hazardous mines.

National Conference: As an active member of the National Association of Abandoned Mine Land Programs, Colorado is hosting the 12th Annual AML Conference in Breckenridge from September 16 to 20, 1990. This conference provides a forum for cooperation, coordination, and communication between states, tribes, and the Office of Surface Mining. This year's conference will also include a workshop on wetlands running concurrently with other technical sessions.

#### THE COAL MINING AND RECLAMATION PROGRAM

There are several federal and state issues that are being debated or reviewed which could effect the State of Colorado's Coal Program. At the federal level, the Office of Surface Mining (OSMRE) is reorganizing which will change the way the state does business with OSMRE. Whereas under the current system the Albuquerque Field Office, as well as other western field offices, reports to the Western Technical Center, under the new system each field office will report directly to an Assistant Director in Washington D.C. Although reorganization is largely an internal matter for an agency, we are

nonetheless concerned that this change may adversely effect the state regulatory programs. We have made our concerns known to the Director of the Office of Surface Mining, and we will closely monitor the change to determine whether it significantly effects our ability to carry out the program.

Another significant federal issue is valid existing rights. At the moment we do not believe that there are valid existing rights issues in Colorado as there has been in the east; however, we are monitoring the issue to determine if the outcome of federal regulations will effect the Colorado program.

At the state level there are three issues in the coal program to be discussed in this paper; the control and management of noxious weeds;, revegetation standards pertaining to shrub reestablishment; and bonding.

Noxious weeds: The infestation of noxious weeds on agricultural and rangelands within the state is a serious problem. Infestations result in reduced productivity, loss of ecological diversity and wildlife habitat as well as posing livestock health hazards. Land disturbances associated with mining provide habitat conducive to the infestations of noxious weeds. In particular, infestations of Canadian thistle, leafy spurge, musk thistle and scotch thistle have been observed on areas disturbed by coal mining activities in various regions of the state.

Presently, there are regulations in place that require mine operators to control and minimize the spread of weeds within disturbed areas. These regulations fall under the general categories of topsoil protection, revegetation, post mining land use, and protection of fish, wildlife and related environmental values.

In order to assist operators in managing and controlling potential weed infestations, the Division has drafted a guideline for the management of noxious weeds on coal mine permit areas. The guideline is presently in draft form, with the intent of finalizing it in March of 1990. The guideline is broken into three sections:

1. Applicable regulations;
2. Operator responsibility, and;
3. Weed management considerations.

It is believed that operators will find this document useful in understanding the Division's policy on enforcing weed control and in the development of site specific weed management control plans.



Shrub Reestablishment: Revegetation of lands disturbed by mining is one of the cornerstones of the Colorado Surface Coal Mining Reclamation Act. Given that one of the major tenants of the Act is restoration of land to a productive post-mining land use, revegetation is a focal point in an analysis of success of the Act. The evidence to date is that the majority of operators have been revegetating disturbed lands in an acceptable manner.

Revegetation success as it applies to bond release must meet four criteria, production, cover, species diversity and woody plant density. Observations to date indicate that operators will be successful in meeting cover, production and diversity standards. In addition, operators have been developing innovative and effective techniques for shrub reestablishment. Therefore, the issue is not can shrubs be established, they probably can at a certain cost. The question becomes, what is an acceptable density standard. One of the main reasons for shrub reestablishment is wildlife habitat. Wildlife use shrubs for cover and browse during the heavy snow months. Since 1981 the Division has set shrub density standards based on a guideline issued by the Division of Wildlife (DOW). This document generally requires a shrub standard of 1,000 stems per acre, and in fact this is the success standard set for the majority of the coal mines in Colorado.

The DOW guidance document was developed in the early 1980's when there were predictions of a greatly expanding coal industry in Colorado resulting in substantial habitat loss. Shrub reestablishment for wildlife habitat became a critical concern.

The predictions of an expanding coal industry did not come true and significant habitat loss was not experienced. Given this, it is appropriate to rethink the requirements for shrub reestablishment and density standards. The Division is currently working with the DOW to reassess our shrub density standards. In addition, we are examining the potential for methods of enhancing habitat that could be used in conjunction with shrub reestablishment.

Traditionally, shrub reestablishment was considered one of the main means for restoring wildlife habitat in areas of winter range. The Division is evaluating other means that may be as effective as the planting of shrubs alone. These include shelter belts, stock ponds, creative drainage reconstruction and manipulation of land surfaces to provide cover.

Reclamation Bonds: Bonding continues to be a critical concern to the mining industry. Securing bonds requires companies to tie up assets that become unavailable for other uses throughout the bond term. In addition, some companies have found it impossible to secure bonds from traditional sources, such as corporate sureties, and have

been forced to look to other financial institutions for bond coverage. The number of surety companies willing to provide coverage for mining operations has decreased during the 1980's.

The reluctance of surety companies to provide bond coverage to mining operations is due to three factors; a lack of understanding of the liability assumed when bonding a coal mining operation; extended liability periods before final bond release; and the general long term commitment that must be made for coverage (life of mine may be 30 to 40 years).

In an attempt to simplify the bonding process, the Division has developed a document that describes the bonding program for coal mines. The document addresses the Division's procedures and requirements for bonding coal operations with the state. The purpose of the document is to describe the management of reclamation bonds, clarify the method of calculation of bonds, and describe the liability and release procedures.

#### SENATE BILL 181

Senate Bill 181, passed in 1989, affects both the Minerals Reclamation Program and the Coal Mining and Reclamation Program. The new law reinforces the relationship between several agencies that have responsibility to manage or regulate water quality and quantity. It recognized the Water Quality Control Commission as the sole authority over the establishment of classification and standards for water quality protection while recognizing the authorities of the other agencies to implement and enforce the standards.

The Mined Land Reclamation Division has very broad authority to address water quality and quantity issues. The Board and Division have exercised these authorities in a manner that will not conflict with the authorities of the State Engineer and the Water Quality Control Commission and Division. The new law underscores the Mined Land Reclamation Division responsibility to ensure that mining companies minimize disturbance to the hydrologic balance. This includes proper management of both point and nonpoint sources of pollution to both surface and groundwater. The Mined Land Reclamation Division has recognized that the enforcement of standards of point source discharges to surface water is the responsibility of the Water Quality Control Division; however the review of design, construction and maintenance of hydrologic structures is the responsibility of the Mined Land Reclamation Division.

Under Senate Bill 181 the responsibility of the Mined Land Reclamation Division will be to enforce Commission set standards for nonpoint discharges as classification and standards are developed, and to select the point of compliance for groundwater based upon criteria established through rule-making. The Mined Land Reclamation Division will enforce groundwater standards at the point of compliance.

Selecting the point of compliance in the Coal Program is a matter that has already received much attention. The comprehensive nature of the coal regulations, the requirement for operators to assess the probable hydrologic consequences resulting from the operation, and the requirement for the division to conduct cumulative hydrologic assessments has resulted in modeling and data collection which identifies the appropriate point to monitor for compliance. Any rules that may be developed under Senate Bill 181 will reflect that experience.

Selecting the point of compliance in the Mineral program is more difficult. Monitoring has been required, but the complex hydrogeology of most hard rock sites makes it very difficult. The alternatives that may available include techniques such as modeling the point of compliance but monitoring prior to the point, thus establishing a monitoring standard for each monitoring point. Also, requirements that may be examined include establishing the point of compliance at the facility in the case of processing facilities such as heap leaches.

Memoranda of Understanding are being developed with the Health Department pertaining to the administration of this new law.

#### SUMMARY

The preceding discussion has identified the current significant issues facing the Mined Land Reclamation Division and Board. The resolution of these issues is having, and will have, a substantial effect upon the regulation of the mining industry and the reclamation of inactive and abandoned mines. The mining industry sectors most affected are the rock products producers and the hard rock mining operations. As the state moves into the 1990's, these two sectors will face significant challenges in meeting the economic needs of the state in a manner that is responsive to community concerns and protective of the environment.

BLUE RIVER RECLAMATION PROJECT

BRECKENRIDGE, COLORADO

**Note:** This writing is a condensed version of the Blue River Reclamation presentation given at the International Erosion Control Association Conference held in Vancouver, British Columbia in February 1989. The entire paper includes approximately 100 slides and further information may be obtained by contacting the author.

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## Breckenridge

### Demographics

Summit County, Colorado, home of sixty mountain peaks over 11,000 feet, three popular ski resorts, two large reservoirs, and enough dredge tailings to build ten Hoover Dams, lies just west of the Continental Divide about 75 miles west of the city of Denver.

### Mining History

The search for precious metals began just to the north of the town of Breckenridge along the Blue River and diffused along the waterways: first into the gulches feeding the Blue; next into the major tributaries of the Blue (the Swan Valley, French Gulch, the Snake Valley and Tenmile Canyon); then into the gulches feeding these tributaries and lastly the mountainsides between the gulches -- all in rapid succession. The spread along the waterways was no accident; the waterways provided access to the areas and water for the early hydraulic methods. Even dry gulches were mined if nearby water sources could be channeled into the gulches via ditches and pipes.

The first and simplest method used by miners in the county, was panning: water and gravels from the streambed were swirled in a large pan with the water and lighter-weight gravels swirling out of the pan and the heavier gold flakes collecting at the bottom of the pan. Only the upper levels of gravel were disturbed. Once panning established the presence of gold, the miner staked his claim and proceeded to make his mark upon the land. Trees were cut; a long sluice box was built; water was diverted to flow through the wooden trough disturbing natural gravels, stream flow, gradient, soils and vegetation. As the gravels were shoveled in, the water carried away lighter materials leaving the heavier gold to catch in the cleats at the bottom of the sluice box. The water for a considerable distance downstream carried a heavy sediment load.

Always looking for ways to find more gold faster, miners changed methods. High pressure hoses, called "giants," fed by diverted streams, were turned against the hillside gravels of the gulches and valleys, literally washing them away. Other hoses directed the loose gravels into sluice boxes. Many miles of diversion ditches were necessary to collect the tremendous volumes of water needed for this type of mining.

Dredging, the third major method of mining in Summit County and the one using the greatest amount of technological expertise and energy, was the most destructive because it literally turned riverbeds upside-down. The mighty dredges chewed up the landscape between 1898 and 1942. A total of nine dredges operated in the county -- all of them along the Swan and Blue and in French Gulch. In the front of a gold dredge was an endless chain of about 90 buckets which could bite 70 feet into the gra-

vels. The buckets lifted the stream deposits to the screening equipment on the upper deck. Here the gold and finer gravels were separated from the larger cobbles which were dropped in piles behind the dredge. Next the finer sands and gravels were washed in sluice boxes. Sands and gravels flowed back into the pond while the gold settled to the bottom of the sluice boxes.

The various types of mining in the county had their biggest and longest-lasting impacts upon the vegetation, the stream systems, and the uppermost layers of soil and gravel. Although current day gravel crushing companies may turn the dredge tailings into profit, much of the mining impact will remain a very long time.<sup>1</sup>

### The Wetlands and the Golf Course

In the early 1980's, the Town of Breckenridge acquired a 200 acre parcel of land from a local developer for the purpose of constructing an 18 hole golf course. Approximately 50% of the existing ground cover on the property was covered with high altitude wetlands, surrounded by tree covered hillsides overlooking the golf course area with a good potential for private development.

During the process it was necessary to complete a wetland mitigation plan with the U.S. Army Corps of Engineers, since in the beginning it was anticipated that some 70 acres of the wetlands on the site were to be disturbed in one form or another. The golf course design team was instructed by the Army Corps to minimize the disturbance wherever possible. Final inspection of the completed golf course revealed that only half the original estimate of wetlands were altered.

In addition to a long list of permit requirements by the Army Corps at the golf course site, it was decided, based on negotiations between the Town, the Army Corps, and the Colorado Division of Wildlife that a 30 acre parcel of land along the Blue River north of Breckenridge would be renovated. This negotiation was later to prove one of the most successful river reconstruction projects in the country.

The river reclamation site was approximately 200 feet wide by 5500 feet long. The dredge boat operations which lasted from 1898 through 1942 left piles of rocks and cobbles nearly 30 feet in height above water levels. The cobbles contained few fine grained soil particles, and what remained ranged in size from 3 inches to 3 feet in diameter. Topsoil and organic layers were virtually non-existent. Water flows ran through piles of cobbles left by the dredge boats in a section which was 50 to 75 feet deep and in some areas 400 feet wide. Channel stability was non-existent.

In addition to the main goal of the project dictated by the Army Corps 404 permit requirements, several secondary goals had been set.

Several groups had placed a high priority on maintaining surface flow through the system for as long a period and through as much of the project as possible. For the vast majority of the project area, flow disappeared below the channel bed except during snowmelt runoff months. A closely related secondary goal was creating fisheries habitat for fish and other small wildlife. Finally, the Town desired an area that complemented the existing bike path and helped serve as an attractive entrance to the Town.

### Engineering

#### Data Collection

The information needed for an adequate engineering design included drilling wells to monitor groundwater levels, establishing stream measuring stations, collecting sediment transport data, and surveying the existing channel and the adjacent rockpiles. Eight wells and four flow measurement stations were established. Sediment transport data collection consisted of sediment measurements and determination of bed and bank material size distributions. Surveying included cross sections at 100 foot intervals, a profile of the existing channel thalweg, and development of a two foot contour map for the project area and adjacent land. Lenzotti and Fullerton, Inc. (Breckenridge) performed the design engineering.

#### Hydrologic Analysis

The design of the project was dependent on two types of hydrologic analyses. The first was a determination of the high flow conditions. The design of stabilization measures, sizing of protection, and dimensions of the channel were all dependent on peak discharges as a design parameter. The second type of hydrologic analysis concerned the prediction of groundwater levels for several crucial periods of the year. Both the ability to provide subirrigation for wetland vegetation and extending the period of surface flow in the channel relied upon good estimation of groundwater levels. Their prediction required an understanding of the interaction between the stream and measured groundwater levels along with determining hydrologic variables, particularly low flows.

Using the information from the hydrologic analysis along with input from the revegetation specialists, several hydraulic design criteria were set. These were:

1. Critical groundwater levels based on a discharge of 25 cfs would be used to determine the elevation of overbank areas for growth of wetlands.
2. The channel would be designed to carry a flow of 750 cfs which corresponds to the 25-year flood. It was reasoned that this

flow reduced the risk that overbank areas would be flooded prior to protective vegetation being established to acceptable levels.

3. Channel stabilization measures would be designed to pass flows on the order of the 50- to 100-year flood (approximately 1100 cfs).
4. Most importantly, a scheme of removing dredge material to lower the channel and overbank areas was adopted. The purpose would be to bring the channel bed and overbank areas close enough to the groundwater table to maintain surface flows in the channel for as many months as possible while providing for subirrigation of wetland areas.

### Drop Structures

From observations of the existing channel and accounts of its historical behavior, it was obvious that the system in its existing condition was highly unstable. The potential success of the wetlands reclamation project was as dependent on creating a relatively stable channel environment as it was on providing appropriate groundwater levels. After investigating several options for channel stability, it was decided that reducing the slope of the channel thalweg, installation of drop structures varying in height from two to four feet, and constructing localized areas of bank protection was the most economical and aesthetically pleasing of all the studied alternatives.

Channels with varying dimensions and bed slopes were considered and the resulting hydraulic conditions calculated for each configuration. An incipient motion analysis was conducted for both the bed and banks utilizing Shields criteria as modified by Gessler.<sup>4</sup> This analysis was used to determine at what discharges various sizes of bed and bank material would become mobilized by the force of the flow. Because of the lack of fine material, the banks were considered non-cohesive. For the banks, the critical shear parameter was adjusted using the equation derived by Lane.<sup>5</sup> From this analysis it was determined that a channel with a width ranging between 30 and 40 feet and side slopes of 2.5:1 or flatter would be highly stable at an effective slope of 0.5 percent for flows up to the 25-year.

To establish an effective slope of 0.5 percent, a series of 21 drop structures with design heights of approximately 3 feet were included in the project design. Sizing of the boulders in the drop structures was based on the factor of safety method presented by Simons and Senturk (1976)<sup>6</sup>. Applying this methodology, it was determined that boulder ranging in size between 3 and 4 feet in diameter would have a safety factor of one for the 100-year flood.

The configuration of the drop structures was designed to concentrate flows in the center with the crest being arched in the upstream direc-



tion and the center being slightly depressed. Therefore, the side slopes would not be exposed to as severe hydraulic conditions as the drop face. To dissipate energy and prevent downstream scour, a plunge pool was provided for each drop structure. The plunge pools were designed to be four to five feet in depth. At the downstream end of the plunge pool, large boulders were intermittently placed to protrude into the flow and function similar to baffle blocks. An apron of boulders ranging in diameter from nine inches to two feet was placed for 15 to 25 feet downstream of the plunge pool. To prevent flanking of the drop structure, bank protection continued for 15 feet upstream of the crest. In addition, the banks were graded to direct overbank flow into the channel upstream of the drop structures. All side slope protection was keyed three feet into the bed. An entire row of boulders was keyed below the plunge pool at the base of the drop face.

The channel alterations just described impose a major change on hydraulic conditions. Therefore, in closing the discussion on the design of the channel, it is necessary to address the sediment transport ramifications of performing such a drastic alteration. For many situations, this would doom the project to failure since the flat sections between drops would be filled with sediment and the drop's effectiveness rapidly negated. However, this will not be the case with the Blue River Project. The coarse material transported and deposited within the project area is derived entirely from sources within the project. These sources will be removed by project grading. Upstream supply of coarse sediments is non-existent because of a ponded area immediately above the project. Supply to this pond is small due to stabilization measures that have been taken on the Blue River throughout the Town of Breckenridge.

It is extremely important that whenever a project that alters the hydraulics and sediment transport conditions of a river system is undertaken, the consequences of the actions are understood. In the case of the Blue River Reclamation Project, the design was conducted so as to eliminate the source of sediment overloading and construct a project that would be in equilibrium with the altered sediment supply.

### Revegetation

#### Plan Development and Literature Search

The wetland revegetation plan began with a review of regulatory requirements and the development of revegetation objectives, and continued through evaluations of existing site characteristics, revegetation literature and general construction plans.

Field pits were dug at selected points along the river bank and existing growth mediums were described with respect to soil texture, percent coarse fragments, pH, and plant root development. These eva-

valuations were seen as a method of determining, in part, minimum plant establishment requirements. Such information could also be used to incorporate existing plant communities on site into the total wetland construction process.

Samples of soil stockpiled nearby for use as a seedbed material cover following grading were collected and sent to a soil laboratory for chemical analyses. Nearby wetland communities were evaluated in the field to assess the characteristics of functioning wetlands and confirm the candidate species list for planting.

In addition to field analyses conducted with the support of project engineers, a high degree of interactions with these individuals and the Cedar Creek & Associates (Ft. Collins, CO) revegetation specialist was maintained throughout the course of the project. (Grading plans were often reviewed and updated in light of wetland construction requirements.) Seasonal water levels in the river, of the highest importance to the development of self-perpetuating wetland communities, were estimated by the engineers. This information was carefully reviewed in light of potential grading plan revisions to enhance wetland establishment potentials.

As the project progressed, a literature review was conducted to aid in the selection of the appropriate wetland revegetation techniques to be implemented. As a part of this process, interviews were conducted with a number of individuals representing a wide range of institutions and agencies concerned with wetland reconstruction. The results of the interviews indicated that a large body of detailed literature was available concerning saltwater marsh, dredge spoil, and freshwater pond/marsh revegetation. Little information was known to be available, however, with regard to riverine wetland reconstruction. No studies were known to exist, at that time, dealing with total wetland reconstruction along river systems in high altitude situations.

As a result of this process, the final wetland revegetation plan was prepared. Presenting site-specifics through text and plan view drawings, the plan also provided for a level of field interpretation with respect to plan implementation in consideration of potential site varieties. Precise material and revegetation techniques specifications were provided under separate cover to the Town for use by field personnel to serve as a basis for on-site plan implementation.

#### Development of Site Types

To meet planning needs, ten "Site Types" were developed and applied to the entire acreage within the construction project boundaries. Each Site Type was developed in direct response to a specific project objective and took full advantage of revegetation opportunities which site conditions had to offer. Specific planting plans were prepared for each Site Type, as appropriate, in response to estimated subsurface hydrolo-

gic conditions, seedbed characteristics, and potentials for subirrigation.

#### Species Selection and Planting Rate Development

A literature review was conducted concurrently with the site evaluations. This review emphasized publications developed by the Corps of Engineers with regard to wetland reconstruction and revegetation studies conducted in high altitude situations. Species tolerance ranges were further defined, potential success rates established, best planting methods selected, and species compatibility considerations developed. Corps publications categorizing wetland species were carefully reviewed to be certain that sufficient "wetland" species would be selected to meet wetland construction objectives.

As a result of this procedure, a final species list for planting was developed. This list was then forwarded to Neils Lunceford personnel (Silverthorne, CO), experienced with landscape plantings in the area, to review as a final check with regard to species adaptation to expected site conditions. Following this review, the planting list was finalized.

With the planting list finalized, seed mixtures and planting rates were developed. Seed mixtures for each site type were prepared given site type objectives.

Planting rates were based on Corps requirements, the literature review, and the experience of those involved in developing the revegetation plan. Rates for grass and forb seedings resulted from a review of recommended planting rates developed for similar disturbances by various federal and state agencies involved in mine land reclamation.

#### Revegetation Standards

A summary of plants, grasses, and wildflowers typical for two of the ten different site types is given below. Although not an exhaustive list of all vegetation which could be expected to grow along a riverbank at 10,000 ft., it is a good cross section.

Site Type V was designed to enhance existing uplands which included some existing vegetation for the purposes of aesthetics and wildlife habitat; soil moisture recharge will be solely a function of incident precipitation.

Plantings (seedlings) included: Potentilla, Woods Rose, Colorado Blue Spruce, Aspen, Lodgepole Pine, Rabbit Brush and Sage (1 gallon variety).

Site Type IX was designed to establish shrub and tree species which require a significant amount of soil moisture to complete their life

cycles. Saturated soil conditions, however, are not required for any length of time.

Plantings (seedlings and transplants) included: Red Berry Elder, Willows, Thin Leaf Alder, Narrow Leaf Cottonwood, Bog Birch and Sedges (1 and 5 gallon variety).

Seed mixture included Redtop, Meadow Foxtail, Red Fescue, Reed Canary Grass, Alsike Clover, and a few of the site V seeds.

### Contracting and Project Costs

#### Project Costs

A final welcome surprise was the overall cost of the project. Although not complete, the total expenditures can be summarized as follows:

- |  |                  |
|--|------------------|
| 1. Removal of approximately 500,000 tons of the old dredge material (rocks and cobbles)  | \$ 100,000       |
| 2. Reshaping and final grading of the river channel, river banks, wetland areas and upper transition areas (1¼ miles x 200 feet)   | 100,000          |
| 3. Construction of 21 drop structures (averaging 300 cu. yds. of boulders and riprap ranging in size from 1 to 5 feet in diameter, 2 to 4 feet high and 20 to 40 feet wide, including plunge pools) and including hauling boulders to the job site, including all equipment and labor time - 6,000 each                              | 126,000          |
| 4. Revegetation for 1¼ miles x 200 feet (excluding the river itself) of various grass seed mixes, wildflower mixes, and all plantings necessary to meet final revegetation plans as approved by the Army Corps of Engineers, plus additions as recommended by the revegetation contractor, and acquisition of finished grade topsoil | 110,000          |
| 5. Design survey, design engineering, construction staking, field engineering and revisions, consultant meetings, construction management and miscellaneous  | 70,000           |
|  | <u>\$506,000</u> |

#### Author's Notes

A few comments relating to the completion of the Blue River Reclamation Project are in order.

As is mandatory for any project of this magnitude and experimental nature, success depends upon the recognition of the project's components and arrangement of the interaction of these components on a timely basis. In this case, the principal players performed the following:

- a) determination of the water table
- b) design of a feasible grading plan
- c) drop structure design
- d) design of river channel ensuring 100-year storm stability
- e) revegetation consulting
- f) construction

It is of utmost importance that those hired are not only well qualified to perform the consulting and contracting work, but that all are able to work together as a team through project completion.

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## **A SYSTEMS APPROACH TO PERMANENT DRAINAGEWAY STABILIZATION ON RECLAIMED LANDS**

**William Agnew<sup>1</sup> and H. Bruce Humphries<sup>2</sup>**

### **ABSTRACT**

Portions of five major drainageways and their tributaries were regraded and appropriately treated to reduce the erosion rate and assist in permanent channel stabilization at Trapper Mine (surface coal mine) in 1987, 1988, and 1989. A wide variety of erosion control materials, methods and sediment reducing measures were used in reconstructed drainageways and on adjacent sideslopes. Vegetation response, decreased flow rates and reduced gully formation were the primary factors in assessing the success of drainage reconstruction projects. Postmine herbaceous cover, above-ground primary production and woody stem density were evaluated in reconstructed drainage channels and compared to sample data from undisturbed premine drainage locations. As expected, vegetation measurements were lower in postmine drainages than in undisturbed drainages. However, considerable vegetation growth was reported in all reconstructed drainages at the conclusion of the initial growing season and during the second growing season. The mean herbaceous cover in postmine drainages was 39% compared to 71% in undisturbed sites in 1988. In 1989, canopy cover had increased to 60% in postmine drainages and decreased on undisturbed drainage segments to 69% cover. Herbaceous primary production was severely limited in 1989 due to severe drought conditions. Flow rates were significantly reduced following the establishment of water harvesting techniques. Following treatments, the estimated erosion rate was reduced 24 times the pre-treatment erosion rates.

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## INTRODUCTION

Surface water runoff is the major contributor to accelerated erosion at Trapper Mine. Runoff is discharged for only brief periods as a result of snowmelt or high-intensity, short duration thunderstorms. Such events can have devastating effects on reconstructed drainageways, maintenance costs, and sediment pond cleaning costs. Thus, Trapper Mine initiated a determined effort starting in 1986 to develop techniques sufficient to control accelerated erosion of reclaimed drainage basin systems at Trapper Mine.

In the semi-arid western United States the loss of topsoil and the degradation of water quality are strongly influenced by natural fluvial processes. Langbein and Schumm (1958) showed that sediment yield varies with effective precipitation, with maximum sediment yield occurring in semi-arid regions and lesser amounts of sediment yield in both arid and humid areas. In semi-arid regions it is not uncommon to find poor soil and inadequate vegetative cover. These factors coupled with significant precipitation events are sufficient to cause accelerated erosion (Langbein and Schumm 1958, Gray and Leiser 1982).

Besides fluvial processes, geologic structure and controls may also influence the form of drainage basins and stream patterns. Drainage basins are often referred to as the basic hydrologic, geomorphic or landscape unit and take into consideration the influence of hillslopes and channels to define a drainage network (Chorley et.al. 1984, and Toy et.al. 1987). The origin and function of a drainage basin is the result of the erosion forces of flowing water and the resistive forces of the geologic materials underlying the basin. Outcrops of resistant bedrock will cause stream channels to turn abruptly or follow the outcrops of more erodible materials developing a deformed (parallel, trellis, rectangular, radial or annular) drainage pattern (Zernitz 1982, and Toy et.al. 1987). When drainages form without the influence of geologic control, a tree-like or dendritic pattern forms that is characterized by irregular branching with tributaries joining main channels at many different angles (Toy et.al. 1987). The design or extent of drainage pattern development is also dependent upon the factor, time.

In summary, the soil erosion factors which included the erosivity of the eroding agent (water and sediment), the erodibility of the soil, the slope of the land and plant cover (Morgan 1986), coupled with other fluvial processes and geologic structure all impact the development of a drainage basin system. Changes to any of these factors will influence the historic rates of drainage development and eventual drainage system expression and stability.

Surface mining and reclamation activity may remove bedrock drainage control and replace such control with unconsolidated spoil material that is relatively homogeneous in nature. Over time, the resultant drainage which develops will tend to dendritic in pattern with possible loss of natural erosion control. The fractured spoil material may produce a modification to what would naturally develop in terms of drainage pattern or hillslope and channel gradients. To compensate for this geologic change, hillslope and channel gradients could be reduced or appropriate conservation techniques (agronomic and physical) could be incorporated to reduce the potential for accelerated erosion over and above baseline erosion rates.

Agronomic measures include the use of vegetation, and soil structure improvements to control erosion and protect soil. Physical methods include some type of manipulation of the surface topography to either reduce gradients, lengthen channels or dissipate the energy of flowing water.



The objective of this project report is to describe viable conservation alternatives, such that successful drainage channel reconstruction of drastically disturbed lands may be accomplished in a cost effective manner.

## **STUDY AREA**

Trapper Mine is a surface coal mine located approximately 6-1/2 miles south of the city of Craig, CO, along the northern slope of the Williams Fork Mountains. The climate is semi-arid steppe and is characterized by cold winters and moderately warm summers. The average annual precipitation is 13.9 inches, one-third of which falls in the form of snow and is the principal source of stream flow for the region. Soils are generally deep and formed in alluvium and colluvium derived from sandstone and shale. The topography is described as rolling hills with relatively steep slopes (average - 14%). The prevalent vegetation type is mountain shrub which interfaces with stands of big sagebrush at lower elevation and aspen types at higher elevations.

## **METHODS**

At Trapper Mine, five major drainageways and their tributaries were regraded and appropriately treated to reduce the erosion rate and assist in permanent channel stabilization in 1987, 1988 and 1989. At the conclusion of the 1989 field season, approximately 36,450 linear feet (6.9 miles) of permanent drainageway reconstruction had been completed at Trapper Mine.

### **Vegetation Sampling Methods**

Herbaceous plant canopy cover, annual herbaceous primary production and woody stem densities were measured on seven postmine reclaimed drainage sites and on two undisturbed premine drainage locations in 1988 and 1989. Plant canopy cover was estimated in 3,100-m transects spaced 10-m apart at each site. Herbaceous plant canopy cover and percent mulch cover were estimated by species using the point-hit technique (Optical Point Bar) (Viert 1985). Herbaceous production was estimated by clipping 6,1/4-m plots (20-m spacing) on each of the three line transects at each site. Woody stem density on undisturbed drainage segments was calculated using the point-center-quarter (PCQ) method (Dix 1961). Five PCQ's were conducted on each line transect at 20-m spacing. Distances from the center of each PCQ to the nearest live stem in each quarter was recorded. Woody stem densities in reconstructed drainage segments are an approximation of the actual seedlings planted at each site.

### **Erosion Control Methods**

A wide variety of soil erosion control materials, methods and sediment reducing measures were used in reconstructed drainageways, on reclaim sideslopes and on regraded

spoils. The following list of measures and/or materials were applied in combination to decrease the likelihood of accelerated erosion, to reduce flow rates and to reduce the sediment loading in downstream sedimentation structures.

Dozer basins (sediment basin) were constructed to trap and store sediment on newly stripped topsoil areas and on regraded spoils to reduce or abate the sediment load. Basins are used to prevent the siltation of diversions, waterways, livestock ponds, and streams; to trap sediment originating from the active mine site and to prevent undesirable deposition on undisturbed bottomlands and reclaimed areas. The dozer basins primary use is to trap sediment, reduce on-site erosion, reduce peak flows at downstream locations, and reduce gully erosion.

Livestock watering tanks (ponds) are used to trap water on reclaimed sideslopes, in drainageways, and to reduce peak flows at downstream locations making available reliable water for wildlife use. The location of livestock ponds is such that a minimal amount of sediment will be deposited. This was accomplished by installation of ponds at headwater locations or on relatively gentle grades often within water harvesting diversions on reclaim sideslopes.

Water harvesting diversions are channels constructed across slopes with a supporting ridge on the lower side that is used to transport excess water from areas that need protection to sites where water can be used or disposed of safely. A diversion's effectiveness as a sediment reducing measure is in diverting the runoff which would otherwise flow across erosion susceptible areas, thus detaching and transporting soil particles.

Contour farming and live haul topsoil transport are used on all reclaimed sideslopes and drainage areas when possible. Topsoil replacement, seedbed preparation, and planting are done on the contour. Contouring can reduce erosion by 40 to 50 percent. When contour farming is combined with live material topsoil transport the erosion loss potential can be further reduced. Contouring provides excellent erosion control by reducing transport from moderate rainfall events. Contouring in combination with diversion establishment can be very effective in reducing erosion potential.

Rock check structures are used to dissipate the energy of flowing water within the drainageway channel. Debris and sediment tend to be deposited and trapped upstream of structures. This in turn permits establishment of vegetation behind structures which further stabilize the channel. In addition, filter fabric is installed and used to line rock check structure core trenches, thus providing additional structural support and reduces the potential for advancement of downstream headcutting to move upstream.

Cover crops and mulch are used very effectively in drainageways to reduce the detachment of soil by rainfall and runoff while providing seasonal protection and soil improvement. Cover crops provide protection from wind and water erosion during vegetation establishment periods when permanent vegetation is inadequate to provide adequate cover.

Permanent vegetative (grasses, forbs and shrubs) cover provides the most significant and permanent long term solution to erosion control problems. The selection of species adapted to the climate and soils is one of the most important steps in achieving success. Woody plants are desirable for the long term stability of a particular site. However, woody plants require time to develop sufficient size to control erosion adequately and the quick cover that can be obtained with grasses and forbs is needed in the interim. The principles for selection of herbaceous vegetation is based on a particular species adaptation to the mine site and its erosion control potential. The ideal species have strong root development. A diverse mixture of plant species increases

the assurance of a stand as it is difficult to anticipate all of the variables that will affect germination and stand establishment on any given site.

Willow wattles and woody seedling transplants are installed in drainageways and serve as energy dissipaters for water and soil moving down the drainageway and provide long term stability. Woody plants filter and trap entrained debris (soil, small rocks, veg litter) and provide a series of areas with reduced slope angles on which vegetation can be established. Deep rooted woody vegetation prevents gully formation and will become part of the permanent stabilizing cover.

Brush matting (crimping) is essentially a deep mulch of hardwood brush and soil crimped into existing drainage cuts. The technique is employed very effectively in damaged stream channels and on stream banks to protect against accelerated erosion rates when a channel needs repair.

Geotextiles, erosion blankets and other erosion control fabrics, are used effectively in reducing stream velocities and increasing sedimentation in drainageways. A variety of materials are used at Trapper Mine and include geoweb - a soil confinement system, C125 coconut blanket, landglas erosion control fibers (landglas is tacked with CSS-1 emulsified asphalt), fibron fibers, mirifi erosion cloth, jute erosion netting and miramat blankets.

## RESULTS

Vegetation response, decreased flow rates and reduced gully formation were the primary factors in assessing the success of drainage reconstruction projects at Trapper Mine.

Postmine herbaceous canopy cover, herbaceous production, and woody stem density were evaluated in reconstructed drainage areas in 1988 and 1989 and compared to sample data from undisturbed premine drainage areas. (Sampling was conducted on drainageways reconstructed in 1987.) Various postmine drainage treatments were incorporated to evaluate vegetation response on topsoiled, non-topsoiled, irrigated, and non-irrigated drainage segments (Table 1). Treatments on undisturbed areas were irrigated and non-irrigated drainage segments (Table 1). Generally, vegetation measurements were lower in reconstructed drainageways than in undisturbed drainage sites. This is understandable due to the short duration of vegetation re-establishment. However, considerable vegetation growth was reported in all reconstructed drainages after the initial growing season and during the second growing season.

Vegetation response was the best on topsoiled and irrigated treatments and was significantly higher when comparing topsoiled versus non-topsoiled areas without irrigation. The overall herbaceous canopy cover for all reconstructed drainage treatments in 1988 (measure of initial growing season) was 39% compared to 71% on undisturbed drainage segments. In 1989, herbaceous canopy cover had increased to 60% in reconstructed drainages and decreased on undisturbed drainage segments to 69% cover.

Herbaceous primary production averaged 876 lbs/acre in reconstructed drainages and 1943 lbs/acre on undisturbed sites in 1988. In 1989, herbaceous primary production decreased to 420 lbs/acres on reconstructed drainages and 521 lbs/acre on undisturbed drainage segments. The reduction in production in 1989 compared to 1988 was a result of severe drought conditions in the area during 1989.

Table 1. Vegetation cover, production and woody stem densities on disturbed (postmine) and undisturbed drainages at Trapper Mine in 1988 and 1989.

Reconstructed Drainage (1)(2)	Herbaceous Canopy Cover (%)		Herbaceous Production (lbs/acre)		Woody Stem Density (stems/acre)	
	Irrigated(3)	Non-Irrigated	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated
	1988	1989	1988	1989	1988	1989
Upper Coyote (topsoiled)		32	61		246	466
Middle Coyote (topsoiled)		46	74		1003	583
Lower Coyote (topsoiled)	51	79	1835	1069	628	1256
Upper West No Name (topsoiled)	36		725		628	1256
Lower West No Name (topsoiled)	50		1687		628	1256
Upper East No Name (not topsoiled)		24	44		210	240
Lower East No Name (not topsoiled)	33		426		236	628
Undisturbed Drainage(4)						
Upper Flume		63	(5)		694	(6)
Lower Flume	80	69	3191	521	2552	7223

(1) Drainageways regraded, topsoiled and drill seeded in late summer 1987.

(2) Woody stem density comprised of Amelanchier alnifolia (Saskatoon Serviceberry), Crataegus spp (Hawthorn), Populus angustifolia (Narrowleaf Cottonwood), Prunus americana (American Plum), Prunus virginiana (Common Chokecherry), Ribes aureum (Golden Current), Rosa woodsii (Wood's Rose), Salix vitalina (Golden Willow), and Symphoricarpus oreophilus (Mountain Snowberry).

(3) Drainage segments irrigated in 1988 may not have been in 1989 due to pit dewatering activity or drying of natural springs.

(4) Woody stem density comprised of Amelanchier alnifolia (Saskatoon Serviceberry), Artemisia cana (Silver Sagebrush), Artemisia tridentata (Big Sagebrush), Chrysothamnus viscidiflorus (Low Rabbitbrush), Prunus virginiana (Common Chokecherry), Quercus gambelii (Gambel Oak), Rosa woodsii (Wood's Rose), Symphoricarpus oreophilus (Mountain Snowberry).

(5) Samples not taken as area was severely impacted by drought and livestock grazing.

(6) Samples not taken as area was severely impacted by drought and livestock grazing.

Woody stem densities on undisturbed drainage areas averaged 4888 stems/acres for both years compared to 471 stems/acre in 1988 and 897 stems/acre in 1989 on reconstructed drainage areas.

Flow rates have been significantly reduced following the installation of stock tanks and dozer basins on reclaim and spoil areas, respectively. Discharge readings were recorded from a 10-year, 24-hour parshall flume (with Stevens Water Level Recorder) located in the north end of the Coyote Gulch reconstructed drainage channel. The peak flow in 1987 (22.24 cfs) occurred as a result of a high intensity thunderstorm in June (.74" ppt) and caused severe erosion within the newly regraded drainage channel. In 1988, following drainage reconstruction and water retention strategies, the peak flow rate associated with a .53" precipitation event (June) registered .04 cfs of discharge water. Similarly, a high intensity thunderstorm in July 1989 (.75" ppt) resulted in a discharge of 1.23 cfs. In addition to assisting in runoff control, the proper frequency and distribution of livestock ponds has aided in evenly spreading big game animal use over the entire reclaimed area, thus reducing their impact on vegetation establishment.

Gully formation and sediment loss was reduced significantly in postmine drainageways when compared to pre-drainage reconstruction. In Coyote Gulch, for example, an estimated 99,400 cubic yards of sediment was lost to gully erosion and sheet and rill erosion from 1984-1987. Following treatment an estimated 1,360 cu yds of sediment is lost annually to sheet, rill and gully erosion. This is a reduction in the annual erosion rate of 24 times the pre-treatment erosion rates. Much of the success for the reduction in erosion rates must be attributed to the wide variety of erosion control materials, methods and sediment reducing measures that were used in reconstructing drainageways and adjacent reclaimed sideslopes.

As a result of appropriate erosion control treatment in re-established postmine drainageways, Trapper Mine has not needed to clean a single sediment pond in two years. A net savings to Trapper Mine of \$50,000 has been realized since drainage reconstruction was initiated and sedimentation pond cleaning ceased.

## CONCLUSIONS

As a strategy for soil conservation planning, the promotion of vegetation in combination with natural and/or artificial erosion control measures, has much to offer. Vegetation is one factor that can be easily manipulated by careful management. Beyond that, better vegetative growth, by selecting plants that are well adapted to a particular climate or soil, will almost always provide direct economic benefits in terms of vegetation production, stability and reduced soil loss.

The proper implementation of erosion control materials and sediment reducing measures on reclaimed sideslopes, drainageways, and on regraded spoils are valuable in reducing peak water flows and sediment loads into drainages. Dozer basins are useful to trap and store sediment on newly stripped topsoil areas and on regraded spoils. Livestock water tanks are valuable as they trap water on reclaimed sideslopes, in drainageways, and reduce peak rates of flow at downstream locations, making available reliable water for wildlife and livestock use. Water harvesting diversions constructed across slopes are important to transport excessive water from areas that need protection to sites where water can be used or disposed of safely. Contour farming is essential to reduce sheet and rill erosion on reclaimed sideslope. When combined

with live haul topsoil transport the erosion potential is further reduced. The installation of rock check structure to dissipate the energy of flowing water and trap sediment and debris is valuable in stabilizing channels and promoting vegetation growth. Finally, the use of geotextiles, erosion blankets and other erosion control fabrics are effective in reducing stream velocities and increasing sedimentation in drainageways.

The combination of appropriate conservation measures and an aggressive repair program add up to successful treatment of reconstructed drainage channels and consequently successful reclamation at Trapper Mine while permanent vegetation establishes.

Perhaps the major problem with such a soil conservation strategy is that it requires continuous, sensitive, timely and knowledgeable management of the soil and vegetation and the use of appropriate and cost effective erosion control techniques and material to be fully effective. But the rewards in terms of reduced soil loss and potential dollar savings are indisputable. One must keep in mind, however, that regardless of soil conservation planning and implementation efforts to stabilize post mine drainageways, their long term stability and that of adjacent undisturbed drainages is subject to the affects of catastrophic weather patterns.

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**TITLE**

DEVELOPMENT OF A CHEMICAL USE MANAGEMENT PLAN

A CASE STUDY

THE RESORT AT SQUAW CREEK

SQUAW VALLEY, CALIFORNIA

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### ABSTRACT

In 1983 Perini Land and Development Company proposed to construct a hotel-golf course complex at Squaw Valley, California. Because of the scenic and environmentally sensitive area, residents and local authorities requested a study of the potential environmental impact. The principal concern was the effect, if any, herbicides, pesticides, and fertilizers used on the golf course greens and fairways would have on surface and ground water. The initial step in the evaluation process was to establish baseline concentrations of the existing chemical constituents in the basin's ground water. Representative fertilizers and pesticides were evaluated for persistence, mobility, toxicity, and efficiency. The data used in the evaluation were obtained from a toxicological review of existing data, leach column testing and operation of a test green.

Results of the study indicated that the potential environmental impact from pesticides could be mitigated through special golf course design considerations and the restriction of the types and amounts of the products used in the operation of the course. The test green was constructed and operated for 2-1/2 years. Modeling data showed that long-term distribution of nitrate increases in ground water would have a relatively low potential impact on ground water in the area, provided the recommended fertilizer application rates are followed.



## **DEVELOPMENT OF A CHEMICAL USE MANAGEMENT PLAN**

### **A CASE STUDY**

#### **THE RESORT AT SQUAW CREEK**

#### **SQUAW VALLEY, CALIFORNIA**

### **INTRODUCTION**

This paper summarizes the methods of study used by Kleinfelder to develop a chemical use management plan for the proposed hotel and 18-hole golf course associated with the Resort at Squaw Creek. The study was conducted to alleviate concerns regarding the effect that chemicals used on the golf course would have on the area's alpine environment.

The project site is located near the Lake Tahoe Basin, which is a world class recreation area and which was the site for the 1960 winter Olympic games. Figure 1 shows the general configuration of the valley and surrounding area.

### **BACKGROUND**

In 1983, Perini Land Development Company proposed to build a hotel-golf course resort complex at Squaw Valley. Announcement of the project sparked immediate opposition by local residents and environmental groups including The Sierra Club. The parties opposed to the project filed suite against Perini, charging that the impact of the project on the environment had not been fully studied. An agreement was eventually reached between

Perini and the project opponents wherein Perini agreed to meet 128 conditions to protect the environment of the valley (Placer County, 1985). In exchange, the opposition agreed not to oppose the project if it could be demonstrated that the project could be managed to reduce or eliminate significant damage to the environment. Kleinfelder was selected for the study because of its experience and familiarity with the Lake Tahoe Basin. The study was subject to the scrutiny and approval of a Technical Review Committee (TRC) mandated by the courts (Perini, 1985). The Technical Review Committee consisted of representatives from both the proponents and opponents of the project.

## **SITE DESCRIPTION**

Squaw Valley is an eight square mile (5,100 acre) watershed in the Truckee River Basin located between Tahoe City and Truckee, California. Present uses of the valley include approximately 800 residential units, an Olympic ski area, and limited commercial development. Water supplies are drawn exclusively from within the watershed, nearly entirely from wells at the western end of the valley floor. The principal source of water for the valley is an aquifer of unconsolidated glacial and post-glacial sediments beneath the 400-acre valley floor. The estimated average thickness of the aquifer is about 80 feet. Previous geophysical studies in the valley suggest that the maximum depth to bedrock varies from about 120 to 180 feet along the longitudinal axis of the basin (Gasch, 1973).

## **BASELINE ENVIRONMENTAL STUDY**

The initial phase of work consisted of establishing baseline conditions in the valley prior to construction of the proposed development. The scope of work used to assess the baseline conditions is presented in the following subsections.

### Surface Water

Development of an accurate baseline required that samples be collected during all four seasons of the year. Due to the alpine setting, collecting samples of stream flows was difficult and even dangerous at times. A telemetry system was set up on the banks of Squaw Creek for remote monitoring during periods when access was inhibited. Close monitoring was necessary because runoff caused wide fluctuations in the rate of sediment transport. The amount of sediment in suspension was found to affect the nutrient level in the stream and therefore the baseline water quality values of the stream. Data collected over 2 years of operation spanned one unusually wet year and one unusually dry year.

### Soil Mapping

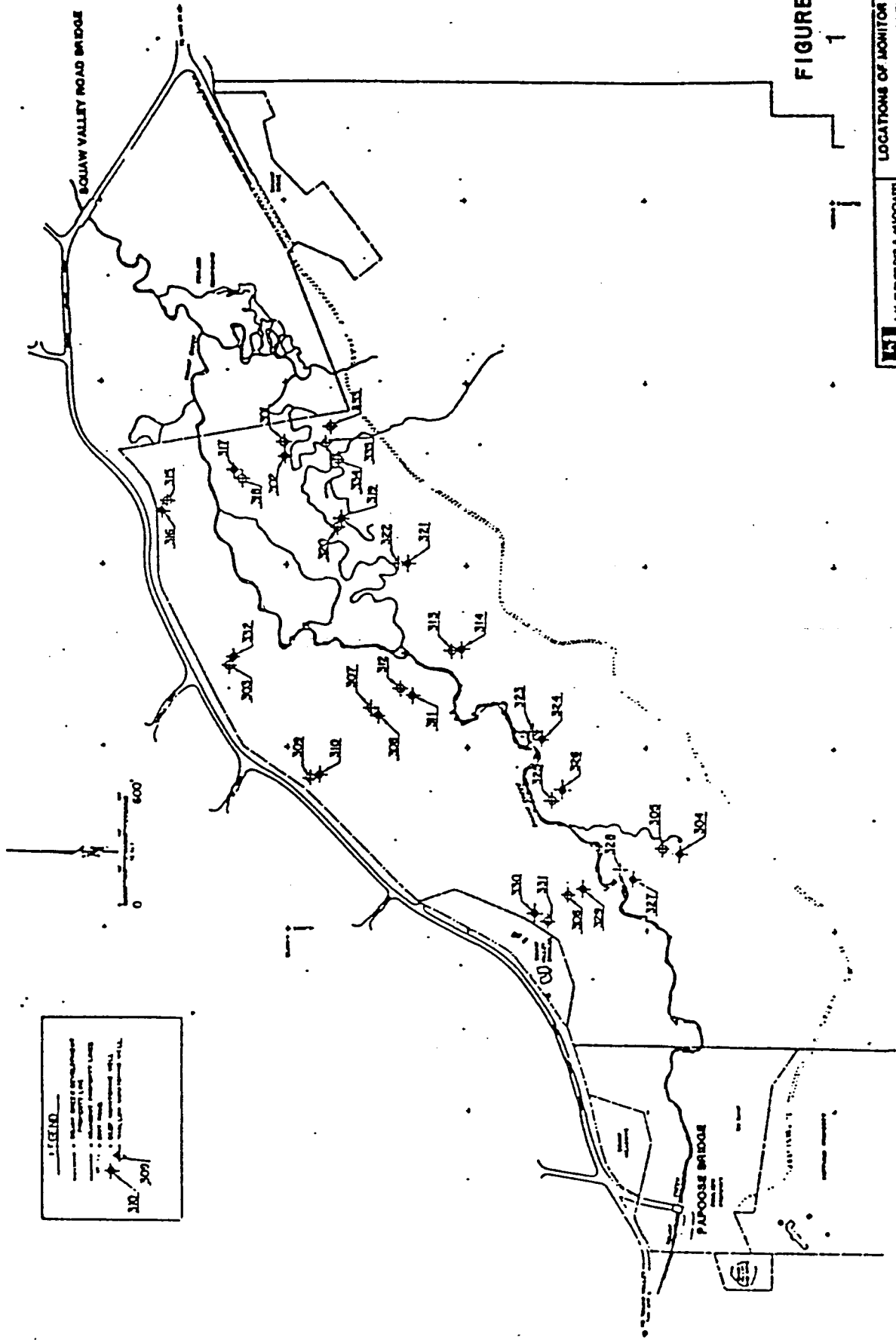
Prior to constructing the test green, the natural soil conditions in the area were studied. Soil samples were collected at numerous locations within the valley. Several samples of material for column leach studies were collected near the proposed test green site.

Analytical testing indicates that these soils are predominantly calcic with fairly neutral pH conditions. As expected, the cation exchange capacity directly correlated with the content of organic material.

### Ground Water

Ground water monitoring wells were installed at the locations shown on Figure 1 to evaluate pre-project ground water quality. A total of 36 paired wells (1 shallow and 1 deep) were installed to aid in the identification of multiple aquifers. The high TDS observed in samples from the deeper wells is speculated to be the result of hydrothermal

FIGURE 1



LOCATIONS OF MONITOR WELLS AT SQUAW VALLEY	
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solutions migrating upward through fracture zones. The deeper wells generally exhibit higher sulfate values than the shallower wells. The well installation specifications followed standard EPA protocol. The wells were secured using 5-foot high security caps to facilitate access during the snowy winter season. Hydrographs for three wells located adjacent to the test green are presented in Figure 2.

## **PESTICIDE USE EVALUATION**

The evaluation of potential pesticides for use on the golf course consisted of a four-step process. Each step in the process was designed to provide additional information on the viability of each compound with respect to the negotiated pesticide selection criteria. The pesticide selection criteria consisted of evaluating pesticide candidates for the following: toxicity, mobility, persistence and efficiency. The evaluation process is discussed in the following subsections.

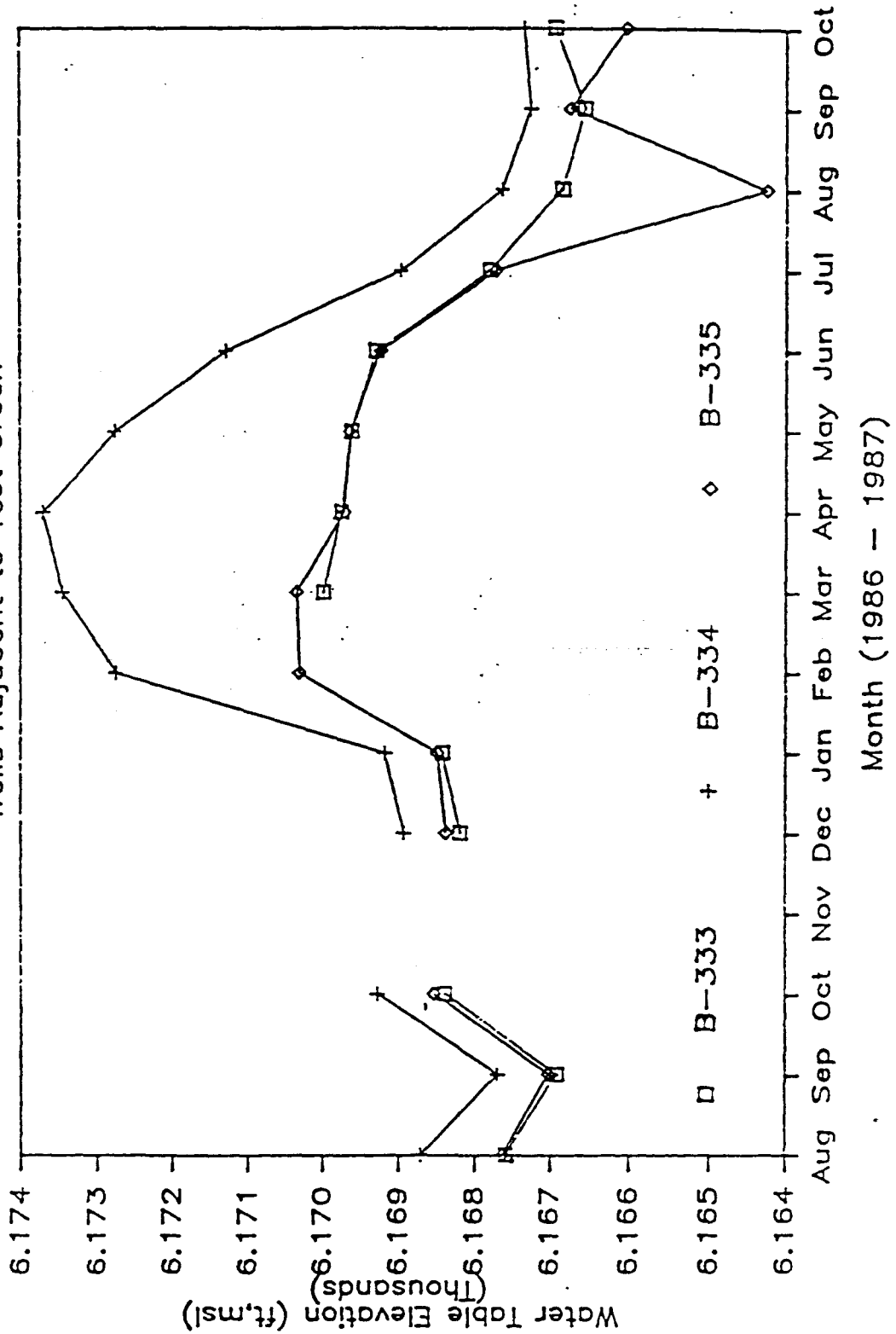
### **Toxicity**

Literature collection on the environmental fate and toxicity of the active ingredients began with a Toxline computerized literature search at the National Library of Medicine. Complete copies of all relevant papers were then obtained from the University of California Library. Additional references were identified from bibliographies of the papers identified in the Toxline search and from the card catalogue of the University of California Library. About 774 published articles were provided to the Technical Review Committee.

Concurrent with the search of open literature, the Environmental Protection Agency (EPA) was consulted for copies of all relevant studies on environmental fate and toxicity. These studies were provided on microfiche and represented the final reports of studies

# WELL HYDROGRAPH

Wells Adjacent to Test Green



conducted by the registrant of each active ingredient to support registration with the EPA. A total of 1,391 pages of microfiche, containing up to 60 pages or original documents per page of microfiche, were provided to members of the Technical Review Committee. In addition, the members of the Technical Review Committee received copies of summaries and evaluations of data gaps provided by the EPA and the California Department of Food and Agriculture.

The literature for each active ingredient was organized by subject (e.g., acute toxicity, subchronic toxicity, etc.) and then organized chronologically within each subject. The documents were read and summarized. An overall summary of all of the databases, with an identification of data gaps, was prepared for each active ingredient. Finally, interactions between chemicals, including fertilizers, were evaluated.

The toxicological review resulted in the identification of four candidate pesticides, which are:

**2,4-d** [2,4-dichlorophenoxy acetic acid] - - used as a herbicide in Weed-B-Gon by Ortho. The chemical is fairly mobile in soils and approximately 95% of it is absorbed by plants. It does not bioaccumulate in the food chain and is quickly degraded by microbes in approximately six weeks.

**Mecoprop (MCP)** [2-(4-chloro-methyl)phenoxy-propionic acid] - - a co-constituent of Weed-B-Gon is mobile in soil and readily absorbed by plants. For biodegradation, it has a half-life of approximately two weeks.

**Chloroneb** [1,4-dichloro - 2,5-dimethoxy - benzene] - - used as a fungicide under the trade name Fungicide II by Scotts is immobile in soil. Its biodegradation half-life is approximately two to five weeks.

**Glyphosate** [N - (phosphoromethyl) glycine] - - is used as a herbicide in Round-up by Monsanto and is immobile in soil. It is rapidly absorbed by plants and biodegrades slowly.

### Mobility

The mobility of the candidate pesticides identified in toxicological literature review was evaluated in the laboratory by leach column testing prior to field testing. The leach columns were packed with soil obtained from the site. A schematic representation of the leach columns is shown in Figure 3. To decrease the observation time required to observe breakthrough, the tests were expedited by using relatively small samples, high aliquot concentrations, and large hydraulic heads. The test results indicated that the mobility of the candidate pesticides under actual field conditions would be very low.

### Persistence and Efficiency

The third step in the evaluation process was the construction of a prototype green/fairway area to field test the compounds that appeared acceptable, based on data obtained from the toxicological evaluation and leach column testing.

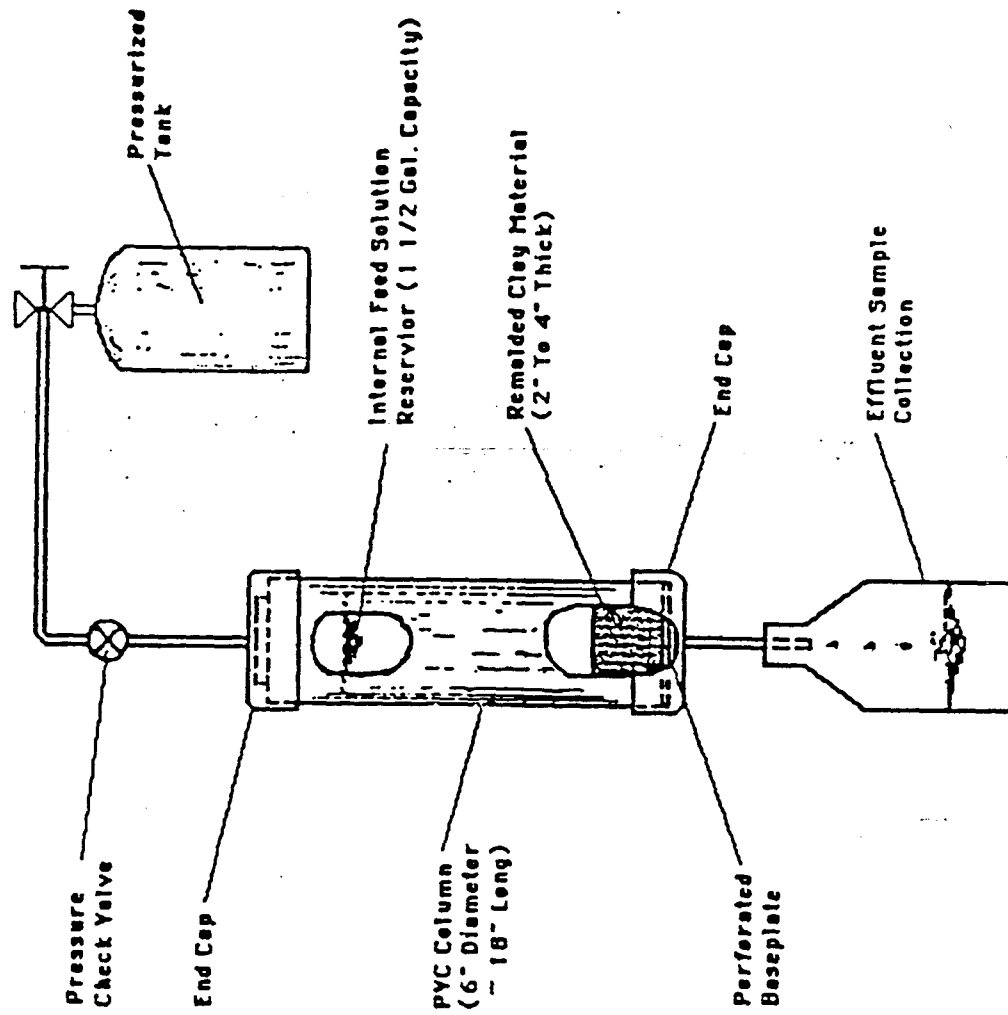
The test green was constructed with both a lined and unlined section (Figure 4). The fill section for the unlined portion of the test green was engineered fill, which consisted of recompacted native soils from a proposed pond borrow site. Rocks larger than 12 inches in diameter were screened out and the remaining material was placed as engineered fill





FIGURE 3

# TYPICAL SOIL COLUMN APPARATUS USED IN LABORATORY INVESTIGATIONS



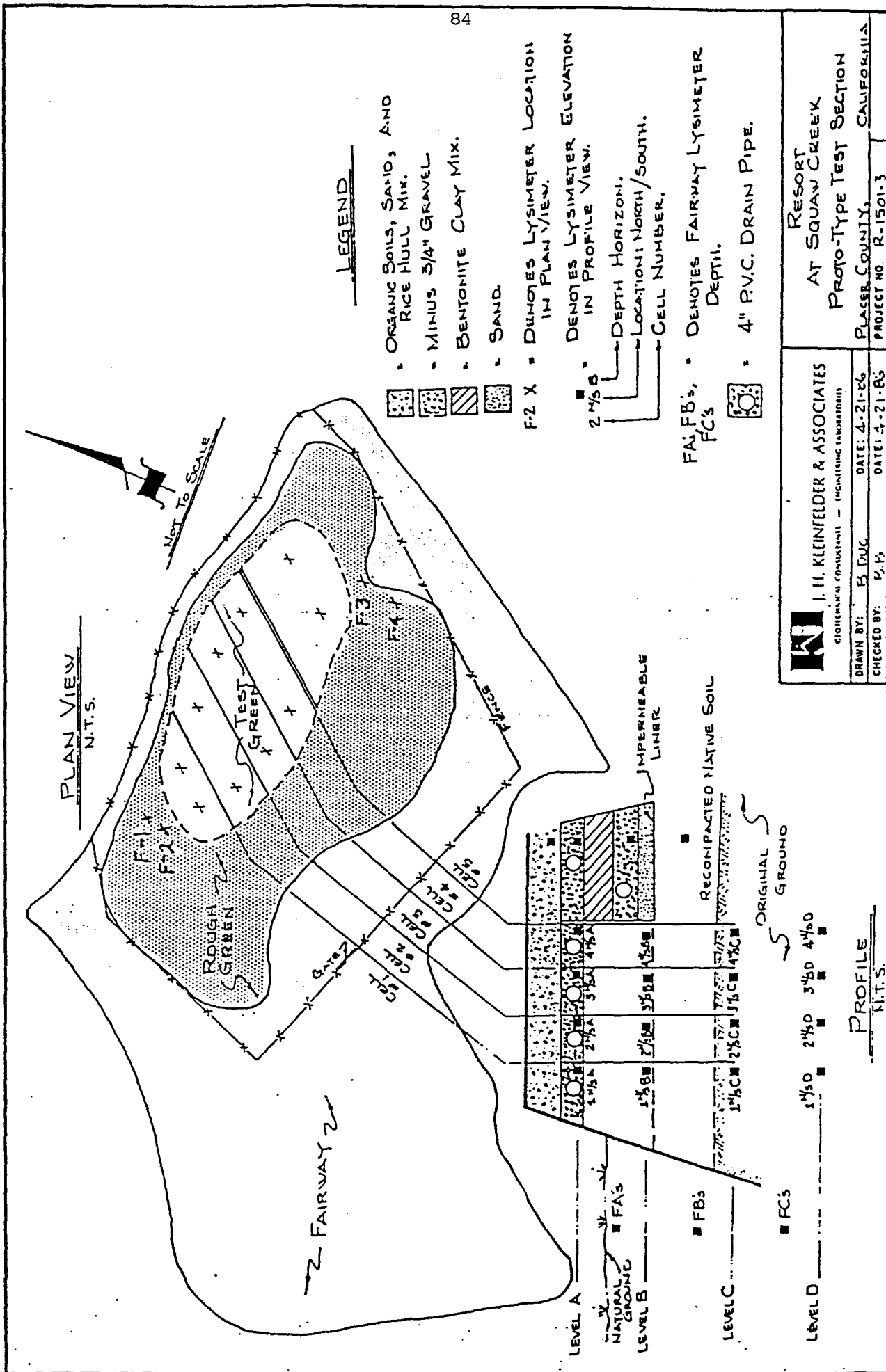


FIGURE 4

<b>KH</b> I. H. KLEINFELDER & ASSOCIATES GEOTECHNICAL CONSULTANTS - (INCORPORATING LABORATORIES)		RESORT AT SQUAW CREEK PROTO-TYPE TEST SECTION	
DRAWN BY: E. J. DUG	DATE: 4-21-86	PLACER COUNTY, CALIFORNIA	PROJECT NO. R-1501-3
CHECKED BY: E. J.	DATE: 4-21-86		

within 12 inches of finished rough grade. The fill was compacted to a minimum of 85% relative compaction, in accordance with ASTM D-1557-78 Standards. A 6-inch thick section of washed 3/4-inch gravel was placed over the native fill. A subdrain was placed within the gravel layer by installing 4-inch diameter perforated pipes running along the centerline of each of the 4 unlined cells. Solid 4-inch PVC collector pipes were attached to the subdrains and daylighted in a catch basin at the west side of the fairway. A 12-inch thick surface layer consisting of sand and rice hulls (as specified by the golf course architect, Robert Trent Jones II) was placed above the gravel layer and served as the turf growing medium. Corrugated fiberglass panels were installed vertically between each cell to function as impermeable dividers to inhibit vadose zone water migration between cells.

The lined portion of the test green was constructed separately from the adjacent unlined green. Two liner types were evaluated - - a compacted soil liner consisting of mixing the native soils with about 10-15% bentonite clay and a synthetic membrane. The cost differential between the two types of liners justified an evaluation of both types of liner systems.

Construction of the lined section of the test screen proceeded as follows:

Initially, an 18-inch section of the engineered fill, as previously described, was placed and compacted above the native ground. Next, an impermeable membrane liner of 30 mil hypalon was placed on the engineered fill section following the removal of surface rocks. Three inches of clean sand was spread across the liner surface prior to the placement of a 6-inch thick section of washed 3/4-inch gravel. Another liner was placed above the gravel layer and consisted of a 9-inch thick section of a compacted soil/clay mixture of 15% bentonite by weight, plus sand and gravel with a maximum of 10% passing the 3/8-inch sieve. Another 6 inches of washed 3/4-inch gravel was placed above the soil/clay liner.

The area was covered with the same 12 inches of sand and rice hull turf growing medium. Subsurface drainage was installed in both of the gravel layers using 4-inch perforated pipes. Each layer flows into collector pipes that daylight in catch basins located on the east side of the fairway.

The vadose zone of both the lined and unlined portions of the test green was monitored by analyzing samples from pressure-vacuum lysimeters. The lysimeters were installed 0.5 feet above the desired depth using a hollow-stem auger, then a split-spoon sampler was driven to the desired depth and the unit installed within the split-spoon cavity. Flexible tubing connected the lysimeters to a central sample collection point. Pressure/vacuum lysimeters were installed at two locations in each of the five cells. At each of the ten locations, four lysimeters were placed at various depths. In each configuration, a shallow lysimeter was placed in the gravel drain layer, while three deeper lysimeters were placed at successive 2-foot depth increments. Flexible polyethylene tubing was used to connect the lysimeters to a central sample collection point. The sample tubing was buried at the locations where freezing was a potential. The lysimeters were set by drawing a vacuum for 3 to 7 days. The samples were collected by displacing the collected fluid with argon. Ceramic lysimeters were selected because of their more reliable performance in granular materials, such as those occurring beneath the site. Some loss in the efficiency of sampling large molecule herbicides or pesticides could conceivably occur, but their use over lysimeters constructed of Teflon appeared justified in light of the overall superior performance of ceramic samplers.

Minor amounts of leachate placed under the lined test plots were collected from drain pipes that had been installed above the liners. Leachate migrating from above the liners was collected in lined basins. The volume of leachate was computed from the record of the water level within the basin and graphically recorded by a Type F water-level recorder.

Samples of surface sheet flow were periodically collected and related to instantaneous discharge or seasonal parameters. The constituents of surface water runoff were assessed from water samples collected in Gerlach troughs.

## MODELING

The ultimate goal of the study was to assess the potential impact of golf course operations on the local surface water and ground water environment. The impact on surface water will be controlled by a network of surface water runoff collectors and activated carbon treatment facilities. To study the impact on ground water, the Konikow and Bredehoft, Version 2.5, March 1988, model was used to simulate ground water movement and solute transport within the ground water regime. The hydrologic assumptions used for construction of the model are listed in Figure 5. These assumptions were based on the results of data collected during previous field investigations at the site. The values used in the model were designed to represent a worst case scenario. For example, nitrate was used as the indicator species for the model because it is the most mobile of all the products identified for potential use. Based on lysimeter data, the nitrogen introduced into the system by fertilization tended to concentrate in the "B" lysimeter elevation. Although the test green was operated for two years, the end point for this concentration of nitrate was not reached during its operation. Similar studies of crop land in the mid-west indicated that this buildup of nitrogen in the subsurface can exceed 20 years (the length of their study) (Jacobsen 1987). The nitrogen loading used in the model assumed that all of the nitrogen applied to the greens would eventually end up in the ground water, thus ignoring biological or other uptake mechanisms. Use of the worst case values made the final model very conservative.

## 1. Aquifer conditions

## Hydraulic conductivity

Bedrock	200 ft/year
Shallow Alluvium	600 ft/year
Glacial Valley Fill	1980 ft/year

Thickness (Areal Models) 30 feet

## Porosity

Areal	25%
Cross Section	30%

Infiltration to ground water 0.96 ft/year

Interflow from hillsides at valley edge cells 1.5 ft/year

## Flow from bedrock

Areal Models	No flow
Cross Sections	Flow allowed through constant head cells and a low permeability zone

## 2. Squaw Creek

## Average annual water levels

## 3. Solute (Nitrogen Concentrations)

Injected at an average annual value with infiltration on cells underlying fairways and greens and at cells at valley edge receiving interflow from fairways or greens uphill from the cell.

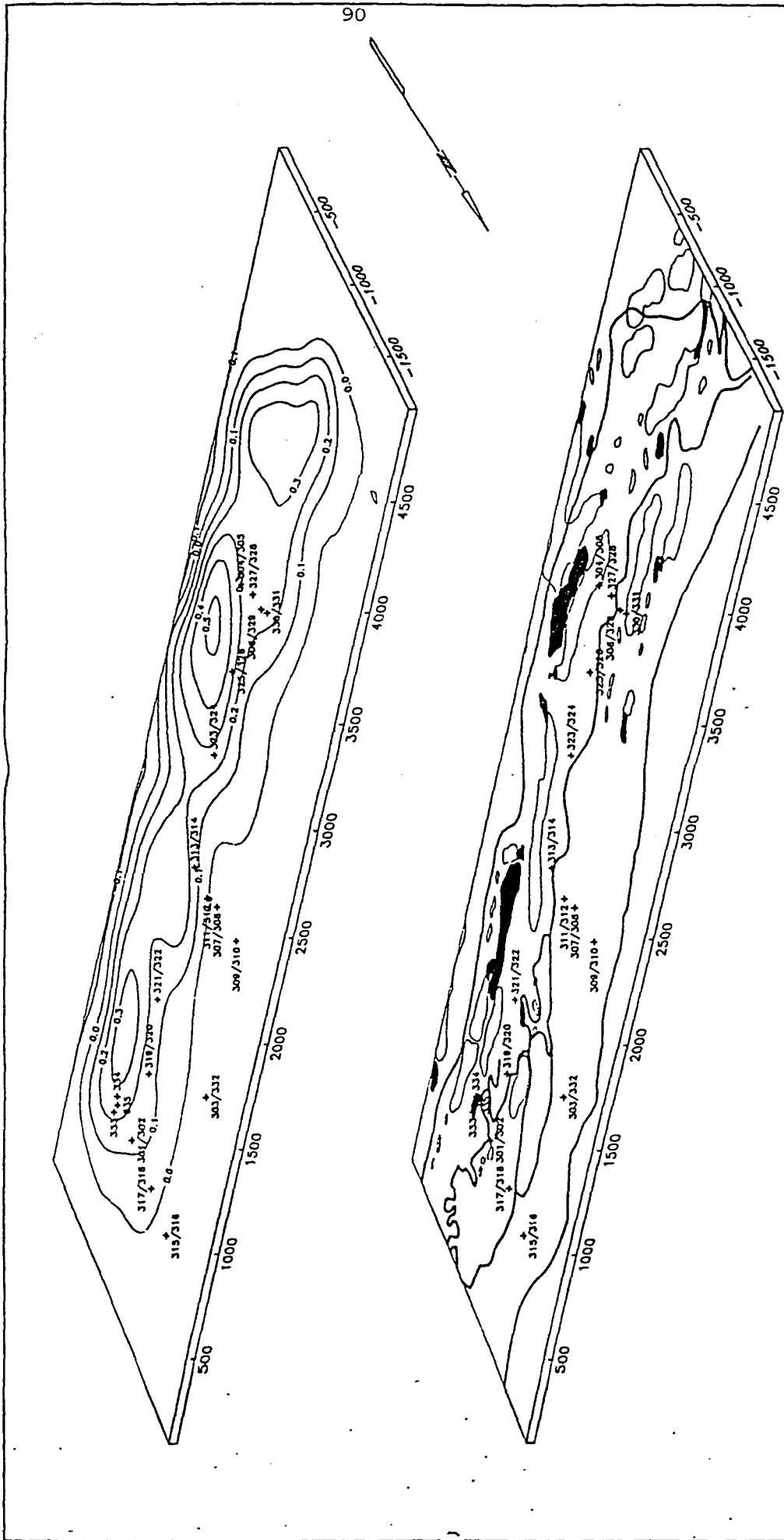
Total nitrogen concentration of infiltrating water calculated as follows:

Fairways	$0.8 \times .90 = 0.72$
Greens	$1.9 \times .10 = 0.19$
	<u>.91</u> mg/l

## CONCLUSIONS

Kleinfelder's study results indicate that:

- o The existing ground water quality in the Olympic Valley Basin is generally acceptable, however, poor water quality with arsenic in excess of drinking water standards can be found in localized areas.
- o The nutrient contents of surface water flows in Squaw Creek are highly dependent on the amount of suspended sediment and therefore stream flows. Squaw Creek appears to be supporting an unusually large amount of sediment, which is probably a result of manmade stream modifications during historic time.
- o The only compounds that satisfied the pesticide selection criteria for the project consisted of 2,4-D, glyphosate, MCPP, and chloroneb.
- o Test green operation for 2 years shows that the optimum fertilizer application rate for the types of turf selected is 0.5 lbs of nitrogen per 1,000 square feet.
- o Based on computer models of the recommended application rates and the hydrologic parameters developed for the project, it appears that the project can operate within the waste discharge requirements set by the Lahontan Regional Water Quality Control Board of 0.5 ppm allowable increase in nitrate nitrogen (CRWQCB, Lahontan District, 1986). An isopleth map plotting the predicted increases in nitrogen content is depicted in Figure 6.





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# AN OVERVIEW OF MINED LAND RECLAMATION IN THE SANGRE DE CRISTO MOUNTAINS, FREMONT COUNTY, COLORADO, 1977 TO PRESENT

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## INTRODUCTION

The Mined Land Reclamation Act of 1976 stands as a watershed of change in the way the mining industry does business in the State of Colorado. This discussion covers the mined land reclamation history of a small surface mine in South-Central Colorado. Seventy years of active surface mining for dihydrous calcium sulfate, commonly called gypsum, had resulted in 100 acres of severely disturbed land near Coaldale, Colorado, in western Fremont County. The reclamation plan implemented in 1977 addressed the long range land use and restoration to wildlife habitat during and after mining. Environmental control during the remaining life of mine operation, app. 30 years from plan implementation, was and still is a priority concern to mining personnel. The climate of the Royal Gorge Region is highly arid with ambient temperature extremes of 90F to -47F. The mountainous terrain allows for little soil development on steep slopes. Average annual precipitation of ten inches is normally received during late winter snows or late summer thunderstorms. Mine site elevations range from 6800' to 7200'. The area might be described as Juniper/Pinon Upland to Upper Transition Zone.

## EROSION CONTROL/MOISTURE COLLECTION

During the past fourteen years of mine development and production, a stripping ratio of 2:1, Waste:Ore, was necessary. Overall SR at life of mine will be 1:1. The bulk of the "waste" rock is a highly fractured, brown dolomitic sandstone, with lesser amounts of low grade gypsum, limestones, and shales. The rock unit encompassing the gypsum ore body is the Minturn Formation, a sequence of evaporite and clastic sediments deposited in late Paleozoic time, some 275 mya. Considerable structural changes were wrought on the originally horizontal beds during the Laramide Orogeny 35-40 mya, resulting in bedding planes attitudes within the mining zone from 55 to 90 degrees from the horizontal. Structural geologic parameters control the method of mining and engineering considerations, ie, grade control and homogeneity of the ore body. No toxic materials have been found to date. Earth forces fractured the hangingwall sandstone units to a high degree, allowing for bulldozer ripping and pushing in lieu of drilling and blasting. A 460 hp bulldozer used for this purpose is also utilized for final contouring of spoils materials and seed bed preparation, although a much smaller machine would be

adequate. Conventional surface mining equipment is utilized for ore extraction. The gypsum ore body necessitates drilling and blasting, after which the ore is loaded into end dump haul trucks and transported to an on site primary crusher. The gypsum ore is screened, crushed to -4 inches, and blended prior to rail shipment 52 miles to Florence, Colorado, for the manufacture of gypsum wallboard. The Coaldale mine ships app. 170,000 tons per year, working year round. Highwalls and waste dump slopes are reduced to preferably 2.5:1 slopes with the D9L Bulldozer. Although very little topsoil is encountered within the mining zone, any outwash gravels or fines materials are set aside for placement on the surface. The slope is then "contour rilled" with the dozer blade corner bit or ripper shanks. The dozer starts at the top of the slope, moving along the contour, with the blade angled slightly into the slope. Each traverse is followed by another slightly below the former, creating a terracing effect that helps to stabilize the slope against sheet washing and gullying. The contour rilling also creates small collection ditches, diverting precipitation into the ground and retaining and concentrating snowfall on the slope. For the first few months after rilling, the terraced slope is quite rough in appearance, but in time smooths out from erosion without loss of slope stabilization. Revegetation of the slope begins as soon as possible after contour rilling.

### REVEGETATION

Broadcast seeding of a native grass seed mixture listed in Table I is performed with hand operated cyclone spreaders. Seeding rate is 40#/acre with repeat applications common. Yellow sweetclover seeding at up to 30#/acre has been effective in establishing a cover crop in some of the most severe, rocky sites. Inorganic nitrogen and phosphorus is applied in the same manner at rates of 300#/acre and 175#/acre respectively. Nitrogen  $\text{NO}_3$  16.75% &  $\text{NH}_4$  16.75%, Phosphorus  $\text{P}_2\text{O}_5$  46%.

Table I Native Grass Seed Mixture, Coaldale, Colorado

20%	<u>Agropyron cristatum</u>	Crested Wheatgrass, variety Nordan
20%	<u>Agropyron trachycaulum</u>	Slender Wheatgrass
15%	<u>Agropyron riparium</u>	Streambank Wheatgrass, variety Sodar
10%	<u>Bouteloua gracilis</u>	Blue Grama Grass
10%	<u>Sporobolus cryptandrus</u>	Sand Dropseed
10%	<u>Astragalus cicer</u>	Cicer Milkvetch
5%	<u>Lolium perenne</u>	Great Basin Wild Rye
5%	<u>Oryzopsis hymenoides</u>	Indian Ricegrass, variety Paloma
5%	<u>Bouteloua curtipendula</u>	Sideoats Grama, variety Vaughn

Early spring or late fall seeding has proven to be most effective in this area. Seeded and fertilized slopes are mulched with clean wheat or barley straw at a rate of 4000#/acre.

A dual planting mode is employed for tree and shrub seedling plantings, due to species propagation limitations and the desire to get seedlings in the ground as early in the season as possible. April planting of dormant potted tree stock, 2"x2"x8", purchased from the Colorado State Forest Service, and dormant bare root shrub stock grown under contract with a local nursery are listed in Table II. These early season plantings are an attempt to establish as many seedlings as possible as early as possible to take advantage of optimum soil moisture conditions and longer growing season for maximum root development. Early season plantings seem to work well for some species, such as Atriplex canescens, Four-winged Saltbush, and Ceratoides lanata, Winterfat, but less successful for other species such as Cercocarpus montanus, Mountain Mahogeny. Approximately 40% of the seedlings are planted early. Survival rates average 70%, but may vary depending on species and weather conditions. After May 1, it is not unusual for the area to receive no precipitation for up to eight weeks. Under these conditions, seedlings planted early and irrigated have a distinct advantage over seedlings planted during the warm, dry month of June.

Table II Tree and Shrub Species, Dormant Stock, April Planting

<u>Pinus edulis</u>	Pinon Pine	
<u>Pinus ponderosa</u>	Ponderosa Pine	Potted Stock
<u>Picea pungens</u>	Colorado Blue Spruce	
<u>Juniperus communis</u>	Common Juniper	
<u>Atriplex canescens</u>	Four-winged Saltbush	
<u>Ceratoides lanata</u>	Winterfat	
<u>Purshia tridentata</u>	Antelope Bitterbrush	Bare-root Stock
<u>Rhus trilobata</u>	Three-leaf Sumac	
<u>Symphoricarpos oreophilus</u>	Mountain Snowberry	
<u>Elaeagnus angustifolia</u>	Russian Olive	

Active potted shrub stock are planted in early June after hardening off. Seedlings are planted near the bottom of the contour ditch, by hand, using a maddox and shovel. Care is taken to not locate the seedling too near upslope "soil" and to remove large rocks from the root zone area. Slow release 10-20-10 pellets and organic polymers are used at planting time. Each seedling is mulched with straw 4" thick and 24" in diameter and rocked down to prevent the mulch from being blown over the top growth of the small seedlings. All stock other than Forest Service tree seedlings are grown by Pleasant Avenue Nursery, Buena Vista, CO. Most shrub seedlings are from mine site progenitors. The development of parent colonies of various species located throughout the mine site not only supplies seed for progeny already adapted to the site, but will promote natural revegetation via wind blown seed dispersion from established green belt areas to area recently under reclamation. Parent colony costs per acre planted are currently 50%-70% higher than normal planting

areas, due to increased plant densities (up to 500/acre). Since 1978, up to 2000 seedlings have been planted at the site each year.

Table III Active Tubeling Seedling Species, from on-site progenitors

<u>Ribes cereum</u>	Squaw Current or Wax Current
<u>Cercocarpus montanus</u>	Mountain Mahogeny
<u>Artemisia frigida</u>	Fringed Sage
<u>Coronilla varia</u>	Crown Vetch
<u>Astragalus crassicaupus</u>	Ground Plum
<u>Rhus trilobata</u>	Three-leaf Sumac
<u>Atriplex canescens</u>	Four-winged Saltbush
<u>Ribes aureum</u>	Golden Current
<u>Ceratoides lanata</u>	Winterfat
<u>Purshia tridentata</u>	Antelope Bitterbrush
<u>Symphoricarpus oreophilus</u>	Mountain Snowberry
<u>Oryzopsis hymenoides</u>	Indian Ricegrass

Survival rates for active seedlings average 65% and vary greatly according to species and conditions. Snowberry propagates best via cutting taken from progenitors in November and rooted in the greenhouse during the Winter months.

#### MAINTENANCE

Irrigation of the seedlings is essential through the first two growing seasons. Under optimum conditions, (rare), the mulch and gel may extend watering intervals up to four weeks. However, it is more common to water seedlings weekly or biweekly throughout the first growing season due to prolonged periods of dry weather and constant winds, inducing dangerously high rates of evapotranspiration. Seedlings will die if root systems are allowed to dry out once during the first year of growth. A simple gravity flow irrigation system has been installed in order to efficiently hand water each seedling on demand. Holding tanks located at higher elevations feed a network of 2" and 1 1/2" plastic pipe with ball valve operated garden hose hook-ups located at 100' diameters throughout the planting area.

Tree seedlings are protected from destructive deer browse by wire cages. The cages cost nearly as much as invested in the each seedling and are susceptible to snow and wind damage. Five and six year old seedlings to large for cages have been destroyed by deer. Topical repellants have been used with little success. This year a systemic repellant will be used along with larger, sturdier cages. Animal damage, especially from mule ear deer, is one of the more expensive and frustrating challenges encountered to date. Success in establishing a diverse community of wildlife habitat species has resulted in moderate to heavy browse year round on the property. Nevertheless, a conservative estimate of increase in plant cover and forage capacity would be five times over undisturbed sites.

### LABOR CONSIDERATIONS

Obviously, Coaldale reclamation is labor intensive. After contour rilling, all reclamation is performed by hand, including seeding, fertilizing, planting, mulching, and maintenance. Most of the labor needs to date have been filled by students from the Environmental Technology Program of Colorado Mountain College, Timberline Campus, Leadville, CO. Over the past fourteen years, dozens of students have worked on short term planting crews and many have worked at the site fulfilling their practicum requirements for graduation. The Environmental Technology Program is an intensive two year course of study leading to an Associates Degree in Applied Science. Two options are offered, water/land reclamation and water/waste management. This program, a little known "jewel" in the rough of Leadville, Colorado, has made a major contribution to the success of mined land reclamation in Coaldale. Each field season students from the Environmental Technology Program earn money while gaining experience and exposure in their chosen profession.

### COSTS

Reclamation costs have been integrated into daily mining costs like any other cost of operation. Budgeted as a variable cost, reclamation actually costs very little compared to other variable mining costs, yet pays big dividends in the areas of community acceptance of the mining operation and reduced liability for the mining company. Table IV presents a comparison of reclamation costs in Coaldale over a ten year period, shown as budgeted cost per ton ore mined and as a percentage of total cost per ton ore mined.

Table IV                      Ten Year Reclamation Cost Comparison

year	Std \$/Ton Ore Mined (dollars)	% of Std Total\$/TOM (%)
1981	.038	1.53
1982	.051	1.77
1983	.020	.69
1984	.048	1.68
1985	.044	1.67
1986	.070	2.14
1987	.123	5.71
1988	.158	4.53
1989	.129	2.82
1990	.128	1.87

The increase in cost in 1987 and 1988 was due more to changes in accounting practices more than other factors. Costs of reclamation should average 3% of the total variable mining cost for several years before increasing to 10% of the total costs in the years preceding

close-in of the mine operation, in about fifteen years. Another way of looking at costs which may be of interest is a cost per acre. This varies in Coaldale for reasons described above, from \$1000/acre to as high as \$2500/acre.

#### SUMMARY

Mined land reclamation is a fact of life. Reclamation can be accomplished at reasonable cost if integrated into daily mining costs and handled like any other cost of doing business. Reclamation need not have a negative impact on a mine's bottom line. An aggressive, visible, on-going reclamation plan will pay back benefits to the mining company during and after mining operations. Reclamation begets community acceptance and support of mining operations from even the most critical opponents. Long range planning of any mine venture, large or small, is critical to its success and important to the people living in its impact shadow. Reclamation can be a positive and proactive aspect of the mining industry. It is good for business and good for the State of Colorado.

## REVEGETATION OF SULPHIDE TAILINGS IN NORTHEASTERN ONTARIO, CANADA

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It may seem strange to many here that a speaker whose experience in revegetation has been gained at an altitude of approximately 1400 feet above sea level, has been asked to relate his experiences in stressed land reclamation during the past 40 odd years. However, there is a direct relationship between altitude and latitude (said by some to be 400' = 1 degree) with the climax vegetation and plant species which are found at comparable sites.

During the past 20 to 30 years, individuals working in the field of land reclamation, often alone and isolated in their areas, began to hear of others working in the same field. Contacts were established between them and experiences, both successful and unsuccessful, were exchanged. This free exchange amongst individuals, without interference from their employing companies, continues to this day.

Some of the ideas which were adapted to fit the local climatic conditions in the Sudbury area, were based on observations of Dr. Bill Berg's test plots at Climax Molybdenum which were part of Jim Brown's program there, the URAD reclamation project by Dr. Larry Brown here in Colorado and Ed Pommerening's work at the Bunker Hill Mine in the Coeur d'Alaine area of Idaho.

In the early days of tailings reclamation, the main objectives were to stop the fugitive dust emissions and to aesthetically improve the image of the mining industry. Starting in the late 70's, increased environmental concern led to the inclusion of tailings effluent water quality as an additional consideration.

All three objectives have played, and continue to play, a roll in the tailings revegetation program of Inco Limited at Sudbury, Ontario, Canada. Sudbury is located approximately 180 miles east of Sault Ste. Marie, Michigan, 265 miles north of Tor-

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onto, Ontario and about 30 miles inland from the north shore of Lake Huron.

Inco Limited's operations at Sudbury are the largest integrated nickel mining operation in the world. At present, 10 mines, 2 mills, a smelter, a nickel refinery and a copper refinery are located there. In addition, the Ontario Division also includes a refinery at Port Colborne on Lake Erie and a mine north of Lake Superior at Shebandowan. There is another integrated operation in northern Manitoba and an offshore one in Indonesia. Some 16 elements are extracted from the ores mined with nickel and copper being the principal ones.

Currently some 40,000 tons of tailings per day are discharged to the tailings disposal area at Copper Cliff. The total area is approximately 5500 acres of which about half are in the new portion of the area which has been under development since the early 1980's. In total, over 600,000,000 tons of tailings have been deposited in the "A", "B", "CD", "M", "P" and "Q" areas which have reached their final elevations and together cover some 2800 acres.

The topography of the Sudbury Area, which is typical of the Precambrian Shield, can be classified as undulating with valleys between rounded hill tops. Glaciation in the late Pleistocene era was responsible for many of the geomorphic formations and soil types in the Shield. The land was heavily scoured and much of the topsoil removed with the result that numerous rock outcrops were and remain exposed.

The climate in the area can generally be described as harsh with long cold winters and up to 130 frost free days. Therefore soil flora and fauna are active less than half the year. Consequently, soil development has been and is still slow. In general, the various ecological factors have combined to develop a podsol type soil with glacial surface deposits of water modified tills, lacustrine silts and sands located in the valleys.

The tailings areas at Copper Cliff (now Ward 8 of Sudbury) are located to the southwest and west of the town and smelter. In summer, the predominant winds are from the southwest with the result that under certain conditions tailings dust storms frequently blanketed the town, smelter and refinery. This bothered the housewives due to the extra cleaning and when the dust insinuated itself into the smelter machinery lubricants, it made them into grinding compounds. This latter impacted on operations and in addition, by contaminating the electrolytic copper refining process, reduced its efficiency.

By the mid 1940's, the need to control the fugitive dust emissions from the tailings area was evident. Various types of chemical sealants were tried but all proved to be ineffective or too costly. In 1942, an unsuccessful attempt was made to establish vegetation.

By the late 1940's, the "CD" area had reached its final elevation and the "M" area was approaching its final elevation of 150 feet. This resulted in a mesa type formation which had an elevation above the local natural land contours. Dust storms could and did occur in all directions. In addition to repeated experiments with chemical sealants and water spray systems, a request was made to the Company's Agricultural Department to investigate the feasibility of establishing vegetation.

The first plots were planted in 1950, in a location on the tailings which provided the most convenient access for viewing. Unfortunately although the seed germinated, the seedlings were either cut off or buried by drifting windborne tailings. In 1951, a more protected site for the plots proved somewhat more successful, but still some of the plots were buried. However, one species, Canada Blue (*Poa compressa* L.) proved to be able to survive this sand covering and continue to grow. One of the keys to success had been found.

The principal ores mined, chalcopyrite, pentlandite and pyrrhotite, are all sulphides. After milling, a selective pH controlled flotation process was used to make a copper rich and a nickel rich concentrate. As a result, the mill tailings have a pH of 8.0 to 9.0 on deposition in the tailings disposal area. However, they rapidly become acidic and usually and within six months, the pH of the surface material is in the vicinity of 3.0. The next steps were to find a suitable seed bed ameliorant and plant nutrition program. This was done by a series of greenhouse pot experiments.

Over the years, the experience gained in the field has led to the development of the following basic practices which are generally acceptable to the conditions found in Eastern Canada:-

1. The first seeding in a tailings area should be located in the portion closest to the prevailing winds during the growing season to minimize damage to or the covering of the young plants by drifting windborne tailings.
2. Agricultural limestone, as required, should be applied and worked into the surface prior to seeding. The major portion should be applied at least 6 weeks before

seeding. This permits sufficient time for the reaction to raise the pH of the tailings to 4.0 to 4.5. The balance should be applied immediately prior to seeding.

3. In the Sudbury area, late summer is the best time to seed grasses. After July 21, the rate of success of seed germination and seedling establishment is enhanced due to more favourable temperatures and the increased availability of moisture from precipitation.
4. Although late summer is the optimum time to seed grasses, the short period remaining in the growing season, is insufficient for the legume seedlings to establish a sufficiently deep and strong root system to withstand the heaving effects of the repeated freezing and thawing of the tailings surface the following spring.
5. The use of a companion crop to provide shade and reduce the velocity of the surface winds is essential.
6. Nitrogenous fertilizer should be applied, at low but sufficient rates, several times as required, during the establishment period to ensure maximum uptake.
7. The surfacing of the slopes with a south and southwesterly exposure with 6 inches (15 cm.) of clay to ensure an adequate supply of moisture for growth is worthwhile.
8. The use of a mulch on the slopes, preferably one containing straw, to provide shade for the seedlings and to reduce the evaporation of soil moisture during the critical period of seedling establishment is worthwhile.
9. When clay is used to surface the outside slope of a tailings dam, the whole slope should be covered from top to bottom. The addition of a clay topdressing on a tailings slope will physically reduce the porosity of the slopes surface. In all cases, it is essential to maintain the structural integrity of the dam and no treatment which will change the dam's structural strength should be employed in establishing vegetation. If and when required, adequate diversion ditches for the safe drainage of the slopes should be included as part of the surfacing program. (Peters, 1989)

The current grass seed mixture is very similar to the

original successful mixture and is:-

- 25% Canada Blue Grass (*Poa compressa* L.)
- 25% Red Top (*Agrostis gigantea* Roth.)
- 15% Timothy (*Phleum pratense* L.)
- 15% Kentucky Blue Grass var. Park (*Poa pratensis* L.)
- 10% Tall Fescue (*Festuca arundinacea* Schreb.)
- 10% Creeing Red Fescue (*Festuca rubra* L.)

The percentage indicates the proportion by weight of each species in the seed mixture.

Scarcity and costs of some species has necessitated some variations from the above percentages in certain years. Although some alfalfa (*Medicago sativa* L.) still persists in one small area since its seeding in the mid 1950's, Birdsfoot Trefoil (*Lotus corniculatis* L.) has proven much more adaptable to the varying conditions found in a tailings area.

Prior to 1964, a program of cutting and selling the hay from the tailings area was followed. In retrospect, this was good for publicity but very poor for our efforts to establish a maintenance free vegetative cover on the tailings. However, in 1964, we became aware of the number of seedling trees which were voluntarily invading the area. These trees were principally White Birch (*Betula papyrifera* Marsh.), Trembling Aspen (*Populus tremuloides* Michx.) and Willow (*Salix* spp.) and are all known as transition species. Nature was showing the way and the steps to follow in helping to establish the climax vegetation for the area.

In the early 1970's, a few test plots of coniferous species, Jack Pine (*Pinus banksiana* Lamb.), Red Pine (*Pinus resinosa* Ait.), Scotch Pine (*Pinus sylvestris* L), White Spruce (*Picea glauca* Voss.) and Black Spruce (*Picea mariana* Mill.) were established. The Jack and Red pine were the two species which made the best growth in these and in later larger test plots. They are the major species used in the current tree planting program. Now all the trees are produced 4600 feet underground at Creighton Mine where 100,000 seedlings are grown annually for the Company's reforestation program on its stressed land.

The voluntary invasion of various insects, birds and small mammals started with the first large sized grass area. As the revegetated area assumed a more natural appearance, different species of waterfowl and shorebirds started to make stopovers during their spring and fall migrations. Again, Nature was making a suggestion and this time it was for a possible end use of the

site. A decision was made to investigate, in conjunction with the Ontario Ministry of Natural Resources, the possibility of developing a Wildlife Management Area. A Wildlife Biologist was retained by the Company to design a development plan toward achieving this result. His report was completed in 1974. Since then various research projects have been carried out by university graduate students and members of the Company's Agricultural Department staff to ascertain that no harmful introductions would be made to the food chain if the program was initiated.

In 1985, satisfied that the project was safe and viable for the environment, the next step in developing the new ecosystem was taken with the introduction of 70 fledgling Canada Geese (*Branta canadensis*). Additional similar sized flocks were introduced in 1986 and 1987. Many have returned to nest in the area and have raised frequently seen broods throughout the immediate Sudbury Area. Other species of birds, both land and water, are nesting in the reclaimed tailings area. The raptors are finding a sufficient number of mice and frogs to live on and they too are nesting in the area in increasing numbers.

To date, this developing ecosystem has reduced the amount of dust emanating from the tailings and presents a major aesthetic improvement. It also plays a role in improving the quality of the seepage water. The vegetative cover reduces the amount of water available for seepage, first by intercepting precipitation which then evaporates from the surface of the foliage and second by the amount of water which is transpired by the plants in the growth process. As the plants develop and grow, the root mass in the top 4" to 6" (10-15cms.) uses increasing amounts of oxygen which reduces the amount available for sulphide oxidation and the subsequent acid generation. Any reduction in the rate of acid generation will benefit the pH of the seepage water and reduce the amount of metals in the leachate.

The improvement in the quality of seepage water is currently a major concern in the development of walk away closure programs for sulphide tailings sites. Different approaches are being tried by mining companies in Canada.

The current objective Falconbridge Limited, the other major nickel producer in the Sudbury area, is to establish a methodology that will allow it to walk away upon the closure and abandonment of tailings areas with no further treatment required. Unlike other companies, Falconbridge has used overburden material as a reclamation technique on which to establish vegetative covers (Michelutti, 1975). However, this overburden material has

not, in some cases, eliminated the upward migration of metallic salts or the acid metallic contaminated seepages (Spires, 1975; Michelutti, 1978).

At present, they are looking at various methods which can be employed and which will result in this walkaway capability on abandonment. One method to achieve this is to prevent the oxidation of the pyrrhotite and sulphur wastes, contained in the tailings, that ultimately generate sulphuric acid. To minimize or prevent this oxidation, various covers to act as oxygen barriers are being tried. These covers may be divided into 2 classifications, dry or wet.

The dry covers are being tested on their Fecunis Lake Tail-ing Area and are:-

- (a) A 6 foot (2 m.) layer of waste rock with individual pieces ranging in size from 1/2" to 6" (1.25-6 cm.). Digested sewage sludge from the Regional Municipality of Sudbury is mixed with the rock layer to fill the interstices. The sludge will not only block the oxygen transfer but will also act as a source of nutrients for the ultimate vegetative cover. A fine waste alkaline by-product, available from a paper mill within reasonable proximity, is also being tried as a material to fill the interstices.
- (b) The use of a 6 foot (2 m.) thick layer of domestic compressable garbage from the same Municipality covered by a soil (local overburden) stabilization layer 1 to 2 feet (30 to 60 cm.) in depth is another approach. It is anticipated that the methane generated by the decomposition of the garbage will act to block out the oxygen.

Various organic materials are being tested on the Falconbridge Tailings Site in developing wet covers on tailings as oxygen barriers ((Griffiths, 1988). The idea is to construct a swamp with water to act as the oxygen barrier along with the growth of swamp plants.

The preliminary results from both types of covers, wet and dry, indicate some improvement in seepage water quality. However, more research is needed.

The revegetation of the uranium tailings at Elliot Lake, again from sulphide ore bodies, have presented similar problems to those in the Sudbury area and have added a few new twists. The ore is milled to a much smaller particle size at Elliot Lake.

Possibly due to the greater area per cubic unit of the smaller sized particles of tailings, the laboratory work determining the amount of limestone required to neutralize the seed bed was greatly different from the amount required in the field tests. Under the controlled conditions in the laboratory, 10 tons/acre (22 tonnes/ha.) were adequate. Under the uncontrollable field conditions, 30 tons/acre (65 tonnes/ha.) were required.

Observations over the years of the revegetated areas of tailings at Elliot Lake indicate that where maintenance fertilization was carried out for at least 2 years after seedig, that a viable stable ground cover has developed. It is also of interest to note that where the fertilization was limited and the herbaceous ground cover was sparse and the area was somewhat protected from water and wind erosion, the native trees and shrubs have colonized these areas.

Over the years, it has been found that the interpretation of conventional soil test analyses which have been predicated on results obtained on agricultural soils have been of little value for determining the nutrient requirements to establish vegetation on tailings. The analytical methods were not questioned, but very few people working on tailings revegetation fully appreciated that the lack of even elementary soil structure in the tailings in relation to their nutrient retention capacity. More attention is being directed toward this facet of tailings reclamation now.

In addressing the various federal and provincial regulations which cover tailings revegetation in Canada, it is safe to say that they are not, in many cases, explicitly spelled out in the legislation of the various provincial acts and guidelines. However, nearly all of them are open to the interpretation that it can be required. The requirement is becoming more and more often the practice which is followed.

Provincial regulations must be as strict as or stricter than the federal ones.

The regulations are subject to change and all projects should be reviewed with the local regulatory personnel before a new project is commenced or a major alteration made to an existing one.

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## **DEVELOPMENT AND IMPLEMENTATION OF RECLAMATION PRACTICES AT HOMESTAKE'S McLAUGHLIN MINE**

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### **ABSTRACT**

The McLaughlin Mine is a world class epithermal gold deposit located in the coastal ranges of Northern California. Reclamation planning commenced with environmental baseline studies and initial project facility design. California law requires the designation of a postmining land use and the preparation and approval of a reclamation plan prior to initiation of mining. The McLaughlin Mine reclamation plan provides for a postmining land use of approximately 10,000 acres as an environmental studies field station. Mine waste rock dumps are designed to facilitate reclamation in annual increments concurrent with pit development. Grasses and woody plant species and planting methods were chosen initially before mine construction based on literature review and on-site test plots. Reclamation performance criteria were adopted and annual performance monitoring implemented. Seed mixes and woody plant species and planting methods were modified following several years of use based on performance monitoring data. Plant succession is evident in reclaimed areas in the first five years following planting. Approximately 1,190 acres have been reclaimed since commencing project construction in 1983 with approximately 76 acres of mine waste rock dump reclamation completed in 1985 through 1989.

### **INTRODUCTION**

Homestake Mining Company's McLaughlin Mine is a world class gold deposit located in the coastal ranges of Northern California, approximately 70 air miles north of San Francisco. The area was identified as an exploration target by Homestake in 1978 and confirmed by drilling to be a commercial deposit in 1980. The McLaughlin Mine ore body contains 20 million tons of gold ore averaging 0.152 ounces per ton and contains approximately 3,000,000 ounces of gold. The Mine was planned, engineered, constructed, and brought into production by March of 1985. Mining is by open pit methods moving approximately 50,000 tons of waste rock, low-grade and high-grade ores per day to provide a millfeed of 6,200 tons per day. The Mine produced 284,000 ounces of gold in 1989. The accompanying waste rock disposal facilities have a capacity of 160 million tons and cover approximately 385 acres. The development of a reclamation plan and the selection of methods for the reclamation of the waste rock disposal areas is the subject of this paper.

## ENVIRONMENTAL SETTING

The Mine is located at the juncture of Lake, Napa and Yolo Counties on a ridge at an elevation of approximately 2,000 feet above sea level. The ridge defines the boundary between Napa and Yolo Counties and acts as the watershed divide, placing the Mine at the headwaters of two drainages.

The climate is Mediterranean with an average annual rainfall of 30 inches with precipitation occurring predominately between October and April. The months of June through September are dry with little or no measurable precipitation. The growing season begins in October with the first winter rains and continues through the winter and spring months until precipitation declines in May and June. Maximum growth occurs in April and May.

Summertime temperatures are typically in the ninety degree Fahrenheit range with peak temperatures occurring in excess of 105 degrees. Winter temperatures are moderate with typical daytime temperatures in the forty degree range with seasonal lows in the twenties. Snowfall occurs at the site only several times per year with a typical snowfall averaging less than three inches.

The project site is remotely located and sparsely settled. The closest community is fifteen miles to the north and is centered around Clear Lake, the state's largest natural lake. The economy and land use of this area is seasonal tourism and agriculture with pears, walnuts and grapes being the predominant produce.

The Napa Valley is located south of the project with the economy and land use centered around the premium wine grape industry, both for agriculture and tourism. To the east lies the Sacramento Valley with an agriculturally based economy consisting primarily of field crops and orchards.

Vegetation at the site is a mixture of plant communities including Cismontane Introduced Grasslands, Blue Oak Woodland, Serpentine Chaparral and Northern Interior Cypress Forest. The Serpentine Chaparral and Northern Interior Cypress Forest are largely restricted to, or associated with, soils derived from serpentinitic parent rock. Serpentine soils have physical and chemical characteristics that limit plant growth including calcium deficiency, excess magnesium, elevated levels of nickel and chromium, and a clay consistency which contributes to local instability.

## RECLAMATION AUTHORITY AND REGULATION

Reclamation is regulated by the California Surface Mining and Reclamation Act which is administered by the local county and city governments. The Act requires designation of a postmining land use and the preparation and approval of a mining and reclamation plan prior to the initiation of mining. The reclamation plan must specify final land form and topography; postmining hydrology; topsoil salvage, storage and

replacement; seedbed preparation and fertilization; species to be planted and planting methodology; erosion and sedimentation control, and maintenance of revegetated areas. The Act also allows local governments to require the determination of reclamation costs, and the posting of financial assurances.

### POSTMINING LAND USE

The McLaughlin Mine Reclamation Plan specifies a postmining land use which provides for the conversion of the approximately 10,000 acre site to an environmental studies field station at the conclusion of mining. This decision was based on an evaluation of postmining assets which revealed that a valuable educational resource will result from the project in the form of accumulated environmental data. Between three and four million dollars were expended for the environmental baseline studies and the ongoing comprehensive monitoring program will produce another twenty plus years of useful data including aerial photography updated annually, surface and ground water quality data, aquatic ecology, wildlife, vegetation and sensitive plant surveys, and more. In addition, physical facilities including laboratories, commercial power, roads, water supply and sanitation facilities will be in place and available at the site. The field station will be made available for the use of the regional public schools, colleges, and universities. The postmine land use as an environmental studies field station provides for productive use of the land and facilities while preserving the opportunity for future mining.

### RECLAMATION PLAN

In addition to specifying the post mining land use, the Reclamation Plan provides specific reclamation goals and specifies the reclamation methods to be implemented to achieve those goals. These goals are to:

- Minimize Erosion.
- Stabilize Disturbed Areas With a Permanent Diverse Vegetative Cover.
- Maximize Productive Land Use and
- Protect Water Quality.

These goals are met through preconstruction engineering and planning of project components to facilitate implementation of the reclamation plan; through preconstruction research and literature review to identify reclamation methods best suited for use at the site; by the identification of soils suitable for reclamation and the stockpiling of these soils during construction; by implementation of the reclamation plan during mining operations; and by annual monitoring to evaluate reclamation performance. Rather than commencing reclamation at the end of the Mine life, the reclamation plan provides for reclamation of the waste rock disposal areas concurrently with mining operations. Reclamation efforts are monitored annually with collected data utilized to evaluate and modify reclamation methods for use in following years.

## PRECONSTRUCTION RECLAMATION PLANNING

Reclamation Planning at the McLaughlin Mine began with the collection of baseline environmental data for vegetation, soils, sensitive plants, climatic conditions, land use, and other factors. These data were tabulated and mapped to provide a useful format for planning purposes. This baseline laid the foundation for further planning and engineering decisions. Detailed reclamation planning incorporated both the baseline environmental studies and revegetation and reclamation experience and research conducted by numerous agencies, private firms and academic institutions in California.

### Facility Siting

As the facilities were engineered, the project baseline information was utilized to develop siting criteria and to evaluate siting alternatives. Project facilities that had siting flexibility such as pipelines, transmission corridors and roads were adjusted to the extent possible to avoid sensitive plant populations and serpentine soils which are more difficult to reclaim. Environmental sensitivity was considered in the siting of all facilities and appropriate mitigation measures designed and incorporated into the project design to minimize environmental impacts.

### Facility Design and Construction

Those facilities with less flexibility in siting, such as the waste rock disposal areas were designed and constructed to facilitate reclamation and closure. The waste rock or overburden disposal areas are designed with an overall slope of 4H:1V to assure mass stability under seismic loading. The facilities are constructed in 50 to 100 ft. lifts with benches of varying widths constructed at the toe of each lift. Interbench slopes are constructed at a slope of 2.5H:1V to provide a slope conducive to revegetation. Topsoil was salvaged from areas disturbed during construction and stockpiled for later placement on final slopes in the waste rock disposal facility.

### Species Selection

Species selections for grass seed mixes were based on research completed through the University of California at Davis, experience gained from twenty years of revegetation at the nearby Geysers Geothermal Steam Field electric generation facilities, state highway revegetation work completed by the California Department of Transportation, through assistance provided by the California Division of Mines and Geology, and by a masters thesis research project on grass species conducted at the site.

Two seed mixes were developed, one for nonserpentine soils, and one for serpentine soils recognizing the particular limitations of this soil type for revegetation. Table 1 lists the seed mixes currently in use and provides a mix of annuals, perennials and legumes.

TABLE 1  
SEED MIXES

Nonserpentine Seed Mix

<u>Plant Species</u>	<u>Seeding Rate Pure Live Seed (lbs./acre)</u>
"Blando" brome (Bromus mollis "Blando")	15
"Alta" tall fescue (Festuca Arundinaceae "Alta")	5
"Luna" pubescent wheatgrass (Agropyron tricophorum "Luna")	8
Annual ryegrass (Lolium multiflorum)	5
"Berber" orchard grass (Dactylis glomeratus "Berber")	8
"Wilton" rose clover (Trifolium hirtum "Wilton")	<u>10</u>
<b>TOTAL</b>	<b>51</b>

Serpentine Seed Mix

<u>Plant Species</u>	<u>Seeding Rate Pure Live Seed (lbs./acre)</u>
"Blando" brome (Bromus mollis "Blando")	15
"Alta" tall fescue (Festuca Arundinaceae "Alta")	8
"Luna" pubescent wheatgrass (Agropyron tricophorum "Luna")	10
Lana Vetch (Vicia dasycarpa)	8
"Panoche" red brome (Bromus rubens "Panoche")	<u>10</u>
<b>TOTAL</b>	<b>51</b>

Native woody species indigenous to the site were reviewed for reclamation potential taking into consideration soil types, seed collection potential from surrounding native plants, nursery propagation potential, and expected survival rates following transplanting into disturbed soils as tublings. Woody Species chosen for planting are listed in Table 2.

TABLE 2  
WOODY SPECIES

<u>Scientific Name</u>	<u>Common Name</u>
<i>Quercus durata</i>	Leather oak
<i>Quercus wislizenii</i>	Interior live oak
<i>Quercus lobata</i>	Valley oak
<i>Quercus douglasii</i>	Blue oak
<i>Quercus dumosa</i>	Scrub oak
<i>Pinus sabiniana</i>	Foothill pine
<i>Cupressus macnabiana</i>	Macnab cypress
<i>Juglans hindsii</i>	Black walnut
<i>Rhamnus californica</i>	Coffeeberry
<i>Cercis occidentalis</i>	Redbud
<i>Cornus sericea</i>	
var. <i>occidentalis</i>	Western dogwood
<i>Umbellularia californica</i>	Bay
<i>Hetermolele arbutifolia</i>	Toyon
<i>Adenostoma fasciculatum</i>	Chamise

#### Topsoil, Fertilizer, and Soil Amendments

Available topsoil was surveyed and salvaged during project construction and stockpiled at various locations for reclamation use. Additional topsoil is salvaged from open pit development for direct placement on final slopes and benches of the waste rock disposal facilities during mining operations. Topsoil is placed on the reshaped slopes of the waste rock disposal facility at an average depth of 1.4 feet. The topsoil is then trackwalked to provide a firm soil surface while also providing microhabitats in the indentations remaining from the dozer grouzer bars.

Fertilizer specifications were developed from previous experience on Northern California soils of similar types. The soils generally have sufficient potassium, but are deficient in nitrogen, potassium, and sulfur. A 16-20-0 ammonium phosphate sulfate fertilizer was specified at a rate of 400 lbs. per acre.

Serpentine soils have a calcium/magnesium imbalance with a significant calcium deficiency. Hydrated lime (CaO) is applied at a rate of 1,000 lbs. per acre as a calcium supplement to these soils. Application is accomplished by mixing the lime with water in a hydroseeder and

spraying the mixture on the areas to be reclaimed prior to the application of seed and fertilizer.

Soil amendments and application rates are shown in Table 3.

TABLE 3

SOIL AMENDMENTS AND MULCH APPLICATION

Nonserpentine

<u>Type</u>	<u>Pounds per acre</u>
Fertilizer, 16-20-0	400
Straw Mulch	4,000
Tackifier, A-Z Tack	90
Hydromulch Wood Fiber	500

Serpentine

<u>Type</u>	<u>Pounds per acre</u>
Fertilizer, 16-20-0	400
Hydrated Lime	1,000
Straw Mulch	4,000
Tackifier, A-Z Tack	90
Hydromulch wood fiber	500

RECLAMATION METHODOLOGY

Grasses

Available reclamation methods were reviewed for use at the site with the objective of finding the methods that provided the best application for site specific conditions. Soil contact with seed and fertilizer was a primary objective for determining application methods. Mulches were reviewed for effectiveness of erosion control and enhancement of seed germination.

Seeding and fertilizing by hydroseeder provided the most reasonable means of application on long and steep slopes while assuring direct seed contact with the soil.

Straw mulch was chosen because of the longer fiber length and subsequent greater erosion protection capability. Seeding is completed just prior to the period of heaviest precipitation and maximum protection from both raindrop impact and sheet erosion is critical for reclamation success. The straw mulch also provides additional insulation necessary to retain surface soil temperatures essential for seed germination and also retains soil moisture between precipitation events to minimize

mortality due to lack of moisture. Straw is available from regional agricultural activities.

Fully seeded straw is used to provide an annual nurse crop of wheats, oats, or barley, depending on regional straw availability. The annual nurse crop is quickly established providing early season erosion protection. The organic matter remaining after the first season's growth provides additional mulch for soil protection. This mulch becomes a soil builder as it decomposes in subsequent years.

Straw is applied by a conventional straw blower with the addition of a long hose extension to reach the bottom of the slopes and to minimize wind loss. Straw is tackified using 90 lbs. of tackifier per acre applied through a hydroseeder.

#### Woody Species

Woody species seed is collected from plants in the immediate area and grown in tublings in a local nursery. The plants are then transplanted using a collar and screen planting method developed by staff for Pacific Gas and Electric Co. The method utilizes one quart cottage cheese containers with the bottom removed forming a collar to contain the seed or seedling. The collar serves to concentrate available moisture to the root zone while providing protection from burrowing rodents. The collar also provides a point of attachment for an aluminum screen which provides browse protection for the young plants during initial establishment. A polypropylene mat is installed around the plant to minimize weed and grass growth which outcompete the young plants for available water and nutrients. The mat is porous, black in color and decomposes after several years.

Plants are watered initially, and may receive one to two supplemental waterings during the first growing season if precipitation is light or sporadically distributed. General irrigation of any type is not practiced.

#### Planting Season

Grasses are seeded prior to the winter rainy season, generally by October 15. This provides maximum opportunity for early gentle soaking rains and warm temperatures necessary for germination and initial root development prior to the onset of heavy winter precipitation and reduced soil temperatures.

Early winter rains can be sporadic with thirty days or more between precipitation events. The use of straw mulch assists in maintaining soil moisture needed for germination and subsequent survival between precipitation events.

As soil temperatures drop in later October and November, germination declines and revegetation success is visibly affected. The use of straw



mulch provides insulation necessary to retain soil temperatures when daytime temperatures are warm and night time temperatures drop to near freezing.

Woody Plants are planted in December and January when soil moisture is high and ambient air temperatures are cool. Precipitation occurring in December through April provides needed moisture for initial plant establishment.

#### PERFORMANCE STANDARDS AND ANNUAL MONITORING

Performance standards for the McLaughlin Mine utilize percent cover criteria as the measure of reclamation success as illustrated in Table 4. Monitoring of reclamation success incorporates two inspections for percent cover in the first growing season and an annual inspection thereafter. The first inspection is completed several months following planting and is an evaluation of mulch application and nurse crop establishment, requiring a 70% cover criteria including mulch. The percent cover standard is based on sediment loss as function of soil cover with 70% cover providing the optimal level of erosion control protection. The second evaluation is completed at the end of the first growing season and is conducted in April or May. This inspection evaluates the first year's success which is critical to erosion control, surface stabilization and establishment of perennials and natives in following years. This evaluation also requires a 70% cover including mulch.

TABLE 4

#### McLAUGHLIN MINE RECLAMATION PERFORMANCE STANDARDS

##### FIRST INSPECTION, TWO TO THREE MONTHS FOLLOWING SEEDING

70% Cover (including mulch)

##### SECOND INSPECTION, END OF FIRST GROWING SEASON

Topsoiled Areas 70% Cover (including mulch)  
Nontopsoiled Areas 40% Cover (including mulch)  
Serpentine Soils 25% Cover (including mulch)

##### ANNUAL INSPECTION

% Cover Estimated Annually for Sustained Level

Annual inspections are conducted in following years to document a sustained 70% level of cover and the establishment of a permanent diverse vegetative community.

Consideration is given to serpentine slopes in the development of Performance Standards, recognizing the respective reclamation challenges provided by the different soil types. Disturbed serpentine soils do not readily support seeded species even with the addition of lime as a calcium supplement. The performance criteria reflect this requiring a 25% cover standard in years following the initial application of seed and mulch.

Monitoring data are reported annually in the McLaughlin Mine Annual Environmental Monitoring Report published in October of each year. The data are used to evaluate and modify where needed the reclamation methods employed.

### SUCCESSIONAL PATTERNS

Successional patterns are evident in the first five years following reclamation as illustrated in Table 5. Generally the first year plants present include the species from the fully seeded straw (oats, barley, or wheat depending on straw species used) and seeded annuals including blando brome and annual rye. The second year monitoring documents a reduction in the annuals and emerging presence of the seeded perennials. Clovers which are absent in the first year also become well established in the second year. The third year exhibits the first signs of native species, both shrubs and grasses invading from surrounding seed sources. The invading species are primarily dependent on seed availability, but include the species listed in Table 5. The fourth and fifth year show perennial seeded species and an increase in native species present.

TABLE 5

#### GENERAL PLANT SUCCESSION BY YEAR

Year

- |       |  |
|-------|--|
| 1     | <b>Annual Grasses and Mulch Species</b><br><br>Annual Rye, Blando Brome,<br>Mulch Species (oats, barley, wheat)  |
| 2     | <b>Annual Grasses, Emerging Perennial Grasses, Clover</b><br><br>Mulch Species absent, Blando Brome, Annual Rye,<br>seed mix perennial grasses become evident, clover.                             |
| 3     | <b>Perennial Grasses, Emerging Native Species</b><br><br>Seeded perennial grasses well established.<br>Native species dependent on surrounding seed source<br>but include both shrubs and grasses. |
| 4 & 5 | <b>Increasing Abundance of Native Species</b>  |

## CONCLUSION

The McLaughlin Mine Reclamation Plan incorporates a unique postmining land use as an environmental studies field station, providing for productive use of the site and facilities while maintaining the potential for future mining.

Development of the reclamation plan incorporated existing information, experience and resources to provide a plan employing techniques and materials proven to be successful in the local region of Northern California. Annual Performance Monitoring and comparison of results to adopted Performance Criteria provide a feedback loop for evaluation and modification of reclamation methods employed.

Annual Monitoring has demonstrated successional patterns in reclaimed areas during the first five years following planting. Continued monitoring will confirm the long-term successional patterns developing in reclaimed areas and provide additional information for evaluation of reclamation techniques. Annual monitoring, evaluation and fine tuning of reclamation methods will continue throughout the life of the project.

Overall reclamation success has been excellent with performance criteria being met in all cases with the exception of occasional rilling in limited areas. Woody species establishment has also met expectations for plant establishment.

Approximately 1,190 acres have been reclaimed since commencing project construction in 1983 with approximately 76 acres of mine waste rock disposal facility reclamation completed in 1985-1989.

## ACKNOWLEDGEMENTS

The author wishes to acknowledge the contribution to this paper from Lorraine Van Kekerix whose annual reclamation monitoring, as published in the McLaughlin Mine Annual Environmental Monitoring Reports, has provided supporting data and insight into identification of successional trends in reclaimed areas. The author also wishes to acknowledge the contribution of Lisa Bush, Rocky Thompson, and the staff of Circuit Rider Productions Inc. for their work on establishment of woody species at the McLaughlin Mine.

CONCURRENT RECLAMATION OF RETORTED OIL SHALE  
AT UNOCAL'S PARACHUTE CREEK SHALE OIL PROJECT

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Unocal's Parachute Creek Shale Oil Project produces synthetic crude oil from oil shale mined from the Parachute member of the Green River Formation in western Colorado.

Principal project components are: (1) an underground room and pillar mine; (2) a Unishale B Retort, which extracts the oil from the shale using pyrolysis; (3) a pipeline which carries the raw shale oil from the Retort to the Upgrade Plant; and (4) an Upgrade Plant which removes impurities in the raw shale oil to produce premium quality syncrude.

Retorted oil shale exits the retort and is conveyed several hundred feet to the shale disposal site, located on the south facing slope of the East Fork Canyon of Parachute Creek. The climate at the site provides 13.5 inches of precipitation in an average year; the mean temperature is 46 degrees. The elevation ranges from 6000 to 6500 feet.

The Colorado Mined Land Reclamation Division's original permit for revegetation of the shale disposal pile required establishment of a reclamation zone directly within the processed shale. The view at that time was that the local soils were not of a depth or quality conducive to stripping and replacement.

Studies conducted by Colorado State University indicated that by leaching four pore volumes of water through the top four feet of processed shale, it would be possible to establish a reclamation zone with a pH and an electrical conductivity capable of supporting salt-tolerant species. These studies, conducted in the 1970's, also gave consideration to species' adaptation and slope repose and exposure, as well as to soil depth and leachate chemistry.

As Unocal began preparation of the disposal area, an in-depth analysis of the method and related costs was developed. This brought to light several practical problems.

1. The application of four pore volumes of water (sixteen acre feet per acre) required to establish the reclamation zone was to be conducted on a 2 to 1 slope in an upward sequence. This would require careful management to prevent extensive erosion and create the possibility of mass slope failure at the point of saturation. Resalinization of the reclamation area below the leaching area as the pile height grew upward was also probable.

2. The establishment of vegetation would require supplemental irrigation and extensive fertilization. This also had the potential to create extensive erosion and adversely impact pile drainage.

3. The plan would probably result in a more sparse vegetative cover and more limited species diversity than desirable to control erosion.

These potential problems resulted in an extensive review of all possible alternatives, which brought out the following points.

1. The East Fork Canyon has extensive deposits of soil material within the alluvial terraces and fans. This soil can be economically moved with large mining equipment.

2. This soil is very acceptable for plant establishment and growth without leaching, having a pH of 8.2 and an electrical conductivity of 0.8. These soil materials also contain a 26% rock cover which enhance erosion control and habitat diversity.

3. The soil material could be placed concurrently with processed shale disposal to maintain a soil cover on the face of the retorted shale pile to retard erosion and preclude handling soil material twice.

As a result of this review, the MLRD permit was amended. As presently practiced, reclamation proceeds concurrently with with retorted shale disposal, as follows:

1. Soil material is excavated from the alluvium in advance of the pile construction and placed live into the reclamation zone. The slope configuration results in a mini-bench every ten feet of vertical rise. This microclimate supports more dense vegetation than the adjacent slopes since moisture is retained by the bench and reduces run off. The benches also provide mule deer winter range. This approach eliminates the requirement for supplemental irrigation and holds runoff to a minimal rate, which in turn retards erosion.

2. The storm water drainage from the pile is carried in drainage ways from the pile into a retention pond. The side canyon drainages are carried under the pile in a culvert during construction, with a rock channel constructed over the top of the land form to connect into the natural drainage at the final elevation.

3. The revegetation method is to apply the fertilizer-seed mix upon the rough soil surface with a hydroseeder, mulch with it with 1 1/2 to 2.0 tons of grass hay, and tack it with a slurry of 100 pounds of organic binder mixed with 600 pounds of wood fiber. The treatment is applied after two, ten-foot lifts are in place. The seed mixture is adjusted as the time of year warrants.

The CSU work on species selection was utilized in the initial plantings and has been expanded as data have been collected from additional plantings. The results have shown these species to establish and persist to date:

SPECIES	ORIGIN
Western wheatgrass	Arriba
Bluebunch wheatgrass	Secar
Pubescent wheatgrass	Luna
Smooth brome	Manchar
Russian wildrye	Vinal
Basin wildrye	Magnar
Alkali sacaton	Solado
Lewis flax	Co/Utah
Milk vetch	Cicer
Penstemon	Palmer/Rockv Mt.
Fourwing saltbush	New Mexico/Rincon
Winterfat	Co/Utah/New Mexico

Other species of interest include sideoats grama, blue grama, indian ricegrass and buffalo grass. Several species are obtained from The Upper Colorado Environmental Plant Center.

The establishing vegetation is monitored for diversity, density, production and chemical uptake. Each planting is tracked for resource input and maintenance. To date the resulting reclamation has shown a more diverse and productive cover than the natural areas.

The reclamation zone is monitored for possible chemical movement within the soil material. The ground water is monitored for possible leachate.

This reclamation and revegetation approach eliminates the leaching requirement and associated potential erosion and lessens the possibility of mass slope movement as well as greatly reducing the drainage maintenance. We are able to accomplish this at a reduced cost while achieving more diverse and productive revegetation.

The resulting land form (disposal pile) presently contains over 5 million tons of processed shale with a surface area of 36.5 reclaimed acres. The final East Fork land form will have a surface area of over 300 acres and extend up the canyon 3.6 miles.

The side canyon land form will provide better winter habitat for mule deer and elk than adjacent undisturbed lands. The relatively flat top of the disposal area will expand the winter food source at a higher elevation within the canyon, above the cold inversion of the canyon floor. This will reduce the animals caloric expenditures in moving up and down the slopes and provide the food source and cover on the sunny part of the slope in winter.

Unocal has participated with the Colorado Division of Wildlife in migration studies for mule deer resident to the area. Unocal trapped and tagged 154 deer which have been followed for 5 years. The deer have shown a pattern of faithfulness to the same areas. The East Fork group has lived in East Fork and the adjacent ridge tops with little intermingling with other herds.

The operational mitigation is to replant any area which

will be stripped of vegetation for more than one growing season. This practice has proven to be more productive than the natural areas and relieves the pressure on the land form reclamation. The revegetation also reduces the maintenance of berms and other features constructed of soil.

Our MLRD permit established the goal of building and operating the project with no net loss of wildlife. We are proud that Unocal has been able to meet that.

## NITROGEN CYCLING IN DISTURBED LANDS

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## INTRODUCTION

The deficiency of plant-available nitrogen (N) is a common limitation to the successful revegetation and long-term stability of disturbed lands. The term "disturbed lands" refers to lands that have been drastically disturbed by operations such as surface mining or road construction, and have subsequently been reclaimed. Nitrogen deficiencies arise because disturbances such as surface mining drastically alter the flow of N through the soil-plant-microbial ecosystem, and decades or centuries may be required for some disturbed lands to accumulate N by natural processes and evolve toward a new steady state. A major goal in reclamation programs is to achieve stabilization of a disturbed site with a desirable plant community that does not require a long-term fertilization program to maintain desired levels of plant productivity and plant nutrient quality. To realize this goal of a self-maintaining, desirable plant community, the reestablishment of an active biological N cycle is necessary, and this requires an understanding of how N transformations differ in disturbed lands as compared to nondisturbed ecosystems. This paper reviews the N cycle in nondisturbed grassland ecosystems of the western United States and discusses the effects of disturbance on the N cycle. Much of this discussion is taken from an extensive review of N cycling by Reeder and Sabey (1987). The findings of several research studies designed to evaluate N cycle processes in western grasslands disturbed by surface mining are used to illustrate the discussion. Although the data presented come from studies on lands disturbed by surface mining, the discussion is also applicable to lands submitted to other types of disturbance, such as road construction or the development of a ski run. This is because the general processes by which N cycles through an ecosystem are the same for all land ecosystems, whether stable or disturbed.

## THE N CYCLE IN NONDISTURBED ECOSYSTEMS

Figure 1 represents the components and interconnecting processes of the N cycle within a generalized nondisturbed land ecosystem. Nitrogen flows from the atmosphere into the lithosphere (soil and underlying sediments and rocks), through the biosphere (microorganisms, plants and animals) and hydrosphere (groundwater and surface waters), then recycles back into and between the atmosphere and lithosphere. The rate of N flow between spheres can be quite rapid, or so slow as to be measured in centuries or millenia. Only some of these N flows directly affect plant



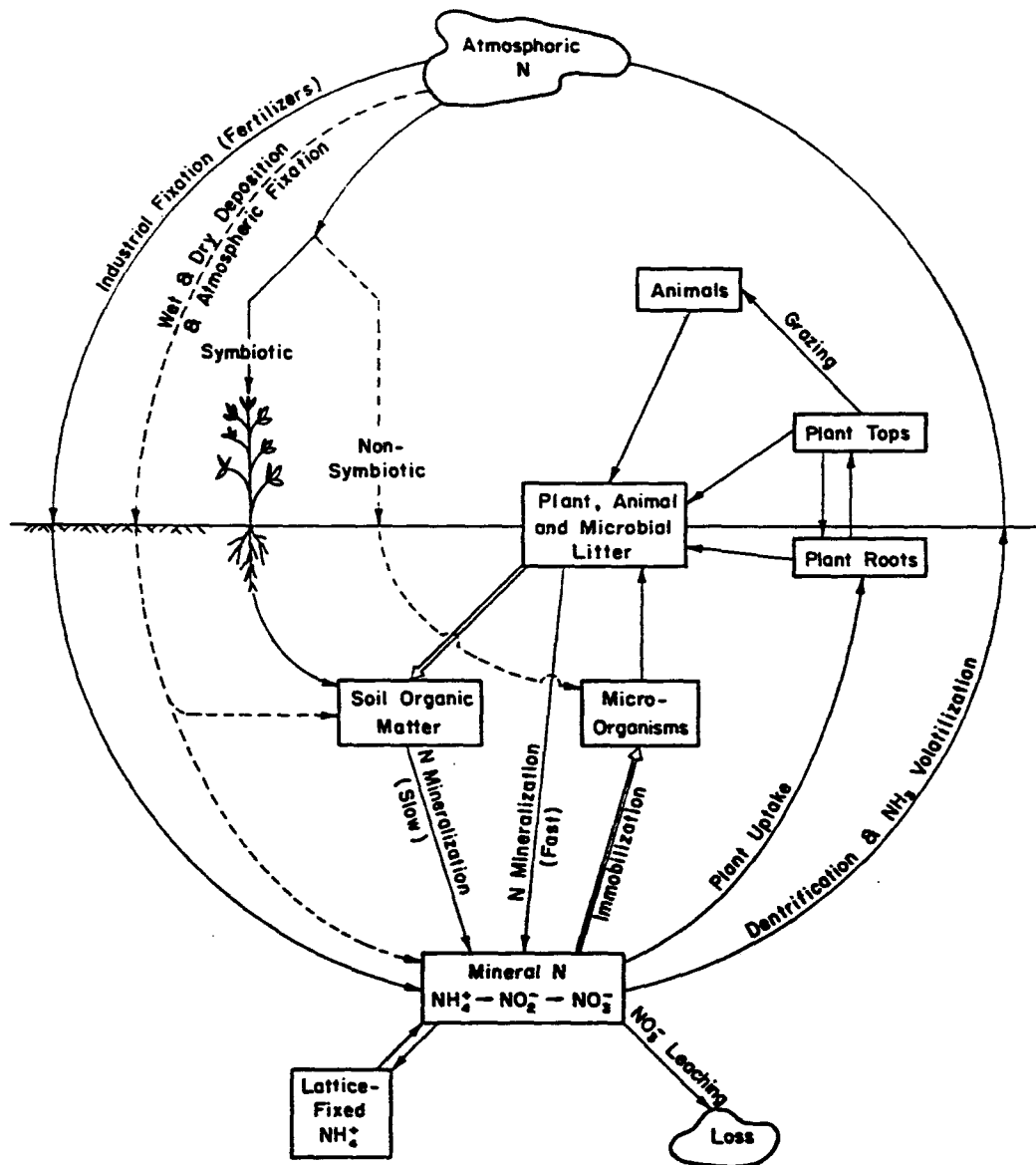


Figure 1. Components and interconnecting processes of the N cycle within a generalized grassland ecosystem. (From Reeder and Sabey, 1987)

growth within a given ecosystem. Annual N transfers between soil and vegetation far exceed other global N transfers; 95 percent of the N flow in the global terrestrial system occurs within the soil-plant-microbial system, while only 5 percent of the total N flow involves exchanges to and from the atmosphere and the hydrosphere. Table 1 presents the inputs, losses and distribution of N in various grassland ecosystems of the western United States.

### Additions of Nitrogen

In stable grassland ecosystems of the western United States, natural inputs of N are low, generally ranging from 2 to 9 kg of N per hectare per year (Table 1). These inputs of N come from the atmosphere: combined forms of N such as ammonium ( $\text{NH}_4$ ), nitrite ( $\text{NO}_2$ ), nitrate ( $\text{NO}_3$ ), and organically bound N associated with terrestrial dust, are common constituents of precipitation; and atmospheric  $\text{N}_2$  gas is captured and utilized by leguminous plant species and by certain microorganisms in the soil (Fig. 1). Inputs of N in precipitation and by dry deposition probably represent the largest natural sources of N to western grasslands because legumes are not a dominant component of the vegetation. Besides natural inputs, N also can be added by fertilizer applications at levels considerably higher than natural input levels (e.g. 50 to 250 kg of N per hectare). However, water is often the limiting growth factor on western grasslands, and native species may not respond sufficiently to added fertilizer N to make the practice economically sound.

### Losses of Nitrogen

The pathways of possible N loss from stable grassland ecosystems of the western United States include nitrate leaching, denitrification, ammonia volatilization, erosion, and grazing by livestock (Fig. 1). However, total annual N loss from all of these processes is usually low, less than 1 kg of N per hectare per year. Nitrogen losses by leaching or denitrification are generally very small in western grasslands because water rarely occurs in sufficient quantity to saturate the soil profile. Losses by wind or water erosion are usually very low because of the fully developed plant cover on most sites, but sizeable losses may occur during intense storms on sites where plant cover has been reduced by fire, drought or grazing. Nitrogen loss as volatilized ammonia from senescing plant parts, animal excreta, and decomposing litter is thought to be the major source of N losses in western grasslands.

In stable grassland ecosystems of the western United States, inputs of N are usually slightly larger than outputs, resulting in a very slight net gain of N into the system each year. This slight gain, generally ranging from 2 to 8 kg of N per hectare per year (Table 1), is insufficient to supply the annual N requirements of the vegetation. For example, atmospheric inputs to the shortgrass prairie are estimated to

Table 1. Inputs, losses and N distribution in grassland ecosystems of the Western United States and Canada.  
(From Reeder and Sabey, 1987).

Ecosystem type	Location	Inputs* --kg ha <sup>-1</sup> yr <sup>-1</sup>	Losses --kg ha <sup>-1</sup> yr <sup>-1</sup>	Net Gain	N in Biomass					N in Soil	
					Standing live	Litter	Roots†	Microbes	Large Animals	Organic Matter	Mineral† N
----- kg ha <sup>-1</sup> -----											
Great Basin shrub-steppe	Southeastern Washington	2	<0.5	2	30	30	140	50 <sup>§</sup>	0 - 3	4170	21
Desert grassland	Southern New Mexico	3	<0.5	3	20	20	20	20	0 - 3	810	4
Shortgrass prairie	Northeastern Colorado	6	<0.5	6	30	90	240	50 <sup>§</sup>	0 - 3	5500	28
Mixed-grass prairie (I)	Southwestern South Dakota	9	1	8	30	70	150	130*	0 - 3	8400	42
Mixed-grass prairie (II)	Southwestern	4	<0.5	4	20	70	140	130	0 - 3	5400	27

\* Principal inputs are assumed to be from the atmosphere as wet and dry deposition.

+ 20% of the N in roots is assumed to be living tissue.

† N in mineral form estimated as 0.5% of N in soil organic matter.

§ Estimate (guess).

|| Includes crowns.

supply no more than 13% of the annual N uptake requirements of the vegetation (Woodmansee et al., 1978).

### Nitrogen Requirements of Plants

Because of the high N requirement for growth and reproduction, growing plants remove far more N than any other nutrient from the soil. Concentrations of N in healthy leaves of rangeland plants generally vary from 1.3 to 1.7 percent N in grasses, 1.2 to 3.4 percent N in shrubs, and 4.5 to 5 percent in legumes. The N concentrations of roots and of root and herbage litter are usually lower than in green herbage. The distribution of N in grassland ecosystems in kg of N per hectare generally ranges from 20 to 30 in the aboveground live herbage; 20 to 90 in aboveground plant litter; 20 to 240 in living and dead roots; and 50 to 130 in the soil microbial biomass (Table 1).

### Sources of Nitrogen For Plants

Most plants obtain needed N by absorbing the mineral N forms of ammonium ( $\text{NH}_4$ ) and nitrate ( $\text{NO}_3$ ) from the soil. However, the amounts of these two forms of N in the soil at any one time are usually very low; in most grassland soils mineral N represents less than 0.5 percent of the total N of the system (Table 1). The supply of mineral N in soils is constantly replenished by a microbial process of mineralization of the N in plant and microbial litter and in soil organic matter (Fig. 1). In this mineralization process, certain soil microorganisms use nitrogenous organic substances as an energy source and, as a by-product of metabolism, excrete excess N as ammonium. The pool of organic N in the above- and below-ground litter from grassland plants and microorganisms is relatively small and ranges from about 40 to 300 kg of N per hectare. However the principal source of N for plant growth in stable grassland ecosystems is from the rapid mineralization of the labile, or readily mineralizable, portion of the organic N in this plant and microbial litter (Fig. 1). The soil organic matter constitutes the largest reservoir of N in a grassland ecosystem, ranging from about 800 to over 8,000 kg of N per hectare (Table 1). However, only a small fraction of this N is mineralized annually because most of the N in soil organic matter is held in organic compounds that are highly resistant to decomposition. The amount of N annually mineralized from this large reservoir is small and insufficient to meet the N requirements of the plant community. Mineralization of organic N and atmospheric inputs of N together supply about two thirds of the annual N requirements of grassland vegetation. The other one third of the annual N requirements of a grassland community is met by internal translocation of N within living plant parts (Fig. 1). In this internal translocation process, N is withdrawn from senescing plant herbage, stored in perennial tissues such as crowns and roots, and subsequently translocated to growing aboveground herbage the following season (Woodmansee et al., 1978).

## THE NITROGEN CYCLE IN DISTURBED ECOSYSTEMS

Drastic disturbances, such as surface mining, frequently result in a deficiency of plant-available N because the disturbance disrupts the N cycle within the ecosystem. The N in a nondisturbed climax or late-successional rangeland is assumed to be in steady-state equilibrium, meaning that the amount of N incorporated into living plant and microbial tissues roughly equals that lost by death or exudation. Stable rangeland ecosystems are not very "leaky", as additions and losses of N to these systems are negligible. Thus the annual N requirements of these stable communities are met largely by the cycling of N already present in the ecosystem, primarily by the rapid cycling of the readily mineralizable forms of organic N in the plant and microbial litter. The mining process disrupts internal N cycling within a stable ecosystem by altering the forms and amounts of N found in the various components of the ecosystem and by disrupting the microbial subsystem responsible for most N transformation processes. The entire living plant biomass, containing about 25 to 80 kg of N per hectare, is destroyed and must be reestablished. The microbial biomass, the hub of the N transformation processes and containing 20 to 130 kg of N per hectare, is partly or entirely destroyed and may be slow to reestablish. If the topsoil is removed and subsequently replaced after the mining operation is completed, much of the large reservoir of N associated with the soil organic matter is restored. However, stockpiling of the topsoil for long periods of time can alter the form and content of N in the soil. When the topsoil is removed and saved, much of the original above- and below-ground plant and microbial litter is mixed within the topsoil and thus eventually returned to the disturbed site. However, the readily mineralizable organic N in this litter component decomposes rapidly and is usually depleted by the time the topsoil is replaced on site. The reestablishment of this readily mineralizable reservoir of N is a principal requirement for the reestablishment of a stable, self-maintaining system.

### N Mineralization and Immobilization

After the drastic disturbance of a site, geologic materials become a more important part of the plant growth media, so an understanding of how well these geologic materials can supply N to plants is needed. The total N content of geologic materials is highly variable, ranging from 11 mg of N per kg in some igneous rocks to more than 4,000 mg of N per kg in some shales. The N in geologic materials is usually in organic form or as ammonium fixed within the lattice structures of silicate minerals. Some shales, however, contain significant amounts of exchangeable ammonium that could support vegetation for several growing seasons.

The organic N content of many geologic materials can be comparable to the N content of topsoil. However, the mineralization potential of geologic organic N is usually much lower than the mineralization

potential of soil organic N, meaning that a significantly smaller proportion of organic geologic N becomes available to plants over time. Because the organic N of geologic materials is not readily mineralizable, geologic materials exposed as surface or subsurface plant growth media will not usually supply much of the total N demand of plants. In general, vegetation growing on geologic spoils takes up less N and produces less biomass than vegetation growing on soil.

Table 2 presents data that illustrates the N supplying capacity of geologic materials. Samples of a topsoil and two spoils were collected from the Energy Fuels mine located southwest of Steamboat Springs, CO. The spoil collected from the Wadge site represented an area that had been mined 10 years earlier but had not been topsoiled or reseeded, so the spoil had been exposed to 10 years of physical and chemical weathering. The spoil collected from the Fishcreek site represented an area that had just recently been mined and had been exposed less than 1 year to weathering. The pH of the two spoil materials was comparable to that of the topsoil, whereas the water holding capacities and cation exchange capacities of the two spoils were significantly lower than in the topsoil. Although the total N contents of the two spoils were quite high, only slightly less than the total N content of the topsoil, the amount of readily mineralizable N was quite low. Less than 1% of the organic N associated with the spoil materials was readily mineralizable as compared to 5.5% of the organic N associated with the topsoil. This inability of the spoil materials to supply adequate levels of plant-available mineral N is reflected in the results of a greenhouse study in which Western wheatgrass was grown in the three materials (Table 2). The biomass production and N uptake by plants were significantly higher in plants growing in the topsoil as compared to plants growing in either spoil material. The data in Table 2 also suggest that 10 years of physical and chemical weathering were insufficient to improve the N supplying capacity of the spoil material.

It is interesting to compare the data in Table 2 with the data in Table 3, which presents the results of a similar study conducted at the Seneca Peabody Mine near Hayden, CO. The spoil materials at the Seneca mine are similar in geologic composition to the spoil materials at the Energy Fuels mine. In this study, samples of a soil and two spoils were collected. The fresh spoil was sampled from a site that had just been mined, whereas the vegetated spoil was sampled from a site that had been mined 6 years earlier, was not topsoiled, but was seeded with alfalfa. At the time of sampling, a healthy stand of alfalfa had been growing for 5 years on the site. The data show that symbiotic fixation of atmospheric  $N_2$  by the alfalfa resulted in a significant increase in the total N content of the spoil. Moreover, the mineralizable N content of the spoil was significantly increased due to the growth of alfalfa. Both total N and mineralizable N contents of the vegetated spoil were comparable to those contents found in the soil. The ability of the vegetated spoil to supply plant-available N at levels comparable to the soil is reflected in the results of a greenhouse study in which barley

Table 2. Properties of a topsoil and two spoil materials sampled from the Energy Fuels mine located southwest of Steamboat Springs, CO. Data taken from Reeder (1985, and 1988).

Material	pH	WHC <sup>1</sup>	CEC <sup>2</sup>	Mineral-		<u>Min.N</u> Tot.N	Greenhouse-Grown Western Wheatgrass	
				Total N	izable N		Plant Dry Wt.	N Uptake by Plants
		%	meq/100g	--mg/kg--		%	g	mg N/pot
Topsoil clay	7.9	21	23	1345	74	5.5	3.54	33.1
Wadge-10yr clay loam	7.8	13	10	1168	11	0.9	1.65	21.1
Fishcreek-1yr clay loam	7.9	14	11	1118	6	0.5	2.35	26.4

<sup>1</sup> WHC = water holding capacity

<sup>2</sup> CEC = cation exchange capacity

Table 3. Properties of a topsoil and two spoil materials sampled from the Seneca Peabody mine east of Hayden, CO.  
Data from Reeder and Berg (1977a, and 1977b).

Material	pH	WHC <sup>1</sup>	Conduc- tivity	Total N	Mineral- izable N	<u>Min.N</u> Tot.N	Greenhouse-Grown Barley	
							Plant Dry Wt.	N Uptake by Plants
		%	mmhos/cm	--mg/kg--		%	g	mg N/pot
Soil clay	7.2	19	0.3	1193	70	5.9	1.32	20.0
Veg. Spoil silty clay loam	7.9	15	1.1	1083	49	4.5	1.49	21.9
Fresh Spoil clay loam	8.0	14	5.9	730	5	0.7	0.84	9.8

<sup>1</sup> WHC = water holding capacity



was grown in the three materials (Table 3). The biomass production and N uptake by plants growing in the vegetated spoil were comparable to biomass production and N uptake by plants growing in the soil.

The data from these two studies show that 10 years of physical and chemical weathering were insufficient to improve the N supplying capacity of the geologic materials, whereas 5 years of alfalfa growth were sufficient to reestablish the rapidly cycling portion of the N cycle.

#### Plant Response to Fertilizer N

For a number of years after reseeding, a developing ecosystem will tend to accumulate biomass and nutrients as it stabilizes. During this time, the plant and microbial biomasses and the litter component act as sinks for N. These N sinks withdraw N from the fast-cycling pools, thereby creating a deficiency of N available for new plant growth. The principal requirements for the reestablishment of a self-maintaining system are the reestablishment of a developed pathway of fast cycling N and an input of N that is equal to or greater than the amount of N channeled into the soil organic matter. Additions of fertilizer N may therefore be needed to sustain plant growth until the system reestablishes the rapid-cycling portion of the N cycle and becomes self maintaining.

Several studies were conducted to evaluate the response of plants growing in geologic materials to added fertilizer N. Figure 2 presents the results of a greenhouse study in which Western wheatgrass was grown in the three materials presented in Table 2. Three rates of fertilizer N were added in the form of ammonium sulfate: 60, 120 and 240 ppm N (equivalent to 120, 240 and 480 lb N per acre, or, 134, 269 or 538 kg N per hectare). The bottom row of graphs represent total dry matter production, while the top row of graphs represent plant uptake of N. The blank portion of the N uptake bars represents plant uptake of N indigenous to the soil or spoil, while the cross-hatched portion of each bar represents plant uptake of added fertilizer N. Plants growing in the topsoil exhibited a classical response to fertilizer N: (1) as the rate of fertilizer N increased, both plant uptake of N and dry matter production increased, and (2) dry matter production failed to increase with increased additions of fertilizer N when other factors became limiting. Plants grown in the topsoil with the addition of 240 ppm N (538 kg N/ha) exhibited "luxury consumption" of fertilizer N; that is, uptake of excess fertilizer N that was not reflected in increased biomass production. In contrast, plants growing in the two spoil materials did not respond to additions of fertilizer N. Although dry matter production was slightly increased by the additions of 60 and 120 ppm N (134 and 269 kg N/ha), the increases were not statistically significantly higher than dry matter production in control pots receiving no fertilizer N. Uptake of fertilizer N by plants growing in the spoils was lower than by plants growing in the topsoil. The

Figure 2. Total N uptake and dry matter production of Western wheatgrass grown under greenhouse conditions in a topsoil or two spoil materials with the application of fertilizer N. (From Reeder, 1985)

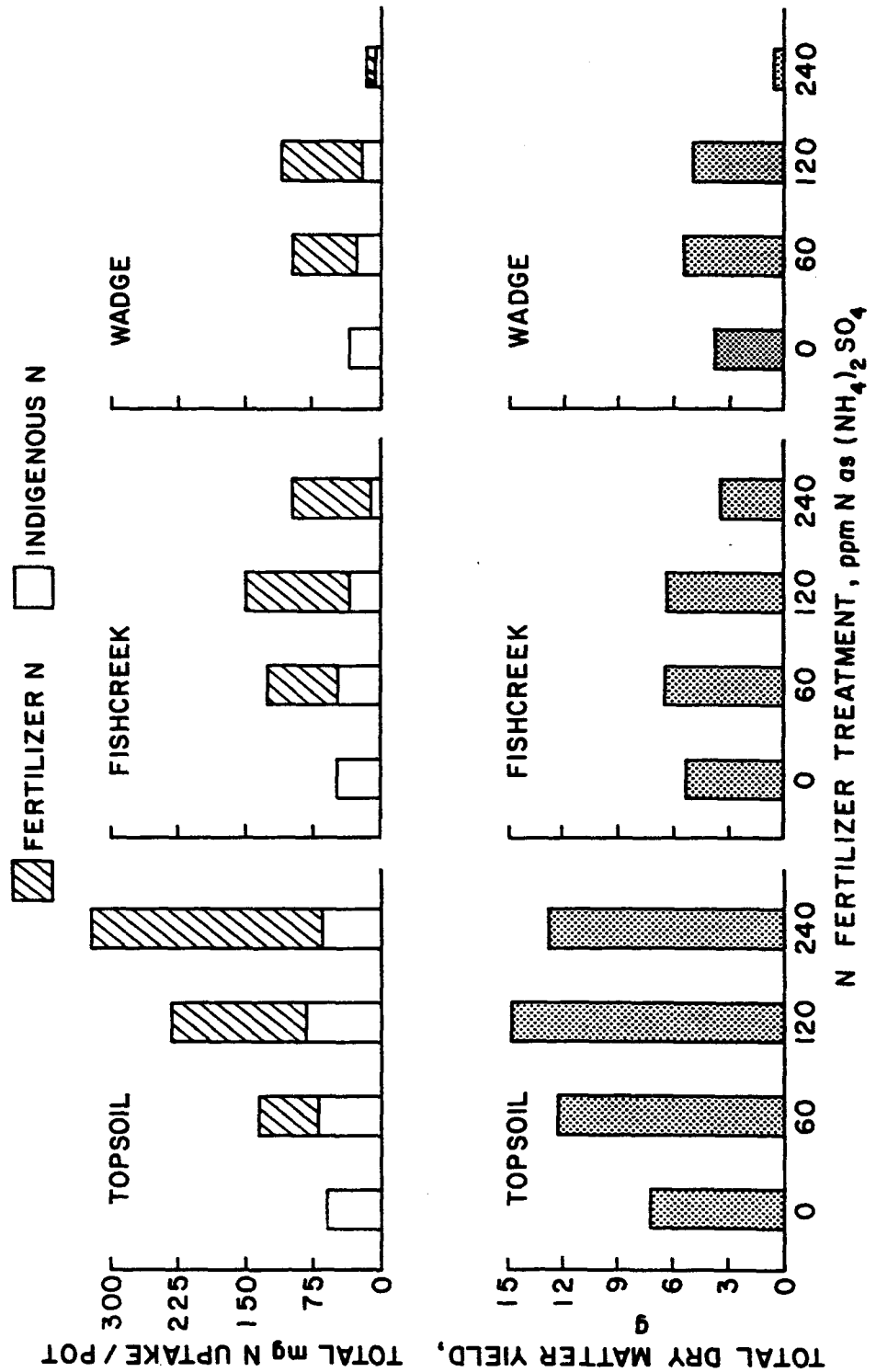


Table 4. Percent recovery of added fertilizer  $^{15}\text{NH}_4\text{-N}$  (134, 269 or 538 kg N/hectare) in various plant and soil components eight weeks after seeding. Data from a greenhouse study in which Western wheatgrass was grown in topsoil and two similar non-vegetated mine spoils subjected to one or ten years of weathering (Reeder, 1985).

[illegible]

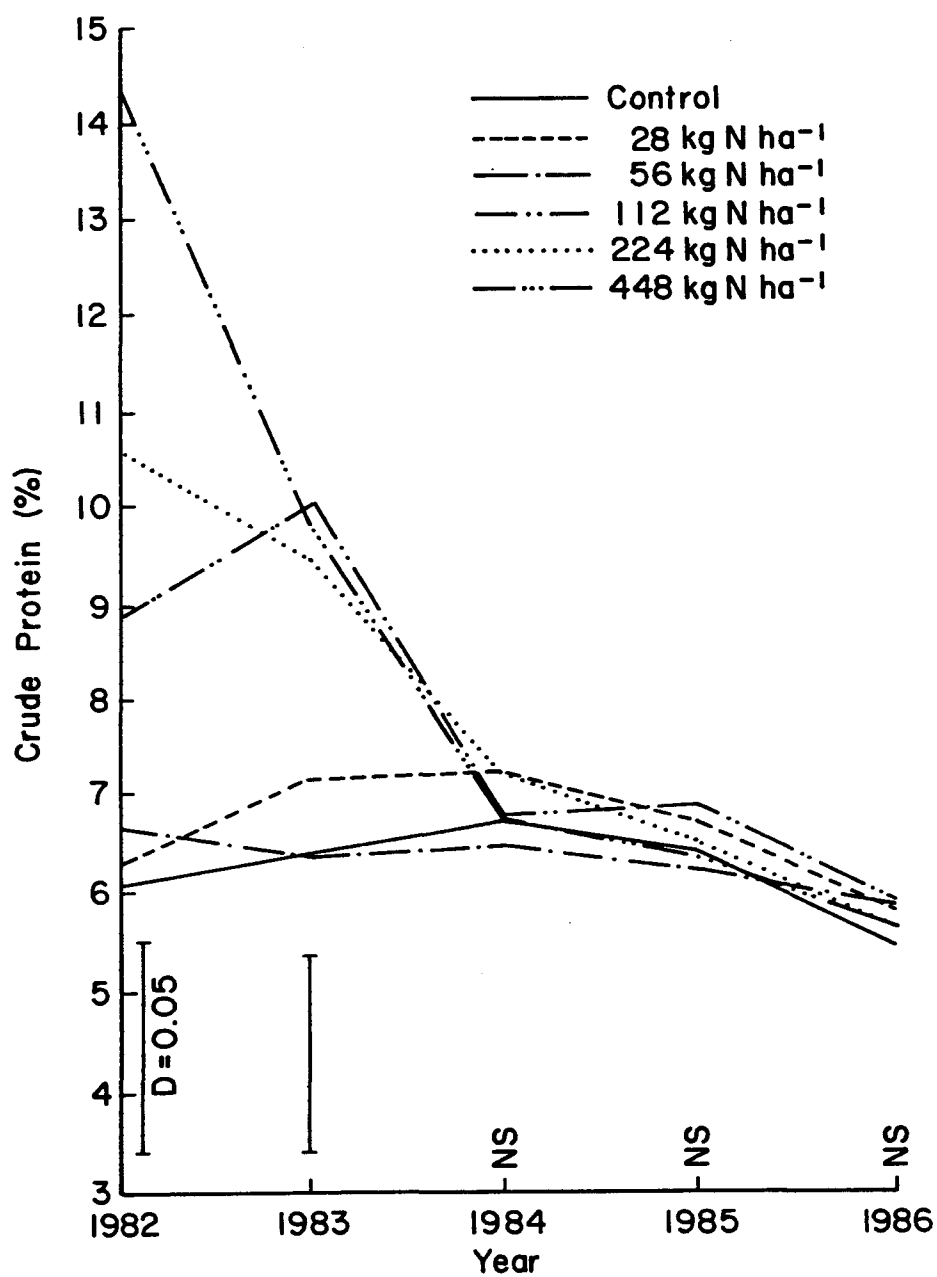


Figure 3. Crude protein concentration of forage during a five year period as affected by a single application of 0, 28, 56, 112, 224, or 448 kg N/ha fertilizer in the fall of 1981. (From Reeder and McGinnies, 1989)

inability of plants growing in these two spoil materials to respond to applications of fertilizer N was due to the low cation exchange capacities and water holding capacities of these two spoils as compared to the topsoil (Table 2), which resulted in excessive concentrations of ammonium in solution in the spoils that were toxic to plant growth and microbial activity. Table 4 shows the distribution of fertilizer N in the various components of the system. Regardless of rate of N application to the topsoil, a large percentage of added fertilizer N was either taken up by plants (52 to 63% of the added fertilizer N) or soil microorganisms (12 to 20%), and the amount of added fertilizer N remaining in mineral form (i.e. ammonium,  $\text{NH}_4$  or nitrate,  $\text{NO}_3$ ) was low (1 to 12%). In contrast, as the amount of fertilizer N added to the spoil materials increased, the percentage of added fertilizer N taken up by the plants or soil microorganisms decreased, and considerably larger percentages of added fertilizer N remained in the soil as  $\text{NO}_3$ , which is susceptible to loss by leaching. At the highest fertilizer N rate, about half of the added N was in nitrate form, and 24 to 34% of the added fertilizer N had been lost via ammonia volatilization. The data show that the active plant and microbial communities growing in the topsoil are able to immobilize most of the fertilizer N added, even when high rates of N are applied. In comparison, the less active plant and microbial populations growing in the spoil materials are unable to immobilize large amounts of added N, so much of this N is susceptible to loss by ammonia volatilization and nitrate leaching.

Figure 3 shows the results of a field study in which single applications of ammonium nitrate fertilizer were broadcast-applied to an established stand of vegetation growing on mined lands at the Energy Fuels mine southwest of Steamboat Springs, CO. Rates of 28 to 448 kg N/ha (25 to 400 lb N/acre) were applied in the fall of 1981, and both dry matter production and plant crude protein content were monitored over the next 5 growing seasons. In the first growing season after fertilizer application, crude protein content of plants increased with increased rate of fertilizer N applied. By the second growing season, a significant response to fertilizer N was noted only with the three highest application rates, and by the third growing season, there was no significant response to the added fertilizer N. The response of plant dry matter production to fertilizer N was similar to the response of crude protein content (data not shown). The data demonstrate that mined land systems do not efficiently immobilize added fertilizer N, and if added at high rates, much of the fertilizer N is susceptible to loss.

#### SUMMARY

1. The total amount of N associated with geologic materials is often comparable to the total amount of N associated with a soil. However, less of this geologic N is readily mineralizable, and weathering does not improve the mineralization potential.

2. Legumes add significant levels of N to geologic materials and help reestablish pathways of rapidly cycling N.
3. Addition of an amount of fertilizer N equivalent the the amount of N added by legumes would be less effective in reestablishing pathways of rapidly cycling N because fertilizer N added to mined lands is highly susceptible to losses by leaching and volatilization.
4. Fertilizer N added to mined lands is more susceptible to leaching and volatilization losses because the plant and microbial communities are less active and immobilize less fertilizer N than the plant and microbial communities of stable non-disturbed grasslands.

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## BIOHYDROMETALLURGY: APPLICATIONS IN RECLAMATION

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## INTRODUCTION

In recent years the definition of biohydrometallurgy has expanded and now encompasses the use of microorganisms to:

- (1) Enhance the extraction of metals from ores, concentrates and sub-marginal materials (BIOLEACHING);
- (2) Recover metals from aqueous waste or process streams with the dual objectives of restoring the water quality and reclaiming metal values (BIOSORPTION); and
- (3) Treat aqueous discharges and mine residues for residual cyanide (BIOTREATMENT).

The purpose of this paper is to briefly review each of these applications of biohydrometallurgy, describe current usage of the technology, and relate these applications to mine reclamation practices.

## BIOLEACHING

Bioleaching is the use of microorganisms, principally bacteria, to enhance extraction of metals from ore minerals. The process of bioleaching was undoubtedly applied in Roman times on an empirical basis. However, the technology reached a higher level of sophistication and application in the 1950's when Kennecott Copper Corporation began to employ the process of dump leaching on a large scale to extract copper from sub-marginal ore materials. Dump and heap leaching is now applied throughout the world to solubilize copper from low-grade oxide and sulfide ore minerals.

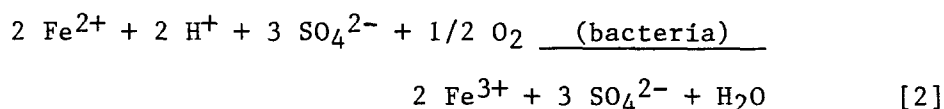
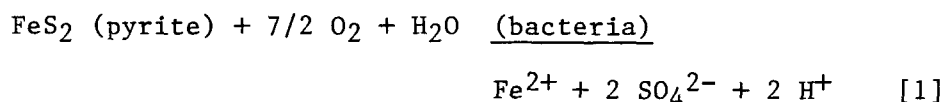
## Bacteria

With the advent of copper dump leaching scientists began systematic identification of the bacteria involved and defined the mechanisms used by these bacteria to enhance metals extraction from ore minerals. Today we know there are several types of bacteria involved in the process of bioleaching: Thiobacillus ferrooxidans; Thiobacillus thiooxidans; Leptospirillum ferrooxidans; a microorganism with the

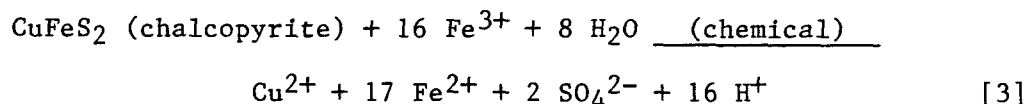


proposed name of Sulfobacillus thermosulfidooxidans; and several other un-named microbes. These bacteria are robust creatures that derive their energy from the oxidation of sulfur, ferrous iron and sulfur/iron containing minerals. They utilize carbon dioxide and oxygen from the atmosphere and function in environments where the pH can range from 1-3 and soluble metal concentrations are high (for example, 30 grams arsenic/liter). Some of these bacteria (for example, Sulfobacillus thermosulfidooxidans) require temperatures approaching 60° C.

The role of bacteria in bioleaching is the oxidation of sulfide- and iron-containing minerals, such as pyrite, to generate ferric iron ( $\text{Fe}^{3+}$ ) and solubilize metals of value:



Ferric iron is a strong oxidizing agent and reacts with a variety of sulfide minerals, such as chalcopyrite, sphalerite, and others to solubilize metals including copper, zinc, uranium etc.:



In all oxidation reactions involving ferric iron, one of the end products is ferrous iron ( $\text{Fe}^{2+}$ ), which is re-oxidized by the bacteria according to equation [2].

#### Bioleaching Applications

The reactions described above are exploited commercially in large dump leach operations such as Kennecott Utah Copper Corporation's Bingham Canyon near Salt Lake City. Leaching is conducted by applying acidic leach solutions to the top surface of the dump. As the leach solutions percolate through the rock material, the bacteria proliferate and colonize the minerals surfaces. The bacteria enhance the dissolution of copper by oxidizing pyrite and copper-containing sulfide minerals (Tuovinen, 1990). The pregnant (metal-laden) leach solution is collected at the base of the dump and pumped to a metal recovery plant for copper extraction. The leach solution is recycled.

The process of bioleaching has achieved a new level of commercial application in the treatment of precious metals ores that are termed "refractory" due to the occlusion of gold in sulfide mineral matrices.

Bacteria are employed to pretreat the precious metal ore by oxidizing pyrite, arsenopyrite and other sulfide minerals that encapsulate or bind the gold and silver. Bioleached mineral residues are neutralized and cyanided to extract the precious metals. Bioleaching in this application is being employed in controlled, agitated and aerated reactors capable of processing up to 1,500 tons per day of ore (Lawrence, 1990).

#### Application of Bioleaching to Reclamation

Past mining and milling processes were not as efficient in extracting metals as today's modern methods. As a result there are millions of tons of waste rock and tailings containing small quantities of high value metals. A significant amount of this mine waste contains sulfide minerals, which can oxidize over time and create acid mine drainage (AMD). Much of this waste material could be economically re-processed to recover the metals. Bioleaching, using heap or agitated tank technologies, may be applicable for the re-processing of certain mine waste residues to enhance metal extraction and lessen the overall concentration of sulfide minerals. Dissolution of the sulfide minerals through controlled bioleaching could be used to contain AMD. Following bioleaching, the re-processed mine residues can be reclaimed using modern reclamation and revegetation practices to effectively mitigate AMD.

Likewise, underground mines, which are potential on-going sources of AMD can be re-worked through in-situ, bioleaching techniques to extract residual metal values and further control acid drainage.

### BIOSORPTION

#### The Biosorption Process

Most microorganisms (bacteria, fungi and algae) accumulate and/or transform metals (Brierley, 1990; Gadd, 1990; Greene and Darnall, 1990). Microbial/metal interactions include: volatilization; adsorption of metals to cell surfaces of microorganisms; intracellular accumulation; complexation; and metal precipitation. The phenomenon of adsorption can occur without the microorganisms being alive. It is the binding of metals to the charged surfaces of microorganisms that is the basis of several commercial biosorption processes (BIOCLAIM and AlgaSORB). In the case of BIOCLAIM, bacteria are immobilized in an organic matrix to form a porous granular bead. Whereas, the algae, which make-up the AlgaSORB product, are embedded in an inorganic matrix to form a resin. Biosorption products are employed in: fixed-bed canisters; fluidized, pulsed-bed systems similar to those used in applications of granular activated carbon; and multi-stage, dispersed-bed, continuous, counter-current reactors for large flow volumes.

Biosorption products possess certain properties that differentiate them from non-selective ion exchange resins. Biosorption products:

- o Are not adversely affected by the presence of organic matter and high concentrations of total dissolved solids;
- o Do not load substantially with the alkali and alkaline earth metals;
- o Do not exhibit sensitivity to rapid changes in solution concentration (i.e. they are not subject to osmotic shock);
- o Demonstrate metal loading that is independent of influent metal concentration within a metal concentration range of approximately 10 mg/l to several hundred mg/l;
- o Demonstrate a reduced preference ratio for metals, which results in a much lower chromatographic effect in treating wastewaters containing mixed metals; and
- o Demonstrate a slow and predictable metal breakthrough, which allows for maximum metal loading while maintaining effluent compliance.

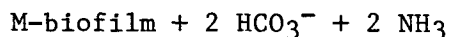
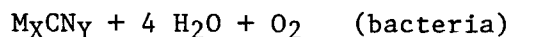
#### Biosorption in Reclamation

Biosorption can be employed to remove a wide variety of metals including environmentally-regulated metals, precious metals and radionuclides. Biosorption, because of its particular ability to recover soluble metals from high flow volumes with low metal concentrations, is well-suited for the treatment of underground and surface mine effluents, tailings dam discharges and contaminated groundwater. Biosorption systems are capable of achieving effluent quality to meet stringent regulatory standards.

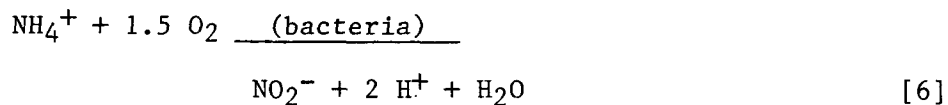
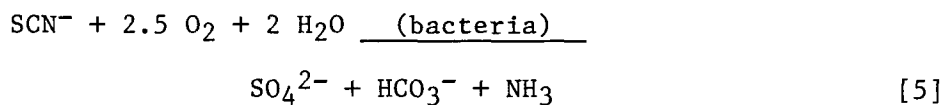
### BIOTREATMENT

#### Biotreatment Applications

Biotreatment is the use of bacteria to degrade hazardous or toxic materials. In recent years a biotechnical approach has been successfully introduced for the treatment of cyanide. The Homestake Wastewater Treatment Process utilizes living bacteria, Pseudomonas paucimobilis var. mudlock that are immobilized on rotating biological contactors (RBC's), to degrade cyanide, thiocyanate and ammonia:



[4]



Soluble metals are accumulated by the bacteria on the RBC's. The patented Homestake Wastewater Treatment Process is currently applied to treat a maximum of 21,000 m<sup>3</sup>/day of cyanidation wastewater from Homestake Mine operations in Lead, South Dakota (Whitlock and Mudder, 1986).

The U.S. Bureau of Mines' Salt Lake City Research Center is investigating biological decontamination of complex wastewaters containing high (280 mg/l) cyanide concentrations and other soluble metals. Research efforts to date have demonstrated biological oxidation of cyanide in highly alkaline solutions (pH 10.5) at elevated cyanide concentrations (Lien et al., 1990).

#### Biotreatment Application in Reclamation

While bacterial processes have been applied commercially to the treatment of cyanide-containing aqueous streams, preliminary research suggests that a biotechnological approach could be used to oxidize cyanide and thiocyanate in solid mine wastes. This biological approach would have considerable application in the degradation of residual cyanide in precious metal heap leach operations following cyanidation and aid in elimination of cyanide run-off from tailings during storm events.

#### SUMMARY

Several biohydrometallurgical processes are currently employed commercially. Bioleaching is used to enhance extraction of base and precious metals. Waste streams and groundwater are being treated by biosorption to remove low concentrations of environmentally-regulated trace metals. Biotreatment is employed to degrade cyanide in high flow volume mine effluents. These technologies potentially have extended application in (1) recovering metal values and minimizing AMD through re-processing of sulfide-containing mine wastes, (2) treating mine effluents and contaminated groundwater to reclaim metal values and restore water quality and (3) degrading residual cyanide in aqueous and solid wastes.

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## MINE DRAINAGE BIOREMEDIATION - THE EVOLUTION OF THE TECHNOLOGY FROM MICROBES TO BIO-CARB

by

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### INTRODUCTION

The observation of a small acid mine seep, separated by rocks and forming two small pools of similar sizes near a coal mine in Fayette County, West Virginia was the beginning of this bioremediation technology. One pool had only a few common mine bacteria and continued to impart the reddish-orange color to the rocks and debris associated with mine waste effluent. The other did for a short distance, then flowed out colorless and clarified. Tests showed the iron in both to be about 6 ppm. Where the two discharged, the colorful one was 5.7 and the clear one showed only 1.5 ppm iron. Why? The answer lies in the mixotrophic population that naturally occurred in the clarified water, but was lacking in its counterpart.

To apply this to the treatment of large mine sites requires more than just "dumping bugs" into treatment ponds. Which microbes do you use? How do you know if they'll work on a specific site? Will they drop out the metals? Will they raise the pH? Will they create ecological chaos in the receiving waters? How many gallons of water a minute will they treat? How many ponds will it take and how deep should they be? Do they build up sludge? Will it work forever? How fast do they work? Will I meet compliance by lunch tomorrow? How soon can you deliver? How much does it cost and what guarantees do I have?

Those are all valid questions - those and more that we ask ourselves every time we install the process. Each answer and each site we do leads to knowledge and understanding of this new technology that has led Lambda from chance microbes in a small pool to the Bio-Carb technology.

### THE LAMBDA PROCESS

The microbes we employ are those that will chelate or bond to metals, microbes that produce oxygen, decomposers and nitrogen-fixers, reducing organisms in the soil and any others that are needed to maintain an ecological balance in

the system (See Fig. 1). We know from hundreds of tests what the microbes can do. To find out if they work on a specific site, we have to analyze that site to see what it has that we know we need and what it is lacking at least in adequate numbers to do the job. We can foresee a generic mix that can be modified slightly from site to site. Each site we do brings use closer to that. They can raise the pH to the historic norm of the area, but effluent pH standards 6-9 are unrealistic at best, unless you are discharging into a trout farm. Average rain water pH should be 5.5 (that has been lowered considerably by acid precipitation in the last 20 years(1), but that is another paper entirely), and the average of Appalachian water runs considerably less than that. Therefore, soda ash or mild caustic as an effluent bed prior to discharge is often in order. They are harmless organisms indigenous to the area, or we do not use them.

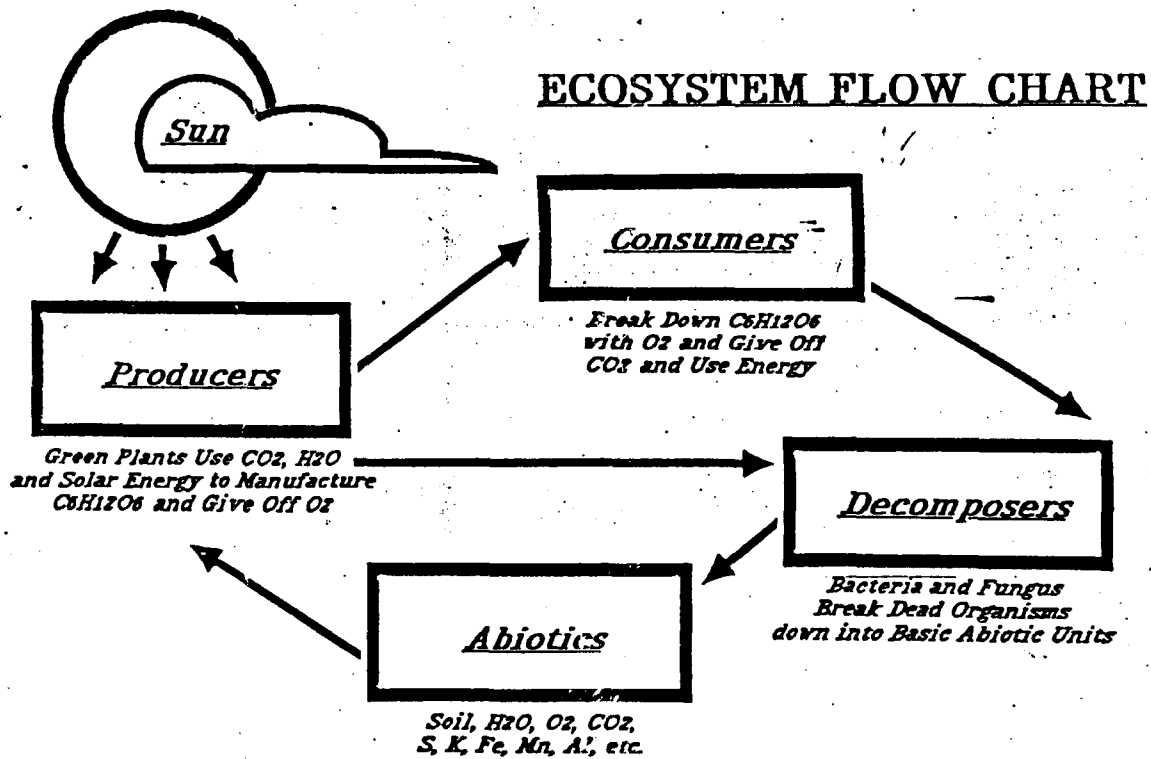
The flow rates are of concern, but can be handled by a properly engineered site and by imbedding the microbes in a substance that will stay on the bottom and not flow out with the water. We feel we need a retention time in the ponds of at least 24 hours to give the microbes time to chelate, oxidize and deposit the metals into the top soil at the bottom of the ponds. This is in a mature system and it takes an inoculated system 1-12 months to mature. Newly constructed ponds leak both water and microbes and an adequate population can't become established as long as they are leaking.

The major evolution in the technology has come in the area of how to most efficiently "imbed" the microbes. The use of the old IMPPS technology required a tanker truck for delivery and was expensive. The material we used kept the microbes alive and active and provided food and moisture and we were transporting a lot of water to keep them moist during the trip.

We are now using diatomaceous earth and activated charcoal. We can add a liquid substance to the growth mediums that suspend the microbes around the diatom skeletons or charcoal particles in a "dehydrated" state that will rehydrate with a 90-95% recovery ratio. Their effectiveness is seemingly unimpaired and 200 lbs. of that material ships easier, is easier to install and less messy than liquid medium.

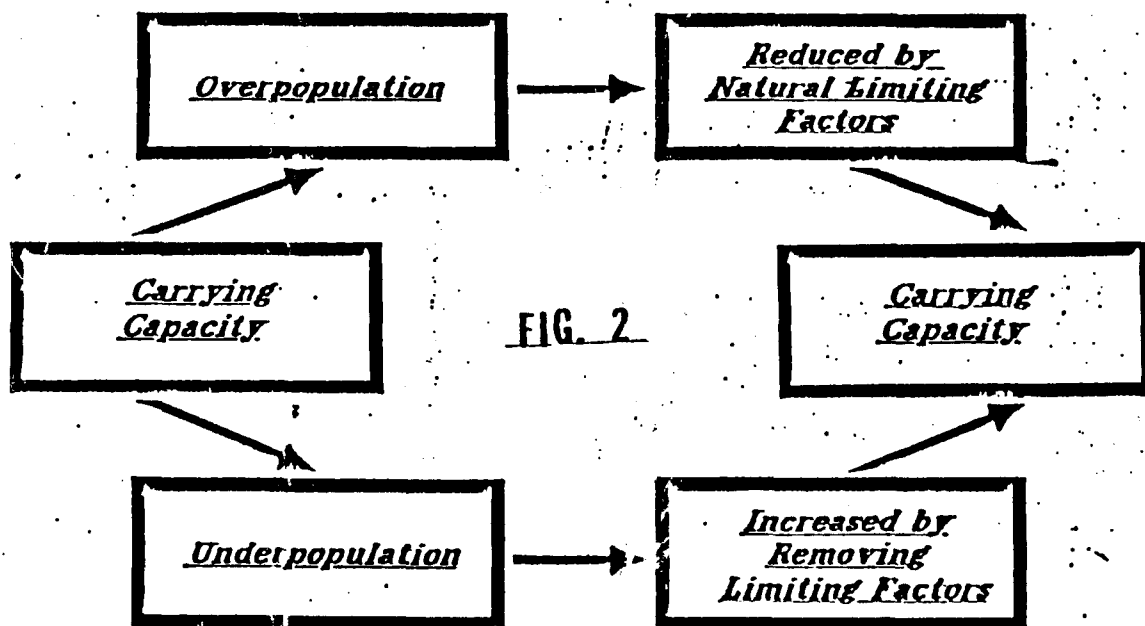
We have found that 3 ponds of equal size, which is determined by how much water we are treating, at least 5-6 ft. in depth are needed, with at least 15" of fill dirt or top soil are best. These should be divided by spillways

FIG. 1



*Matter Cycles and Energy Flows through the System*

### Negative Feedback Flow Chart for Natural Population Control





with straw and sandstone rip-rap for deposition purposes, since limestone coats and becomes impervious too quickly. They should empty into a fourth round solar pond about 2 feet in depth and then discharge through soda ash or mild caustic to achieve pH requirements. Only one inoculation is required, unless there are major changes in the system. Once in compliance, it should hold compliance. And no, they do not build up "sludge". The sludge is the result of caustics and metals in combination. Remove the caustics and you remove the sludge problem. On the soda ash at the end, you remove the metals and you remove the sludge. We have seen no sludge problems on our sites and have, in fact, used a "sludge pit" as a fourth or "polishing pond" to the benefit of the water and the sludge. The critters tend to break the sludge there into soil.

Compliance comes with maturity. The bigger the system, the longer it will take. The microbes reproduce and populate very quickly, but it does take a reasonable period of time. Will they outgrow the system and develop a blob large enough to eat Charleston? No, they will not. They are controlled by a natural cycle called the "Negative Feedback System" (Fig. 2) and won't grow beyond their carrying capacity. Its nature's birth control system and highly effective. They don't die if the system dries up either. They have slime coats that make them efficient chelators, help them adapt to environmental stress and encapsulate them if the moisture is removed from their environment.

It takes 6-8 weeks to do a site study and identify what a site has and needs and another 3-4 months to grow enough for a site, imbed them all and get them ready to ship. The cost is affordable and will vary from site to site. When compared to treatment costs over 1-2-5-10 years, it will save mine owners money. As far as guarantees are concerned, we won't take a job we can't do.

#### SITE STUDIES

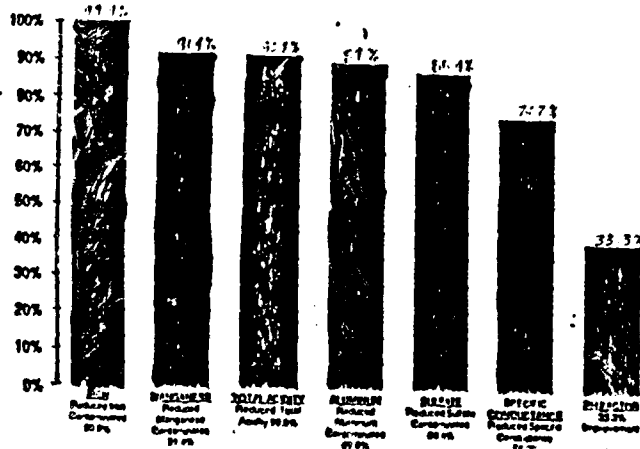
The technology has been successfully used at 3 mine sites over the last 3 years and 2 other non-mine sites where metal pollution was a problem. Two of these sites, The FT. HILL MINE in Somerset Co., PA, and the ROBIN HOOD MINE in Twilight, WV, have been reported at previous conferences (2)(3) and a summary of the data is presented in Graphs 1 and 2.

Graph 3 refers to the BOILER MAKER'S Pond and the HICKORY CREEK Pond data is show in Graph 4. These last 2

RESULTS SUMMARY  
PERCENT EFFECTIVE

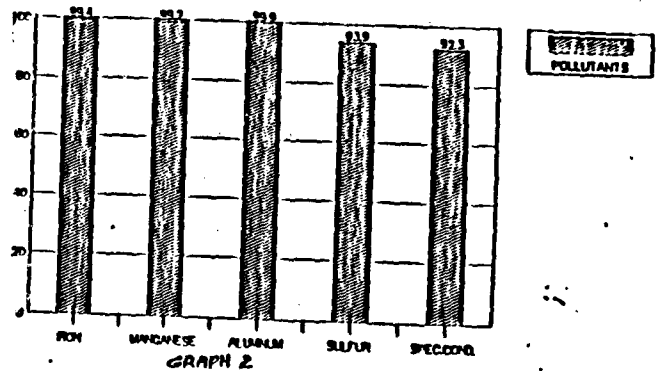
GRAPH 1

FT. HILL MINE 3/87 - 5/89



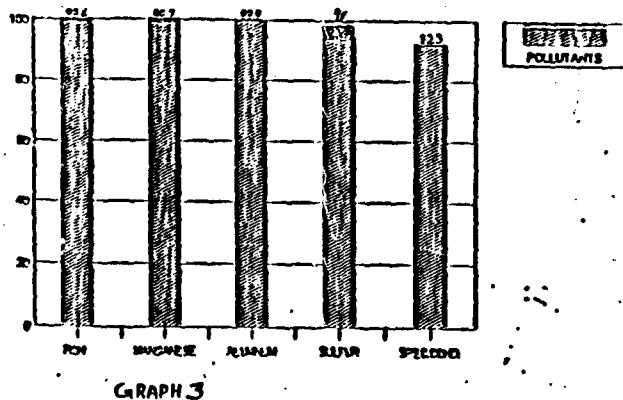
## PERCENT OF POLLUTANT REMOVAL

ROBIN HOOD MINE 11/88-12/89



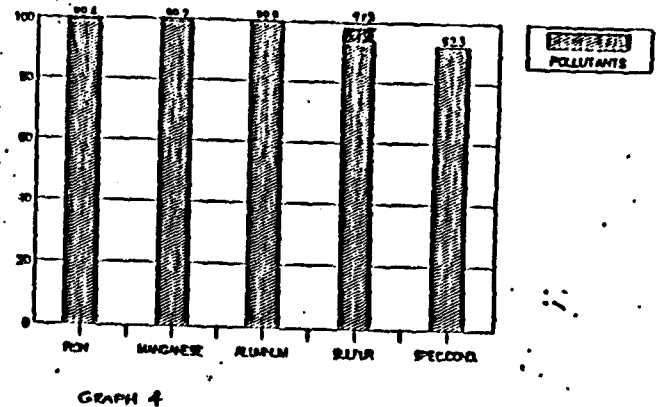
## PERCENT OF POLLUTANT REMOVAL

BOILERMAKER'S POND 5/88-5/89



## PERCENT OF POLLUTANT REMOVAL

HICKORY CREEK POND 8/89-12/89



are stationary ponds. The Graph 3 pond is fed from a heavy metal containing aquifer from a pipe that flows up to 25 gal. per minute for 2-3 hours per day. Graph 4 is a pond that receives primarily surface run-off and some enhancement from a groundwater pipe with a much lower metals concentration. Both were built for decorative reasons.

The process has only recently been installed at the LECKIE SMOKELESS COAL MINE into one of their treatment areas. Inadequate data was available at the writing of this paper to include, but from personal correspondence(4), compliance is anticipated and treatment costs have already been reduced by 50%. This is an interesting site, because it had been treated with anhydrous ammonia for 2 years before the BIO-CARB process was tried. The complexing of the metals by the ammonia makes them inherently less susceptible to bioremediation than does treatment with other caustic forms. These problems will be addressed in a future paper.

## RESULTS OF SITE STUDIES

We were able to achieve a 99% reduction in iron at the Robin Hood site, and a 99% reduction in iron at the other sites. The manganese discharge was reduced by 99% at the Robin Hood site and 99% at the Ft. Hill site. 99% reduction was achieved at the stationary sites. Sulfate was reduced 94% at the Peabody site and 94% at the Ft. Hill site. 98% reduction was achieved at the stationary sites. The pH was improved 33% at the Ft. Hill site and 61% at the Robin Hood mine sites. Compliance was met and held at the mine sites. No N.P.D.E.S. compliance requirements were in force at the stationary ponds.

All of these results were achieved quickly for the scope of the site (one week for the stationary ponds, 36 days at Ft. Hill and 8 months at Robin Hood). Each one was inherently different and each responded well to bioremediation. Information on individual sites is available upon request from Lambda.

## SUMMARY

The Lambda technology has evolved from a random collection of microbes in a pool to a viable new BIO-CARB application. It seeks only to successfully emulate and enhance the natural microbial cleaning processes nature has employed for countless eons to insure us of having viable aquatic, marine and terrestrial ecosystems and their surrounding ecotones. Even though we are fortunate enough to reside on a planet that is 75% water, the supply of clean, fresh water is not finite, unless we assist as best we can to clean up the messes we make in supplying our other needs. Caustics, surfactants and flocculants offer their own solutions and create problems in their solving of problems. They also require continual application, often in greater and greater amounts if they are to be continually effective. In evaluating treatment technologies, cost and effectiveness, practicality and ease of use are all important considerations. If bioremediation can offer equal effectiveness, a single application (being dumped in from a 20 gallon drum), and permanent remediation, it will surely fulfill its bright promise.

One problem is the inability to leave a system alone once it is working properly. There is a desire in many cases to make it a "little better". Tampering with the ponds, in any way, whether it be by dumping materials other than what they were designed for, changing the pond sizes, changing the water levels, etc. can disrupt the system. It will eventually rebalance itself, given time, but it will not work as effectively as it did before, until the new balance is achieved. If what you add kills the key microbes or starves the system for balanced oxygen-carbon dioxide, it could kill it. Then you have to start over.

It is a hard lesson to learn, but the old adage still applies - "If it ain't broke, don't fix it". Left to her own devices, Mother Nature will continue to provide us with clean water, fresh air and arable lands. When we "fix" things by changing the existing systems, then she needs a helping hand. Bioremediation is that helping hand and one that won't give the earth terminal indigestion.

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**LANDSCAPE INFORMATION SYSTEM:  
VISUAL RESOURCES AND VISUALIZATION OF CHANGE**

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Scenic/aesthetic/visual values are coming under increasing pressure by demand for mineral, energy, and recreation resources and resultant landform and vegetation disturbance. The environmental assessment / environmental impact statement process (National Environmental Policy Act of 1969) requires characterization of affected environments, prediction of impacts brought on by development, and establishment of mitigation measures. The Landscape Information System, written in C for SUN Microsystem ATARI ST supermicrocomputers, has been designed for data capture, spatial analysis, and two or three dimensional display of existing viewsheds, proposed actions and alternatives, and surface model prediction of the effectiveness of mitigation measures and design alternatives. GIS applications research conducted in a wide variety of physiographic provinces over the past fourteen years has resulted in highly accurate and cost effective spatial analysis for characterizing visual resources and visualizing changes to the visible landscape.

## Roadway Esthetics - "Lipstick on a Pig - or Are They Real?"

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### Introduction

Whether your primary function is mining, ski areas, harvesting of forest products, or just about any other activity that I can think of, you will need a transportation system to get people and goods to and from your site. This seemingly narrow topic can have direct application to your situation also. The guidelines suggested here should be used as guides and the direct application should be qualified and refined to fit your particular situation.

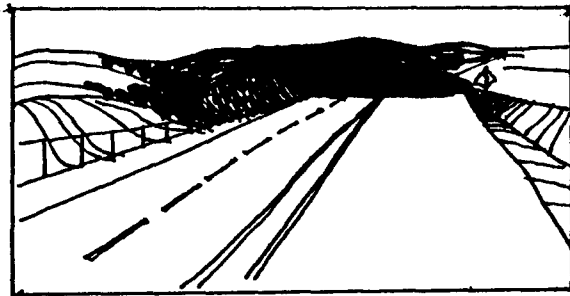
### Discussion

The title for this presentation was taken from, a forum of five, shakers and movers in the road design field. An Engineer for the Federal Highway Administration, an architect/civil engineer that was involved heavily in Glenwood Canyon design, two practicing landscape architects one in private practice the other for the National Park Service, (principal designer of the Linn Cove Viaduct extension of the Blue Ridge Parkway.) And last but not least was William Rieley, who teaches landscape architecture at the University of Virginia and is a principal of Rieley Associates.

It was a student of William Rieley's that referred to "putting lipstick on a pig" as the role landscape architects often find themselves in when road design is involved. That is, after engineers have determined alignment, with cuts and fills, the landscape architects should "make it pretty". I am sorry to report that is too often the case. It is usually too late to make significant changes by that time. There are however, some techniques that when implemented can change the overall perception of the road's fit to the natural landscape.

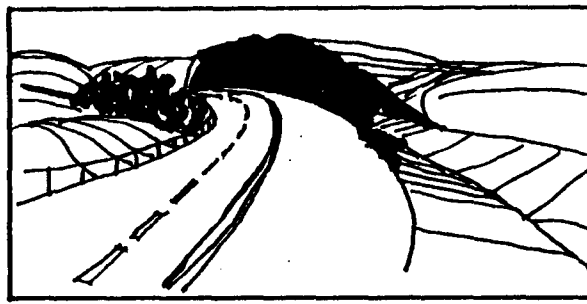
Undoubtedly, the most important features are the horizontal and vertical alignments. These could be entire chapters in books and sometimes are. For our purposes, some generalizations will be stated here. When roads are designed for the public, usually there are many "cookbook" type guidelines that predetermine things such as the maximum percent grade, the width of lanes, and degree of curve allowed for certain speed. The thing that most often is said about an alignment is that it either flows or it is hard and does not appear to fit. At the most simplistic level of road design, it should "lie lightly on the land". Changes in grade should not appear as a hinge

but more as a string suspended by two points and allowed to drape or flow onto the existing contours. Instead of pencil and straight edge maybe a tube of toothpaste would be a more appropriate design tool. Soften the angles and the edges, this is difficult when most all engineering is done to nice crisp straight lines. There are times when long tangent section are the correct solution. Then the challenge becomes how to work in diversity of grading, plant massing and by varying median or right-of-way widths to build in diversity to an otherwise homogenous landscape. These perceptions are not just nice, they involve safety also. Even a very gentle curve after a long tangent alignment through open homogenous landscapes can be dangerous. The driver tends to speed up and without a feeling of enclosure or some other warning. Landform grading or a change in grade or a combination of these, helps the driver to perceive an upcoming change and slow down.

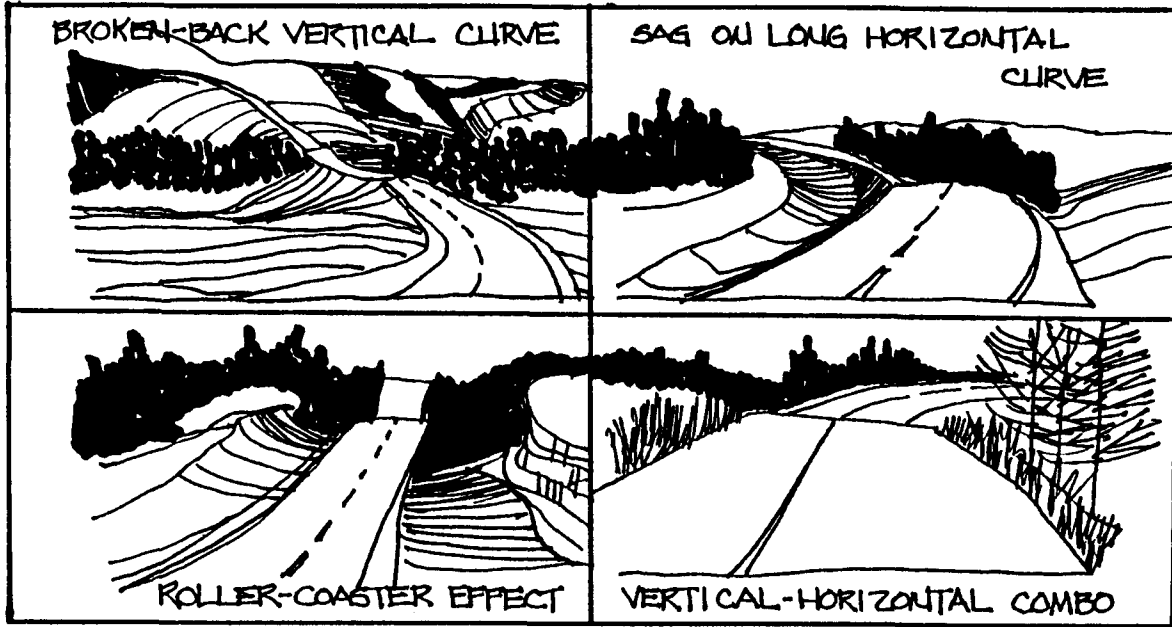


LONG STRAIGHT TANGENT SECTION  
ENCOURAGES HIGHER SPEEDS  
ONLY TO CHANGE ABRUPTLY  
WITH LITTLE WARNING.

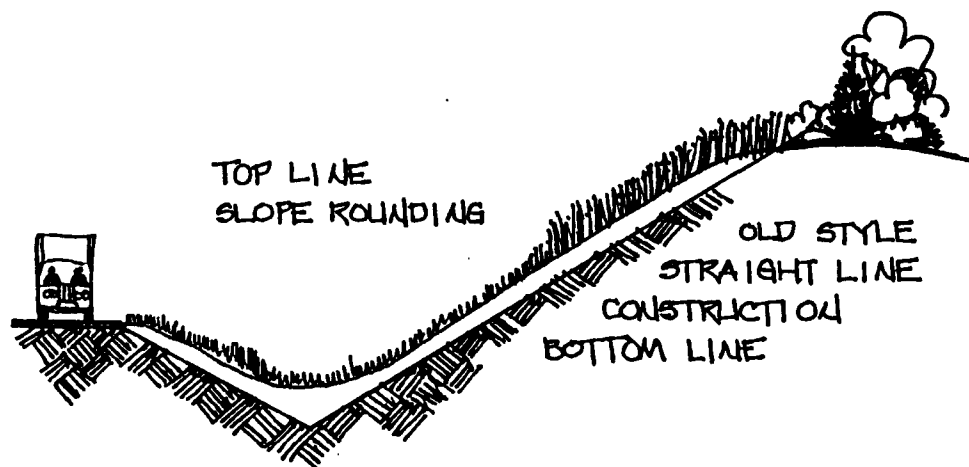
PROGRESSIVE  
CURVATURE TO WARN  
DRIVER OF UPCOMING  
CHANGE.



Often, the most difficult part of roadway design is to visualize three-dimensionally from the traditional horizontal plan and vertical profile method. Horizontal and vertical discontinuity can result in any or several of the following conditions, broken-back vertical curve, roller-coaster effect, short sag on long horizontal curve, or a vertical curve at the beginning of a horizontal curve. There are issues of Horizontal/Vertical Integration which are too complicated to address in this article.

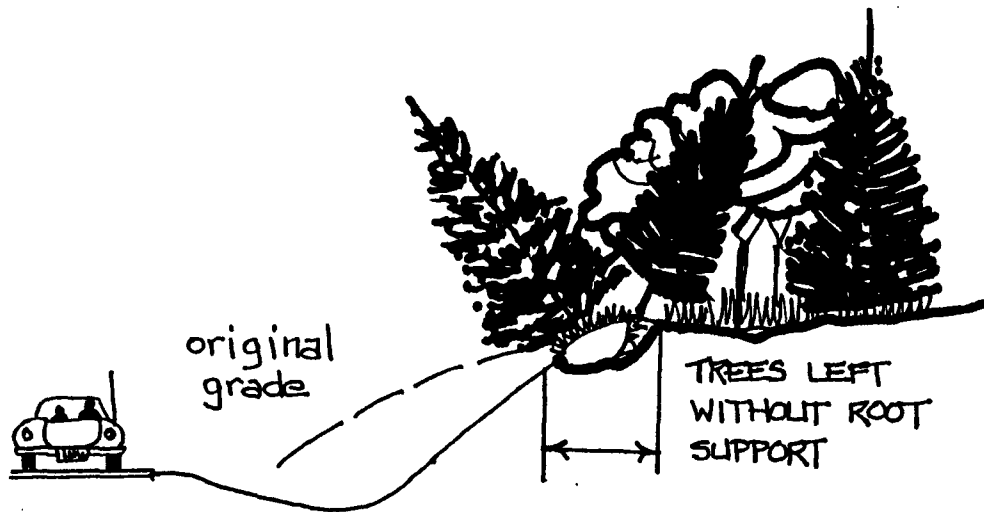


I will concentrate on those treatments that directly effect things such as slope stability, erosion control and revegetation. Since most often the problems that effect us are the cut/fill slopes and their treatments I will start with them. On all Department of Highway projects, tucked away in the General Notes, there is a statement something to the effect that all "top of cuts and toe of fills shall be rounded to a pleasing appearance." Most of the time, nowadays, this task does get accomplished. It is a simple yet very effective method of softening.

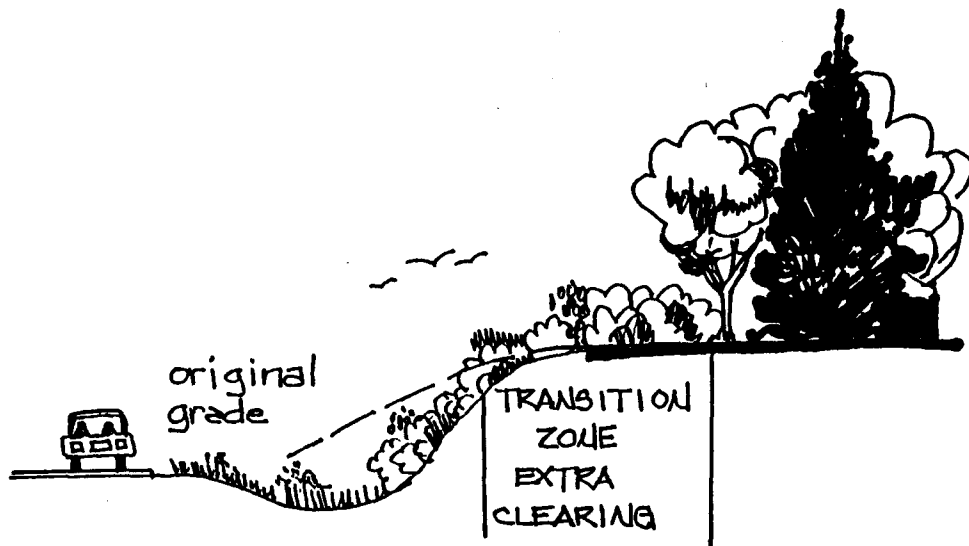




This may make a difference where the "cut-line" is staked or you may want to utilize an off-set line of stakes to allow for room to work at the top of the cut. How often have you seen the overhanging lip of soil and grass on old roadway cut slopes? This is not only visually unappealing but contributes extensively to erosion that does not need to happen. A few passes with a dozer backdragging the edge make a significant difference. This may also involve some communication between the designer and surveyor or the field person and the dozer operator. This is a very important step to get started correctly with the cut slopes. Directly related to this is to have sufficient clearing beyond the cut slope to allow for this slope rounding without being up against a wall of trees, generally 15-18 feet. The feathering of vegetation is critical for several reasons, to do away with the "wall" effect of usually even-aged trees, without transition or feathering many forest species, both coniferous and deciduous trees, are prone to wind-throw or sun scald due to their new position in the scheme of things.



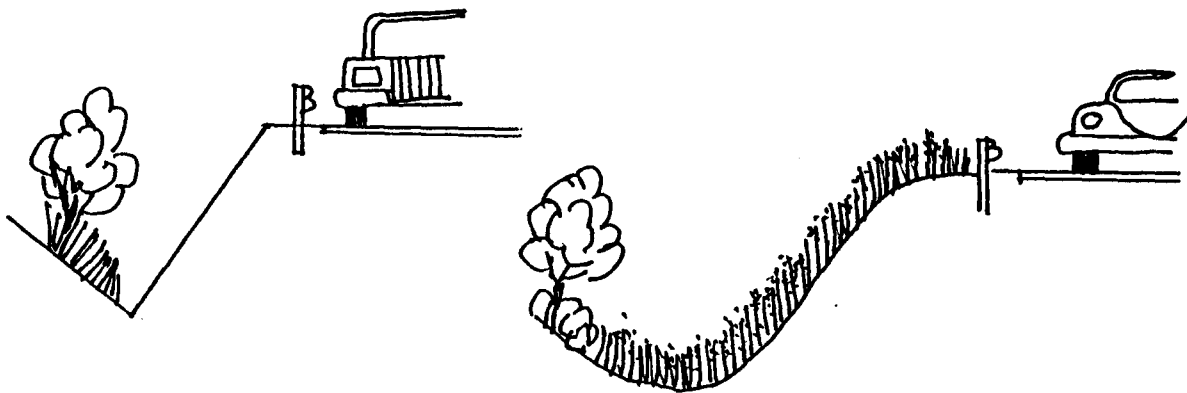
As you can quickly see, many of these techniques dovetail in their purpose and needs. A spin-off of establishing a clearing line is not to establish a "line" at all, but to vary the amount of vegetative material removed to allow for the undulation of space and the flow of the edge. Caution is needed to develop evenly spaced variations without relation to the landform that they occur in or on. In our noble effort to remove the fewest trees, sometimes we do more harm than good.



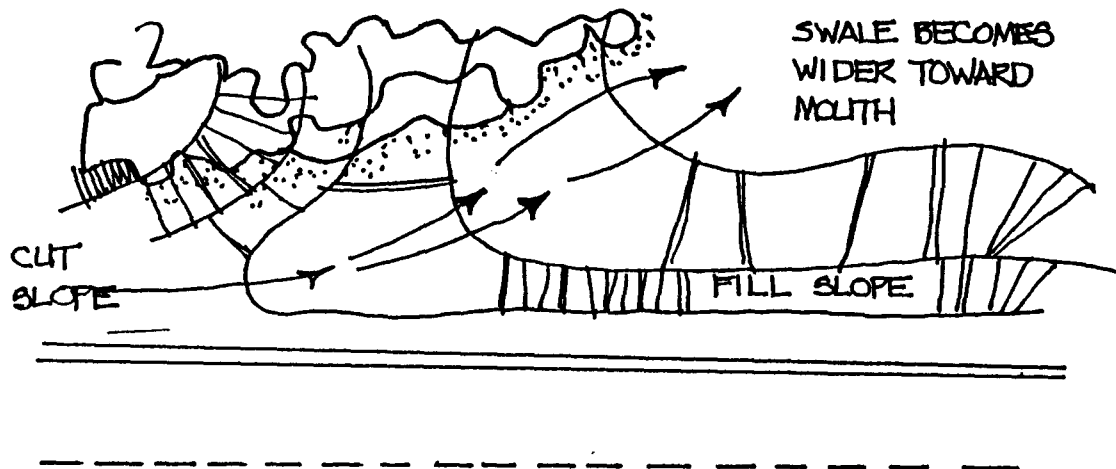
This is one case where less is not more and by leaving the rigid barrier of tree trunks we have created nothing, but may cause long-term maintenance and visual problems with an artificial sameness that can be dangerously boring to the road user, as well as allowing for less abrupt changes from light to shade and the reverse for safe driving conditions.



The other side of the slope treatment is just as important, where fill slope meets the ditch or natural ground. The end results should be a gentle rounded curve not a have "V". If you equate this area to geologic terms, it should be a glaciated valley not an erosional one, in most cases it will only be one-half of the valley. This area will be one of the first to fill in from erosion if you do not build it correctly. The natural forces that shape the face of the earth will see to that.



Another problem area that can be better "designed in" than fixed later is the transition between cut and fill slopes. Usually this area ends up as an eroded gully because the run off from the cut runs longitudinally along the road to the fill slope and erodes at the interface of natural and constructed material. Again, slope rounding can help lessen this problem. Also, construction of "bell-mouthed" draws can help to spread out instead of concentrating the sheet flow. How the grading of disturbed areas is handled will determine a lot about how that job will be perceived. If ridges are "slabbed off" and draws indiscriminately filled in the road will have a different "feel" to it than if the contours are respected. If you feather the transitions between cut and fill, flare the mouth of the draws and ease the corners of cut slopes, the roadway will be perceived as fitting the lay of the land. A buzz-work phrase to remember is fill on the ridges/cut up the valley. Sometimes large cut slopes are unavoidable due to other constraints, that is when the techniques mentioned previously should be employed.



One of my basic tenets is that the landform you leave will be there long after most of the plants you plant are dead and gone. Most of my co-workers have heard the admonition of "get the shape right." Even if it means removing more vegetation or soil to get the landform so that it "looks" right. We have inherited some interesting problems from the engineering design that make us try some new things. The elevated viaduct sections have scupper drains that are basically holes through the deck of the cantilever roadway. In places the roadway drainage all collect and is dissipated through these holes and water is released to fall up to 28 feet onto 2H:1V median slopes. The drains occur at regular intervals on the deck, creating the need for some type of energy dissipators at regular intervals. This results in very strange looking replicated green patches up and down the alignment. The green patch is the result of extra water being concentrated at these locations and producing more succulent vegetation. Originally, we constructed "rock donuts" to help absorb the impact of water falling onto the slopes below, these worked to a degree. As the slopes become steeper, the volume of water larger, and the walls higher, something different needed to be tried. Simple grading to control the run-off appeared as a very artificial earth "wave" along the retaining wall. Several hundred feet of that was overwhelming. By working with several suppliers some products were finally arrived at that worked. The larger open-celled geo-textile matrix seems to work the best. (Geo-grid and Armitier) These products allowed us to hold the soil in place while allowing the flexibility longitudinally to grade a more natural landform in the median.

Rock cuts are controversial in several respects. A lot of engineers, geologists, blasters, construction company owners, superintendents, and workers feel that the ultimate rock cut is a pre-split cut. If they truly believe that I usually don't waste my breath about the virtues of rough and natural appearing faces. But for the purposes of this paper, I will state my personal beliefs about this topic. I think of it as sculpture on a huge scale. And like art of other types there are believers and those that can interpret the true meaning and desires of the artist. However, with man-made rock cuts unless there are geo-technical reasons for a pre-split cut, I cannot endorse the use of it as a visually pleasing element in the natural landscape. A pre-split cut is one where the drill holes determine the break line along a straight two-dimensional plane in the rock. Leaving the half-round tracers of the drill holes in the rock face. There are many technical aspects of blasting and rock stability that we cannot address here that may determine the final outcome and configuration of any given rock cut, but generally there are few instances where rock would have to be pre-split. Something that we have done when the cut rock is a much lighter color than the naturally occurring face, is to stain or pigment the cut rock. This has been one of the most controversial items that have done. With color being second only to form as part of the visual experience and 87% of what we perceive being visually communicated, I feel it is important to

mask our man-made scars as well as we can. In the case of light colored rock faces, the technology exist to "age" the rock. The real key to success with the colorants is with the applicator. If the material is put on poorly or inconsistently with natural patterns, mottling and striations, you could end up with a bigger problem than if not attempt to "fix" it were made.

I believe the same principles apply with our revegetation efforts as were stated concerning rock cuts. The forms, colors, textures and scale must all be similar. Plantings out of scale, color, and context are as out of place as the light colored or pre-split rock face. Careful consideration needs to be given to the use of all plant materials. Although a certain grass may provide excellent erosion control, establish well and be adapted to the site; it may not always be correct visually. It may be too green, too lush, and turn the wrong color in the fall. Thereby accenting rather than down playing or blending in.

The "Lipstick on a Pig" phenomenon occurs in various professions and manifests itself in many ways. I am sure each of your could cite examples of being frustrated by "the system". You know you could do a better job if only . . . These are the challenges that we as stewards of the land are charges with. We sometimes have to produce inspite of the handicaps we are presented with. Hopefully, the techniques shown in this article will help to make roadways more presentable and function better as well.

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MISSION IMPOSSIBLE: THE COLORADO MOUNTAIN SCAR COMMISSION

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BACKGROUND AND COMMISSION CREATION

It has been many years since the environmental movement became a major force in our society. Many problems have been tackled, some solved, others are under attack, and everyday we discover more problems. At times it seems the more progress we make the further behind we fall.

In recent years a "new" problem has appeared. Although of less consequence than global warming or the demise of the ozone layer, visual impact is a growing concern throughout the United States. Visual impact problems are not actually environmental problems. Nature does not care whether something looks good or not. Adverse visual impact is a social problem with roots in environmental problems.

Most people like to look at pretty scenery and anything that degrades the scenery removes some of their pleasure. A few states have passed visual impact laws, but regulations that address visual impact mitigation are still rare and subject to considerable controversy. Rules governing adverse visual impacts are usually found at the local government level as part of land use regulations. Some state legislatures are listening to public demands for the passage of laws to control the adverse visual impacts of mines, highways, housing developments, high rise buildings, and even seemingly innocent electric and communication lines.

In Colorado Springs, controversy over mining is not a new issue. It began in the middle 1960's. In 1989 it reached a peak never before seen. The concern had been building for some time. The Chernobyl nuclear power plant incident elevated world environmental consciousness. In Colorado Springs, local concern increased in 1988 when Rocky Mountain Materials proposed reopening the inactive Waldo Canyon Quarry near Manitou Springs. Then the Exxon Valdez had an unfortunate encounter with some rocks in Alaska and the whole nation came unglued. Meanwhile, in Colorado Springs, a 9 acre amendment to one of Castle Concrete Company's limestone quarries, the least visible of the three they operate, threw gasoline on an already roaring inferno.

Colorado Governor Roy Romer received hundreds of irate letters from citizens in Colorado Springs. Some of the letters even mentioned the Exxon Valdez incident. Often the citizens confused the various local issues, but the message was clear. They wanted something done about the quarry scars.

In part, the surge of concern was related to the depressed economy. People blamed the quarries for reduced tourism, the lack of interest of several companies to locate in Colorado Springs, and a few other difficulties. There was no hard evidence to support any of the contentions, but when it comes to public opinion perception often determines "reality" more than fact.

In the early to middle 1980's few expressed much concern over the scars. The city was booming. But when the bottom fell out of the economy about 1986 the citizens looked for something to blame or on which to vent their anger. Whether the quarry scars are the cause of the economic problems in Colorado Springs does not actually matter that much. The quarries are there and the people became concerned.

In September 1989 Governor Romer responded to the citizen outcry. He created the Colorado Commission on Mountain Scars. At the introductory meeting in Colorado Springs it was apparent the Governor was serious about finding solutions. But, there was also clear evidence of a political incentive in establishing the commission. Governor Romer is a Democrat and El Paso County is about as Republican a community as you will find anywhere in the country. The political implications are obvious.

The commission was composed of two subcommittees with 15 people each. One was the legislative subcommittee and the other the existing scars subcommittee. Governor Romer should be highly commended for finding 30 people of tremendously divergent interests willing to attack a problem with such vast ramifications as mountain scarring in Colorado.

The legislative subcommittee was charged with drafting a bill for introduction to the Colorado Legislature. The subcommittee was instructed to devise a means by which future quarry applications to the Colorado Mined Land Reclamation Board would contain designs to mitigate the visual impacts of the mining. If necessary, they were to develop standards for determining where quarries could not be established because of the severity of the impacts. But, the subcommittee was not charged with examining any cause of mountain scarring other than from quarry operations. Highways, housing, ski areas, and lumber operations, to name but a few, were not within the subcommittee's charge - only rock quarries.

The legislative subcommittee met almost weekly. Dr. Davis Holder, former member of the Mined Land Reclamation Board, chaired this subcommittee. The legislative subcommittee eventually hammered out a bill that was carried in the Colorado House of Representatives by Representative Renny Fagan of Colorado Springs. While this bill was being written, Senator Mary Ann Tebedo of Colorado Springs drafted another bill, partly in conjunction with the Colorado Division of Mined Land Reclamation. The Tebedo bill was designed to accomplish the same goal using a different and less complex approach.



The existing scars subcommittee, on which I served, was composed of representatives from industry, law, reclamation science, landscape architecture, and local government. Our subcommittee was charged with investigating methods to reclaim existing scars. We were to recommend solutions and, if necessary, incentives to quarry operators to stop quarrying, move elsewhere, and reclaim the existing scars. Funding mechanisms to raise money for implementing more creative reclamation or even purchasing the mines were also to be discussed by our subcommittee.

Our subcommittee met about twice a month and was chaired by Bill Cameron, then Director of Operations for Southern Colorado with U.S. West Communications. Everyone received a crash course in reclamation science from commission member Dr. Edward Redente of Colorado State University. There was also a quick course in landscape visual analysis from commission member Lois Brink, Associate Professor of Landscape Architecture from Colorado University. With that background the subcommittee attacked the problem of mitigating the visual impacts of the Queen's Canyon and the Pikeview quarries near Colorado Springs. Although the subcommittee could have examined other quarry scars, time expired before any others could be examined in detail. It was also decided that without some kind of funding to do something about the existing scars there was little point in continuing the analysis.

#### RESULTS OF THE COMMISSION

The bill drafted by the legislative subcommittee gave broad power to local government in regulating visual impacts. The process of interfacing between the local and state government probably would have been effective, though complex to implement. The mining industry felt the bill provided too much power to local government and believed it would fracture the already established state program. The industry felt the bill could create chaos. They contended, as the industry always has, that reclamation is a matter of state interest and local government involvement in reclamation should be minimal to none.

House Bill 1190, the scar commission's bill, was considered by a House committee on January 31, 1990. After less than two hours of discussion the committee postponed indefinitely the bill. In effect, they killed it.

A primary cause for this action was Senate Bill 162, passed into law two years earlier. SB162 had disconnected local government and state consideration of mine permit applications. The House Committee viewed HB1190 as an attempt undo SB162. Also, there was some implied sentiment that the mountain scar problem was mainly an El Paso County problem and that state laws to address isolated local problems is usually a bad idea.

Meanwhile, Senate Bill 133, carried by Senator Tebedo, proceeded to committee hearings. On February 8, 1990, after a similar amount of

discussion, this bill was also postponed indefinitely. SB133 did receive the conceptual support of the industry, but it was the details and its addressing a highly controversial subject, that killed it. The Tebedo bill called for more limited local government involvement in the process.

The death of these two bills, both of which had considerable conceptual merit, is undoubtedly related to 1990 being an election year in Colorado. Controversial bills often die a quick death in election years. Although it took less than two hours to shatter three months of work by 15 dedicated citizens, all was not lost. A seed was planted. That is how highly controversial subjects are often brought into law. Both bills contained some potentially serious flaws and, in my opinion, it is perhaps best that neither survived. Out of their death may eventually come a far more capable law that addresses not only mines but all the other causes of undesirable visual impacts.

The existing scars subcommittee, on the other hand, developed methods and recommendations for analyzing and mitigating visual impacts that could not be so easily ignored. When the legislature says "no" they mean "NO!" But methods of analysis and implementation techniques can be adapted to fit specific situations that result in tangible visual improvement. Many of the actual techniques recommended for reclaiming existing scars are standard methods used when land is reclaimed. No new reclamation techniques were developed by the subcommittee.

Without a doubt the single most significant contribution of the scar commission, besides planting the seed for legal control of visual impacts, was the development of a technique for analyzing the benefit to cost ratio of different reclamation plans with respect to visual impact mitigation. The method is also useful when comparing benefit to cost ratios of visual impact reclamation plans on different sites. Although the method is far from objective, it derives much of its power by using form, color, line, and texture in examining the effectiveness of a particular reclamation plan option with respect to time.

#### THE SCAR COMMISSION ANALYSIS METHOD

The method developed by the existing scars subcommittee involves several steps. First, the site is analyzed from several different view points. Second, the site is divided into various units, defined by the topography and the relationship between the unit and the surrounding lands. Third, the various reclamation approaches are defined and outlined in general terms. Fourth, the estimated cost of implementing each plan is determined. And last, the various plans are placed on the benefit/cost matrix with respect to a time scale. This last step is the most subjective because it involves predicting the effect of a treatment plan. Its validity depends upon the accuracy of predicting how the plan will develop with time, and assumes the treatment will proceed and develop as predicted. It is known that predicting the effects of

reclamation plans beyond a couple of years is only slightly more reliable than a guess. Yet, if the plans are not too elaborate or unreasonable in expectation, all plans are subject to about the same degree of error. Therefore the method is valid for general comparative purposes, although vulnerable as a predictive tool.

Most sites can be divided into visual units. These units are defined by the form, color, line, and texture of the area itself and its relationship to the form, color, line and texture of surrounding lands. Sometimes, an area will change in the balance of these four primary visual characters when viewed from different locations. To avoid spending the rest of your life preparing matrix diagrams for every possible viewpoint only the most critical viewpoints are included in the analysis. Often, if the view from the most adversely affected location is improved the less adversely affected locations are also improved. This is not always true because treatments of one portion of the site can interact adversely with treatments on adjacent or nearby areas. Cross-checking the effects of the treatments on each area is an excellent idea. Computer modeling, although not done by the commission, could be useful in conducting this analysis, provided the budget will allow the expense.

Defining the possible reclamation approaches can be restrictive if economic constraints are initially used to limit the possible actions. To avoid this restriction, ignore cost when defining the available options. These costs are addressed in a later step. For example, physical reconfiguration of a mountainside can cost \$100,000 per acre. If it is technically feasible to reconfigure then reconfiguration should be included in the possible corrective actions, even if it is known the cost is too high.

Once the various options are defined and rough plans drafted for each option on each zone of the site, the costs of implementing each option is determined. This can be a very scary process, especially when "after the fact" reclamation is planned. The costs of each plan are then reduced to an average cost per acre for that zone on the site. For example, if the zone contains ten acres and two acres are to be reforested, the cost of reforestation should be amortized over the 10 acre zone. Without this averaging, calculating the total cost per acre of treating the entire site becomes a mathematical nightmare.

At this point the matrix can be developed. Figure 1 shows the basic benefit/cost matrix diagram utilized in the scar commission's work. The vertical axis is cost. The scale of this axis should be linear.

The horizontal axis represents visual compatibility. Because there is no known way to quantify visual compatibility, this scale is qualitative. The left end (origin) of the axis is the worst imaginable condition. The right end of the axis is considered the "Ideal." An "X" is placed below the visual compatibility axis and indicates the

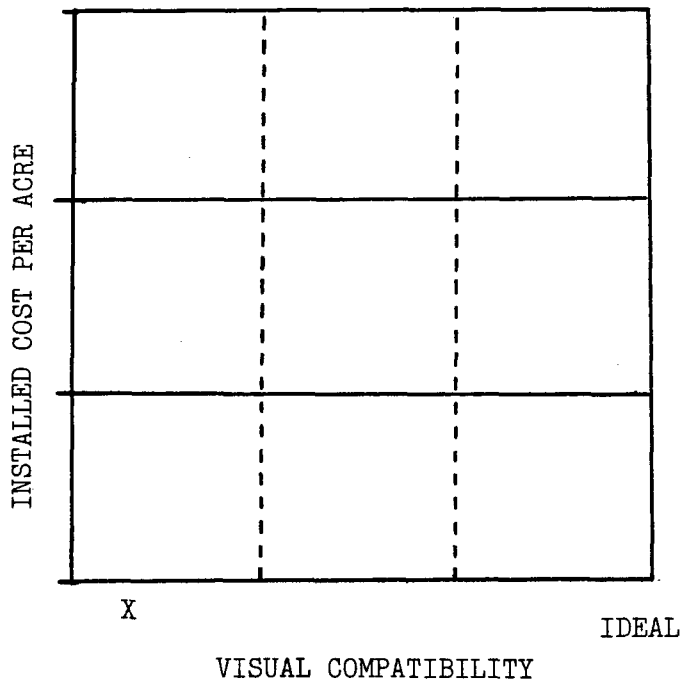


FIGURE 1

## THE BASIC BENEFIT/COST MATRIX

The number of vertical and horizontal divisions can be varied to suit needs.

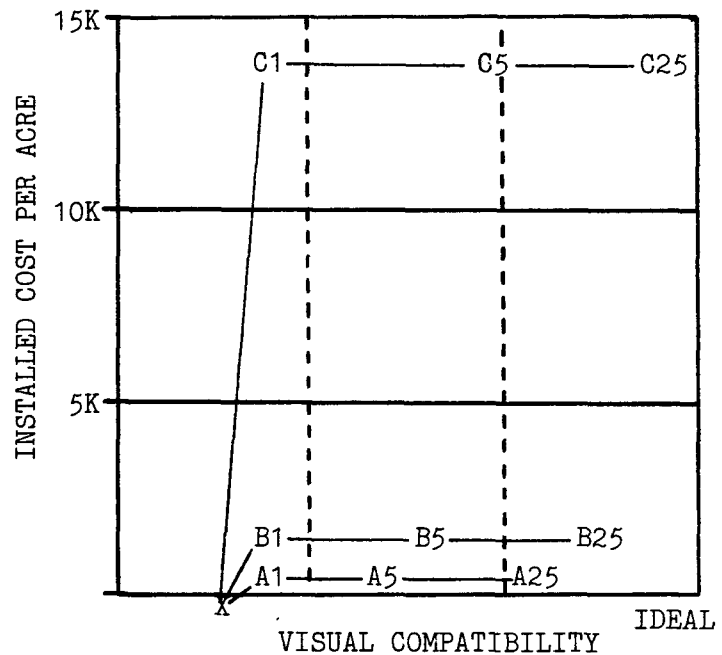
The X is the location of the existing condition with respect to its visual compatibility.

FIGURE 2

BENEFIT/COST MATRIX  
WITH RECLAMATION PLAN  
SOLUTIONS LOCATED.

Refer to Table 1 for  
description of the  
reclamation plan solutions

Plan B is the preferred  
because it produces  
the best results for  
the least cost.



existing visual compatibility of the area. This is already defined by the analysis of the form, color, line, and texture of the zone.

Actually, the visual compatibility axis extends to eternity. Because it is difficult to describe the visual effects of a plan on the landscape 4.5 million years from now it is necessary to end the axis at some reasonable point in time. We used 25 years as the cutoff point for determining the effect of each treatment. We also defined "ideal" as essentially "Achievement of visual compatibility with the surrounding landscape." So, when the site blends with the surrounding lands the ideal has been achieved. The 25 year limit for consideration was used because most people have difficulty visualizing or even caring much about effects 100 or more years in the future. Thus the 25 year limit is based more on psychology than on any natural importance of 25 years in the reclamation process. By coincidence, 25 years is roughly the generation span of Homo sapiens.

Table 1 shows the various solutions for the example area which is the South Knob of the Queen's Canyon Quarry. Figure 2 shows the placement of these various solutions on the matrix diagram. Each solution is represented by a capital letter that refers to the descriptions in Table 1. The number beside each letter is the number of years to achieve that degree of visual compatibility.

During the placement of these points the scar commission found a wide range in opinion about where the points should be placed. Where a particular person placed a point on the matrix was most controlled by their personal opinion about what should ultimately be accomplished by the reclamation. The value of the committee approach came into play at this point. To reconcile the widely divergent attitudes and opinions of commission members, each point was established by agreeable compromises.

It is unlikely there is any way to objectively locate each point on the matrix. Each plan is full of unknowns. Each person also develops a different image of what will be visible after a given period of time. Locating each point objectively would require finding a path either around or through the chaotic maze of interactive processes that characterize reclamation systems. For now, attaining an agreeable average of divergent opinions seems to be the only way to place these points on the matrix. The whole process is based on the rash assumption that the extremes of the past which often alter the course of development will not occur during the time period under consideration. This is clearly presumptive, but there is no easily available way around the indefinite nature of "future thinking."

The final step also is shown in Figure 2. Here the various points of each plan are connected to the existing condition, the "X" on the visual compatibility scale. The shape of the lines help decide which approach will have the greatest effect in reaching the "ideal" condition for the least cost. In the early years, very expensive approaches may or may not have dramatic effects. But, in later years less expensive

TABLE 1

Exhibit 2 Page 3 of the final report of the Existing Scars Subcommittee of the Colorado Commission on Mountain Scars.

See Figure 2 of this paper for the Benefit/Cost Matrix.

## SCAR INVENTORY

QUARRY: QUEEN'S CANYON                      AREA: SOUTH KNOB 5.5 ACRES

EXISTING CONDITION: PILES OF SPOIL, MOTTLED COLOR, MOSTLY WHITE, SOME HARSH EDGES

IDEAL CONDITION: APPROXIMATE CONDITION OF AREA IMMEDIATELY SOUTHEAST. MOTTLED TEXTURE, DARK GREEN TREES WITH HERBACEOUS UNDERSTORY, SHAPED SLOPE CONSISTENT WITH ADJACENT AREA. MINIMAL VISIBLE EDGE.

## SOLUTIONS:

A. SHAPE, SOME BENCHES, APPLY TOPSOIL, SEED, PLANT SHRUBS, TREES ON NORTH FACES, ELIMINATE WALLS. (COST TO PUBLIC: FREE AS IT IS COMPANY PLAN.)

\*\*\* B. ADD MORE TREES TO BASE PLAN. \$1250/ACRE FOR TREES ONLY. 500 TREES PER ACRE PLANTING. SMALL CATCH BASINS, \$200/ACRE. TOTAL COST IN ADDITION TO COMPANY COST = \$1200/ACRE.

C. ADD DRIP IRRIGATION TO SOLUTION B. \$12,000/ACRE FOR THREE YEARS. TOTAL COST IN ADDITION TO COMPANY COST = \$13,200/ACRE.

\*\*\* RECOMMENDED PLAN

approaches can catch up with expensive approaches, resulting in essentially the same perceived effect. Which plan is selected depends upon how long one wishes to wait. If the time scale is extended, for example, to 1000 years doing nothing at all is the preferred approach. Its benefit to cost ratio is infinite because it's free. On the other hand, if the time scale is limited to three years then the most expensive approach may be the only one that will accomplish the goal. The approach selected largely depends upon two factors. First, how patient you are, and second, how rich you are.

#### MAIN CONCLUSIONS OF THE EXISTING SCAR SUBCOMMITTEE

Based upon the 25 year time frame and an expected limitation in funds to implement corrective actions, several interesting conclusions were developed.

First, the scar commission did not select any revegetation approaches that included drip irrigation for reforestation. This conclusion, after extensive discussion, was based on several factors. The cost of drip irrigation, largely because of a need to haul water up a mountainside to storage tanks, was placed at about \$12,000 per acre for a total of three years of treatment. It was agreed by everyone that drip irrigation would have very significant effects in the first decade. But, after 25 years less costly approaches were judged to achieve essentially the same effect. Less expensive methods include mulching, physical protection, replacement of dead trees, water accumulation using microtopography, and the use of polyacrylamides during planting. In essence, drip irrigation was not considered worth the expenditure when a 25 year time span was used.

Always, the use of soil instead of spoil as a growth medium was deemed worth the expenditure. Spoil takes a long time to establish nutrient cycling. In contrast, soil develops vegetation much more rapidly. If a 100 year span was used then using soil as the growth medium might have been questionable.

On these two quarries, using topographic reconfiguration was determined to have very significant and rapid improvements on visual compatibility. However, the cost of topographic reconfiguration was placed at \$10,000 to \$110,000 per acre, depending on exactly what is done. Therefore, extensive reconfiguration was considered to be economically unrealistic.

Instead of topographic reconfiguration, producing visual illusions was selected. With minor, localized, and inexpensive topographic reconfiguration and the alteration of color pattern, much the same effect could be created as that produced by millions of dollars worth of reconfiguration. In one instance of intense brainstorming, Bill Cameron, chairman of the subcommittee, suggested placing piles of old tires or painted 55 gallon barrels on the ground to create an illusion

of trees. At first it seemed comical, but further consideration showed it would produce the desired effect when viewed from several miles away. None of the commission recommendations included the placement of piles of tires or barrels on the quarry. But, this example shows how valid seemingly silly ideas can be when visual impact mitigation is the guiding factor in designing a plan.

Because of the light color of these two sites in a generally dark surrounding land, darkening the color of the site was considered vital. Using emulsified asphalt to darken the surface was considered but was not selected. It is a temporary treatment. Darkening would be more permanent by using soil and producing more rapid vegetation growth.

The surrounding landscape is dominated by trees and shrubs. It has a rough texture. Creating a similar texture on the quarry is also a key to creating visual compatibility. The problem with growing trees and shrubs on the Queen's Canyon Quarry is the presence of Rocky Mountain Bighorn Sheep. They keep shrubs and trees to a small stature by browsing. Finding methods to protect the young plants could reduce the impact and allow the texture to be created. The company is planning to use piles of discarded Christmas trees to produce local barriers to protect the trees and shrubs from browsing and add some texture to the scene.

Staining exposed rock walls was also considered but was not selected in any of the options because of the cost. Current staining techniques can cost \$20,000 per acre. Some types of land reconfiguration are less expensive than staining and is more permanent. Reconfiguration is therefore preferable to staining, provided the cost is acceptable.

Public education was not included in any of the recommendations, but it was considered an important ingredient in the success formula. Often, the public does not understand the time frames required in reclaiming drastically disturbed land in arid and semi-arid climates. The public is accustomed to going from bare ground to a bluegrass lawn in a few hours. Most people realize it takes longer to revegetate land when sod and sprinkler systems are not used. But, most people do not understand just how much longer. Educating the public to be more patient is important.

The existing scars subcommittee was charged with examining solutions for already existing mines. Through our discussions it became clear the best way to repair mountain scars is to start reclaiming before the ground is broken. By integrating reclamation into the mining plans many problems of existing scars can be avoided.

The first question is whether there is a better place to put the disturbance. Steep mountainsides are usually not suitable for development unless the entire mountain is removed. After selecting the site the visual impact at various stages is assessed. Mitigation



measures are then applied as the disturbance develops. Through preplanning high repair cost can be reduced. A much more acceptable product is produced than occurs without preplanning. Yet, no matter what is done, even if the site is not disturbed, somebody is probably going to be offended. The object of the process is to satisfy most of the people.

#### FUTURE DIRECTIONS OF VISUAL IMPACT CONCERN

Visual pollution is a valid concern. It cannot be eliminated as easily as indigestion is cured with a glass of bicarbonate. Visual impacts are a growing concern everywhere, especially where tourism is a major industry and mountains are involved in the scenery. It involves our quality of life and is therefore a sensitive issue.

In Colorado current attention is on mountainside mines, mainly rock quarries. Most landscape photographers will attest that, being successful at producing beautiful images is dependent upon an intense sensitivity to the art of landscape. Noticing the fine nuances of form, color, line, and texture, and the play of light on these features is vital. The landscape photographer must be aware of deviations in the landscape, far more so than the average person. Tiny deviations can mean the difference between a great image and a worthless image. Even though the landscape photographer's sensitivity is not representative of people in general, the landscape photographer can tell us much about the most significant impacts. Major power lines, mountainside roads and housing developments, and antennas located on mountaintops present the most serious problems. Designing the world around the hypercritical needs of landscape photographers would be improper. But, it is interesting that mines are either absent from or far down the photographer's list of visual problems that cause heartaches.

Mines do cause severe local problems with the enjoyment of landscapes, but housing developments can be just as bad. A mine in an otherwise pristine landscape may look terrible. Surround it with urban sprawl and the mine looks much better. A new, high intensity light installed beside a farmhouse on the prairie can have very significant visual effects, while that same light installed in Los Angeles wouldn't even be noticed. Therefore, our perceptions of a feature's relationship to its surroundings determines the degree of adversity. However, adverse visual impact is also independent of cause. Whether it is a mine, a highway, a housing development, or a power line, the impact can be perceived as adverse.

Because visual impact is largely independent of cause it is unjust to write a law that only addresses one industry or even one part of one industry, such as rock quarries. To be successful and equitable a visual impact law should address the visual problems associated with everything that could potentially cause problems. This is probably idealistic. It is more likely the law or laws will be piecemeal and

fractured. As an example of fractured legislation, Colorado has a law to require the reclamation of mined land but lacks a law to require the reclamation of housing developments that go bankrupt soon after the roads are built.

Unfortunately government often attacks only small portions of a larger problem. It can create a morass of laws and regulations of which many could be consolidated into one set of rules everybody must observe. On the other hand, perhaps a fractured approach is better than doing nothing at all.

In Colorado, HB1190 and SB133 both planted important seeds. Neither germinated, largely for the same reasons. In the legislative process new ideas often take some time before acceptance. Some are never accepted. Perhaps approaching visual impact mitigation as a social problem rather than an environmental problem would help draft an acceptable law.

The recommendations of the existing scar subcommittee were only directed at two sites. There are hundreds of others that deserve just as much attention. Perhaps in time they too will come under such intense and critical scrutiny.

Castle Concrete Company, the owner of the two quarries considered by the commission, is currently considering the various recommendations. Some of them may be rejected while others will be incorporated into the existing plan. The company continues to hold firm to the position that the primary end use of the reclamation on the Queen's Canyon Quarry is the production of Rocky Mountain Bighorn Sheep habitat. The law gives them the right to select this use, and the company believes it is a valid use for the land. Castle Concrete has no intention of reclaiming for ONLY visual purposes. They believe the primary function of reclamation is the establishment of environmental stability; not making the site look pretty. On the other hand, options are available that can mitigate some visual impact without affecting the quality of the sheep habitat. It is this compromise plan the company is seeking.

Was the scar commission a Mission: Impossible? In some ways, the answer is, "Yes, the mission failed." No law was passed. No land was reclaimed. But, this program may have simply paused for a commercial break. Proper television script writing dictates that the second half of a show should be the best. Viewers leave if the climax occurs in the first ten minutes. But unlike most Mission: Impossible episodes, this one is unique. The script is being written as the show progresses.

Colorado has a history of coming up with some unique ideas, and some really dumb ones (e.g. Colorado is the only state that does not allow branch banking). Where the visual impact problem will lead nobody can tell, but one thing is sure. The show isn't over yet. It may turn out to be a long lived series as scandalous as Falcon Crest. On the other hand, it could be more like Leave it to Beaver.

THE SNOWY RANGE ROAD: A HIGH ALTITUDE, HIGH VISABILITY,  
RECONSTRUCTION PROJECT

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The Snowy Range Road in Southeastern Wyoming is the major route to the high elevation recreational use area of the Medicine Bow Mountains. The high altitude portion of this road (above 9,600 feet elevation) was scheduled for reconstruction in the mid-1970s by the U. S. Forest Service (USFS) and the Federal Highway Administration (FHA). However, planning for the project, which reached its maximum public involvement in 1978, met with considerable public concern. A committee of Federal and State agency representatives (The Landscape, Erosion Control Advisory Team (LECAT)) was formed to address public and agency concerns associated with fishery habitat loss, soil erosion, highway alignment and realignment, top soil salvaging, revegetation, and revegetation research. The final design addressed those problems identified by the LECAT. Further, it directed construction to blend road alignment with the landscape, to fit parking areas form with function, to incorporate specific recreational functions, to separate pedestrian and vehicular circulation patterns, and to link design details such as slope rounding, rock sculpturing, traffic/pedestrian barrier design and viewer orientation to recreation and possible interpretive sites. The final phase of the reconstruction was not completed until 1988. The triad of careful planning, design and reconstruction, as well as the integration site specific revegetation technology resulted in successful reconstruction of this highway. It was designated as the USFS's 2nd Scenic Byway in 1988 and received the FHA's first place 1988 Design Award.

## INTRODUCTION

The Snowy Range road traverses the highest elevation mountain range in southeastern Wyoming. The area has considerable aesthetic appeal as well as a long cultural tradition. Original Survey plats of 1877 and 1879 show the "Range Road" near Centennial, crossing Libby Creek and continuing on the north side of the creek. A road labeled "Centennial to La Plata" (Libby Flats was formerly La Plata) is shown on a survey plat registered in Cheyenne, Wyoming, dated November 11, 1899.

The staff of the Medicine Bow National Forest recognized the recreational access potential of the road in the early 1900's. Automobiles were then primarily used as recreation vehicles. In 1909, Medicine Bow Forest Supervisor, P.S. Lovejoy, in cooperation with the Albany County commissioners and the Centennial Commercial Club obtained \$2,500 to improve the existing road. During the course of this project, the Laramie, Hahns Peak, and Pacific Railroad made the first official survey of Snowy Range Highway. The first recorded auto trip took place between Centennial and Brooklyn Lake in 1910. With the change of the auto's primary use to transportation, the road's use changed too. In the 1930's the road was rebuilt as a Forest Highway and extended from Laramie to Saratoga.

Further modifications were made for transportation purposes in the early 1960's. Both ends of the highway were reconstructed in conformance with existing transportation and revegetation technology of the day. Resulting road cuts were steep. Therefore slopes in these areas remain largely unvegetated and serve, even today as a reminder that without proper care during reconstruction, slopes can remain barren for decades. The thirteen mile section of the road, the highest elevation portion of the road, was left for modification in the future.

In 1985, the first of three sections of the high elevation portion of the Snowy Range Highway reconstruction was initiated. Planning and design for the project had been going on since 1978. The final section of the road was finally completed in 1988, a full 10 years after initiation of planning.

Two primary issues were identified during the public scoping process in planning for the reconstruction of Snowy Range Highway in early 80's--revegetation and recreational

use. The absence of vegetation on many of the slopes from the 1960's reconstruction made revegetation one of the primary considerations. The other pertained to the public's desire to use the road for recreation and that the road not be closed during reconstruction. Highway planners and designers used planning, design, and reconstruction phases of the project to respond to these two issues.

As a road passing through scenic areas and near many recreation areas providing winter and summer recreational opportunities, the road was a prime candidate for use as a recreation and transportation route. Because of many of the recreational considerations included during planning, design, and reconstruction, the Snowy Range Highway was made the Forest Service's 2nd Scenic Byway in 1988. Those same features prompted the Federal Highway Administration (FHWA) to recognize the highway by giving the project a first place 1988 Excellence in Design award. The triad of careful planning, design and reconstruction, as well as the integration of "state of the art" revegetation technology makes Snowy Range a good example of a successful high altitude, high visibility, reconstruction project.

This paper is a mixture of applied science, aesthetic considerations, design and reconstruction details and site characterization. The authors view this paper as containing some general information for planners of revegetation projects. There is some information here which is specific for high altitude environments, but much of what follows pertains to any construction or reconstruction project in a biologically sensitive area. A biologically sensitive area may be one where indeed rare and/or endangered species persist, or unusual land forms exist. However, a biologically sensitive area may also be so designated because the general public perceives it as such. In a larger sense, any terrestrial environment is a biologically sensitive area for any amount of construction, or reconstruction results in disturbance which ultimately is measurable as a net loss in biological activity. In this sense, any level of disturbance, and particularly events such as road construction, or surface mining, exacerbates the process of desertification, which is, in part, defined as loss of biological activity (Sheridan, 1981).

When vehicles access an alpine environment that has many highly scenic attributes, extensive human use of this landscape is almost always assured because of the recreation potential that this environment offers. Successfully managing alpine areas to minimize human impacts is largely dependent on the way people are distributed. Highways provide the initial recreation transportation network. Their

parking areas serve as nodal points for distribution of humans. Further, the openness of alpine areas make them particularly susceptible to use by vehicles. Off road vehicle controls are very important to minimizing effects of vehicle damage to alpine areas. Access and its management are key to the reduction of impacts. Concepts contained within this paper reinforce ideas of people and vehicle management to control access to the alpine environment.

The objectives of this paper are (1) define the setting and location of the Snowy Range and the road right-of-way, (2) detail the aspects of planning of this project, (3) outline several of the design characteristics of the road which were instrumental in the appeal of the road to the public, (4) specify criteria necessary for contractors compliance during the reconstruction phase (these criteria are herein oriented towards the environmental impact of the road and not the engineering specifications, although these two sets of criteria are not always mutually exclusive), (5) describe the revegetation of the disturbed road sides with emphasis on those techniques and problems peculiar to high altitude environments and (6) show how planning, design, reconstruction and revegetation when superimposed on a given landscape can result in an architecture of a transportation route which has public appeal, minimizes impact to and to a degree, harmonizes with the high altitude environment.

#### LOCATION AND SETTING

The mere location of the old highway in an area rich in scenic diversity, majestic granite rock cliffs, alpine meadows, and exquisite high altitude lakes gave the project all the ingredients necessary for a recreational roadway. It gave planners an opportunity to make the road what it has now become - a western parkway. The reconstructed part of Snowy Range Highway runs from a point just below the Green Rock Picnic Area west to Headquarters Park snowmobile parking area. The road provides numerous access points to U.S. Forest Service recreation sites for both summer and winter activities. With such an abundance of these types of resources and the road's proximity to them, this project had an excellent chance of success.

Easy access from the old road's access allowed alpine areas to be adversely impacted by human use. The twenty foot road and shoulder was too narrow for safe mountain driving and allowed unrestricted access to adjacent alpine areas. This made control of the human use difficult. Off road vehicle use marred many open alpine meadow areas.

Recreational users made their own parking therefore impacting adjacent meadows.

The eastern flank of the Snowy Range is located about 30 miles west of Laramie, Wyoming. Highway 130, the Snowy Range Road, runs from Laramie to Saratoga, Wyoming -- a distance of about 80 miles. The road at Laramie is at an elevation of about 7,200 feet. As the road progresses west across the high plains of the Laramie Basin, it rises in elevation until it reaches about 8,000 feet at Centennial, Wyoming. Approximately 1 mile west of Centennial, the road passes into Medicine Bow National Forest and rises over the course of nine miles to Snowy Range Pass at an elevation of approximately 10,850 feet. The road continues on another 18 miles to the town site of Ryan Park, several miles beyond that to the forest boundary and hence on to Saratoga at an elevation of 6,900 feet. The portion of the road slated for reconstruction, and therefore the focus of this paper, was about 13 miles in length and runs from Green Rock Picnic Area at 9750 feet elevation on the east flank of the Snowy Range and ends on upper French Creek at an elevation of 9,800 feet. An 11 mile segment, or 85%, of the road is above 10,000 feet in elevation. The portion of the reconstruction project below 10,000 feet in elevation traverses primarily subalpine forest (Abies lasiocarpa, and Picea englemannii) The portion above 10,000 feet is largely in an alpine environment including alpine meadows, alpine turf, krummholz most of A. lasiocarpa and P. englemannii, and barren rock.

The geology of the Snowy Range is primarily metamorphic, with quartzite comprising the core of the range. The Snowy Range Road project east of the Snowy Range Pass is on mostly glacial moraine of various lithologies. However it passes over or near small areas of exposed gneiss, gabbro, quartzite, slate, greenstone, and slate and marble schists. West of the Snowy Range Pass, the lithology is more complex. Again there are areas of glacial moraines including many forming permanent alpine lakes. Exposed outcrops of gneiss, gabbro, quartzite, slate, greenstone, and slate and marble schist are more common as well as alluvium, talus slopes and one small rock avalanche zone (USDOT, 1979).

The soils adjacent to the Snowy Range Road right-of-way from approximately Lake Marie on the West to the head waters of Libby Creek at the east are shown in Figure 1. These soils are representative of the 11 miles of the project above 10,000 feet, although Figure 1 shows only about 4 miles of the project. The soils were mapped by Art Bauer (formally at the Medicine Bow Forest) and identified using the U.S. Soil Conservation Service taxonomy system (Soil Survey Staff,

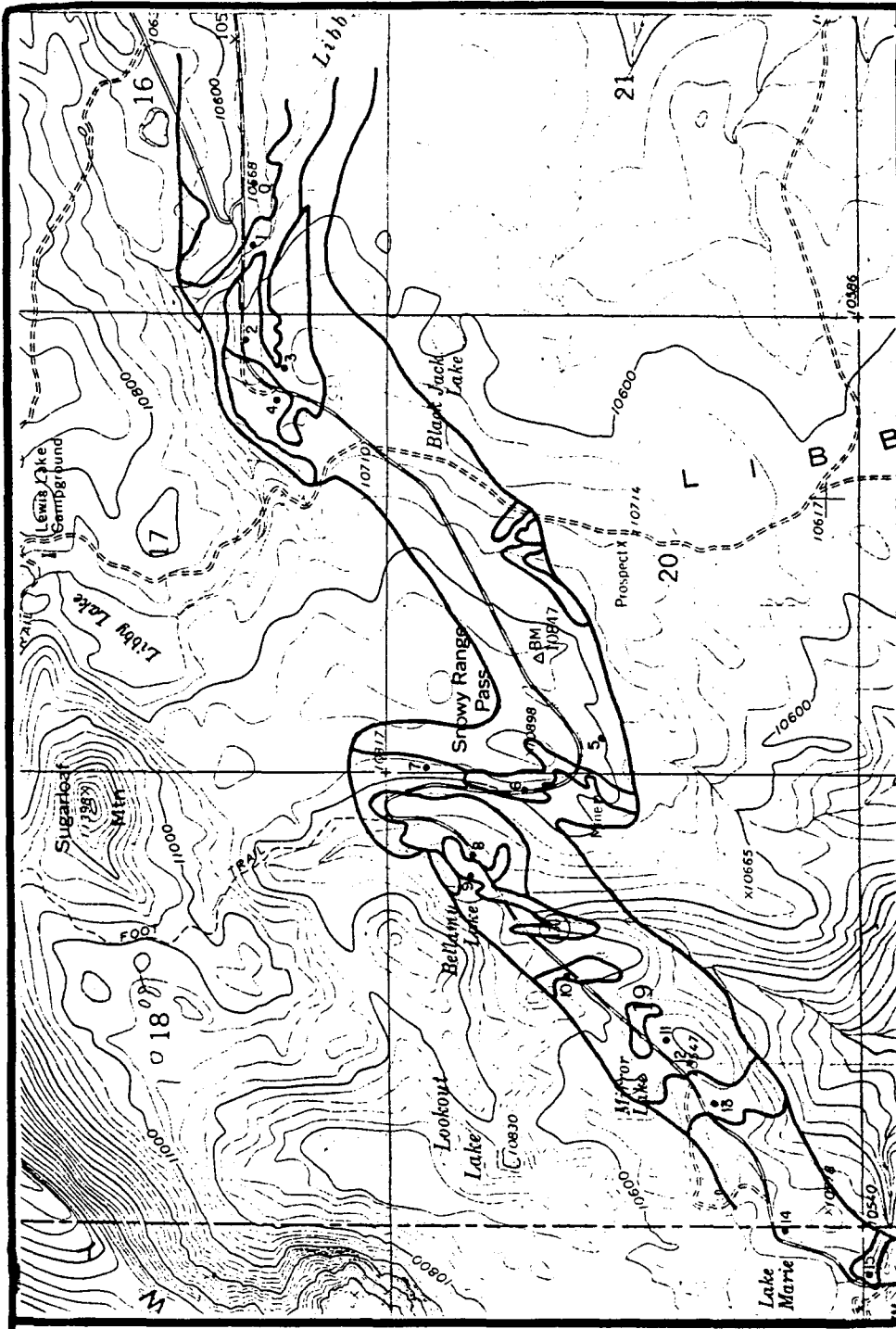


FIGURE 1. Topographic map of a portion of the study area showing soils and sampling/vegetative locations (numbered points). Sample sites 0, 4, 5, 8 and 13 are on Typic Cryumbrepts (7-12% slopes); 2, 3, 7, 11, 12 and 14 are on Lithic Cryumbrepts (12-25% slopes); 6 and 15 are on Cumulic Cryaquolls; and 1, 9 and 10 are on Cumulic Cryaquolls.



Table 1. Plant survey of soil sampling sites adjacent to the Snowy Range Road (see Figure 1 for site locations). General abundance is indicated by the following codes: R (Rare) - 1 or 2 plants in a 100 m<sup>2</sup> area, O (Occasional) - 1 plant in a 10 m<sup>2</sup> area, F (Frequent) - 1 plant per m<sup>2</sup> area, and A (Abundant) - 10 plants per m<sup>2</sup>.

[illegible]

Plant	Site Number															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<i>Erigeron ursinus</i>	A		A	F	F	F	A	A	A			0	0	0	0	0
<i>Eritrichium nanum</i>						F										
<i>Erythronium grandiflorum</i>			A				A		A		0	A	A	A	A	A
<i>Festuca brachyphylla</i>	0		0		F	F	0	0	F							
<i>Festuca saximontana</i>	F		0		F	F			F	F		0	0	0	0	0
<i>Gentianopsis detonsa</i>		A		0					A							
<i>Geranium richardsoni</i>	0	0														
<i>Geum rossii</i>				A	A	A										
<i>Hieracium gracile</i>			0								F	0	0	0	0	0
<i>Hymenoxys grandiflora</i>						F										
<i>Juncus triglumis</i> var. <i>albescens</i>									A							
<i>Juncus castaneus</i>		0							F	F						
<i>Juncus drummondii</i>	0			F		0	F	A	F	A	F	0	0	0	0	0
<i>Kalmia microphylla</i>											A					
<i>Ligusticum porteri</i>	R															
<i>Luzula spicata</i>	0	F	0		F	0				A	0					
<i>Mertensia ciliata</i>							0									
<i>Minnuratia obtusiloba</i>																
<i>Osmorhiza depauperata</i>			R													
<i>Pedicularis bracteosa</i>												0	0	0	0	0
<i>Pedicularis groenlandica</i>		A							A	F						
<i>Pedicularis procera</i>				0	0		0									
<i>Pedicularis racemosa</i>											0	F	F	F	F	F
<i>Penstemon whippleanus</i>	R	0				0										
<i>Phleum alpinum</i>	A	0	F	F	F	F	0	F	A		F	0	0	0	0	0
<i>Phelum pratense</i>				0												
<i>Picea englemannii</i>	0	0	0	F	0		0	0			F	F	F	F	F	F
<i>Poa alpina</i>	A	0	A	F	F	A	A	F	A							
<i>Poa cusickii</i> var. <i>epilis</i>	F		F		F			A	A		0	0	0	0	0	0
<i>Poa interior</i>				0	F		0									
<i>Poa nervosa</i>			0	0	0	0	A	F			F	0	0	F	0	F
<i>Poa pattersonii</i>					0											
<i>Poa reflexa</i>				0		A		F			0	0	0	0	0	0
<i>Poa secunda</i>	F	0		A	A	F										
<i>Polemonium viscosum</i>				F	F	F	0									
<i>Polygonum bistortoides</i>	F	0		A	A	F	0	0	A	A	0	0	0	0	0	0
<i>Polygonum viviparum</i>		A														
<i>Potentilla diversifolia</i>	0	0			F	A	A		A	A	0					
<i>Potentilla ovina</i>					F											
<i>Potentilla rubricaulis</i>		F	A	A			A									
<i>Ribes montigenum</i>	0		0		F		0	0								
<i>Salix monticola</i>		0														
<i>Salix planifolia</i>										A						
<i>Salix wolfii</i>		0			R											
<i>Sedum lanceolatum</i>			F	F		F		0								
<i>Sedum rhodanthum</i>		0								0	F					
<i>Selaginella densa</i>					F											

Plant	Site Number															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Senecio crassulus	R	0	0								0	0	0	0	0	0
Senecio triangularis		0														
Sibbaldia procubens L.							F	F			A					
Silene acaulis					0	F										
Silene drummondii	0		0		0			0	0							
Solidago multiradiata		F														
Solidago spathulata								0								
Spergularia rubra	0															
Stipa nelsonnii							0									
Swertia perennis		A		F						F	0					
Taraxacum officinale	0			0	0	F			F						0	
Thlaspi montanum	F				F	A	F	F	A							
Trifolium dasyphyllum						A										
Trifolium parryi	F	A	0	A	A	A	A	A	A							
Trisetum spicatum	F	0	A	F	F	A	0	F	A			0	0	0	0	0
Trollius laxus		F								A	A					
Vaccinium scoparium	0	F				0			A	F	A	A	A	A	A	A
Valeriana edulis		F														
Veronica wormskjoldii		0	F					F		F	F	0	0	F	0	
Zigadenus elegans	R	F				0				A						

1975). The major soils in this area are Typic Cryumbrepts. These soils have acid, dark colored surface horizons whereas subsurface horizons have varying degrees of alteration and weathering. They have no hard bedrock within 40 cm of the surface and have no mottling within 75 cm in horizons whose chroma is 2 or less (Retzer, 1971). Lithic Cryumbrepts have hard bedrock within 40 cm of the surface (Retzer, 1971). Cumulic Cryaquolls listed here are usually stream side or lake side soils which are permanently wet and have relatively high organic matter in the surface. Although the soils sampled in this wet environment had an average surface (to 6 inches) organic matter content of 32.2 %, many have high surface organic matter contents and would probably, therefore, be classified as Histic Cryaquolls. Analysis for these soils can be found in Williams et al. (1985).

The vegetation of the Snowy Range above 10,000 feet is fairly typical of that found throughout the Central Rocky Mountains in alpine zones. A notable exception is that the actinomycete nodulated genus, Dryas, is not represented here even though it is found to the south in Colorado and to the north in Wyoming's Wind River Range. Table 1 shows the plants present at the sampling sites (0-15) indicated in Figure 1. This list was made with the assistance of Dr. Ray Unger (at that time with the Department of Botany at the University of Wyoming). These species have been confirmed recently through the Rocky Mountain Herbarium, Department of Botany, University of Wyoming.

## PLANNING

Initially, the primary purpose of the reconstruction of the road was to provide a better road for the transportation of forest products. Most highways of this type through National Forest land function within the broad spectrum of a transportation network and serve a variety of users. At first, the planning objective and preliminary issues for this road were no different than those for any other State Highway. But through the public input planning process and subsequent development of the public issues that would later drive the design and reconstruction of the road, the recreational aspect of the road was recognized. From a broad perspective, then, not only were the planning objectives for the road oriented around transportation, but recreation as well. From a narrower viewpoint, however, planning focused on solving the following issues:

(1) What road width standards could be used to maintain the quality sightseeing recreational experience, while at the same time insuring motorist safety?

(2) How should the road be aligned to provide safe transportation and at the same time maintain the recreational aspects of a mountain road (e.g. the switchbacks), as well as viewer orientation to scenic resources?

(3) How could the road reconstruction be completed, in a timely manner while providing adequate transportation, maintaining the aesthetic quality, reducing the scars of the old highway and revegetating new disturbances wrought by the reconstruction?

(4) How could recreation amenities be incorporated into road design to provide low-impact recreation access to alpine scenery, including access for persons with disabilities? Designs for major parking, snowmobile parking, "bubble turnout" pull-offs, Lake Marie, major road alignment, and revegetation, as well as subsequent Forest Service recreational facilities, came out of the resolution of this issue.

(5) How could road design be used to reduce recreation-related impacts but still provide recreational opportunities and access? This included reducing unauthorized motorized use, which marred fragile alpine meadow, providing an invitation to low-impact recreation use such as hiking, and providing the opportunity for interpretation (pull-off) for the Forest Service to relay its multiple-use mission to the public.

Planning for the project culminated with an Environmental Impact Statement being filed and a Record of Decision choosing an alternative that resolved many of the planning issues related to balancing the needs of recreation and transportation. The overall effect of the planning effort was that it set the groundwork for the successful completion of the Snowy Range Highway.

**Public Meetings and Input.** As part of the public scoping process requirements under NEPA, public workshops, meetings and public hearings (during the presentation of the Final Environmental Impact Statement (FEIS) were held). Pressure from public interests such as the Save Our Snowies (SOS) committee and the Sierra Club eventually forged a compromise solution, in which the recreational aspects and revegetation consideration of the highway were broadened and included in the final alternative. The effect of the public on the project was that it eventually lead planners to better solutions. It provides a good example of the effectiveness of public input in the planning process. Table 2 records the dates of the public meetings where either the Forest Service or Federal Highway Administration were involved.

**The Landscape Erosion Control Advisory Team (LECAT).** Primarily in reaction to the public input, the FHWA formed a special committee to deal with revegetation issues of a high altitude highway. This group was called the Landscape Erosion Control Advisory Team (LECAT) and was made up of representatives from the FHWA (Mr. Robert L. Jacobson, Landscape Architect), Forest Service (Mr. Christopher C. Marvel, Landscape Architect, Chairman), and Wyoming Highway Department (Ms. Lynn Painter Lanning, Landscape Agronomist). These people formed the permanent core of the committee; however, the team was frequently but temporarily expanded to include other people with special knowledge or concerns pertaining to the project. These other groups included personnel from the Forest Service, several state universities (Colorado State University and the University of Wyoming), the FHWA, the Wyoming Highway Department, and the Wyoming State Game and Fish Department. The function of this team was to formulate recommendations for revegetation for the project as well as measures to lessen any environmental impact of the reconstruction project. This included specific recommendations on design and specifications for revegetation and parking area location and design.

**Funding Forest Roads.** The Snowy Range Highway Reconstruction Project, although a state highway, was federally funded as part of the Forest Roads program. The program was set up to improve roads within National Forests for transportation purposes. It includes participation of the State, the Forest Service and the FHWA in prioritizing roads for selection. Once the project has been selected, the FHWA acts as the lead agency and has the responsibility for planning, design, and construction of all roads selected.

**Time Table for Reconstruction and Revegetation.** Because the Snowy Range Highway is a high elevation road, the reconstruction season as well the growing season can be very short (30-90 days). Therefore, the project was broken up into three reconstruction contracts for operational and environmental reasons. Stipulations within each contract limited contractors from disturbing more than one mile of road at a time before roadsides had to be regraded and revegetation initiated. In addition, timed sequencing of hydromulch applications; the stripping, storage, and placement of topsoil; the collection of native seed and cuttings; the application of hydromulch (with special consideration of adequate time for seed germination); and the planting of containerized, high altitude shrub species; all had to be critically timed and related to the harsh and unpredictable climate found at the project site.

Table 2. Public meetings with United States Forest Service (U.S.F.S.) involvement held prior to approval of the Environmental Impact Statement (USDOT,1980) for the Snowy Range Road Project. FHWA is the Federal Highway Administration, WHD is the Wyoming Highway Department.

<u>DATE</u>	<u>LOCATION</u>	<u>SPONSERS</u>
9/26/75	Centennial, WY	Izaak Walton League U.S.F.S.
2/22/78	Centennial, WY	U.S.F.S. public meeting
2/23/78	Saratoga, WY	U.S.F.S. public meeting
3/8/78	Laramie, WY	U.S.F.S. Sierra Club
5/22/79	Laramie, WY	U.S.F.S., FHWA, WHD public meeting
5/23/79	Saratoga, WY	U.S.F.S., FHWA, WHD public meeting
3/26/80	Laramie, WY	U.S.F.S., FHWA, WHD public meeting

## DESIGN

Design of the road was done by the FHWA, with primary input for the recreational amenity aspects of the road provided by the U.S. Forest Service. Revegetation, a major component of the successful completion of a scenic highway, was directed through an interagency committee, the Landscape Erosion Control Advisory Committee (LECAT). The University of Wyoming played a supportive role on the committee and, later, in the reconstruction phase of the project. Drawings contained within this paper (Figures 2 and 3) illustrate the "quick sketch" method and the initial thinking used in determining, locating, and otherwise formulating ideas for the highway, from a recreational perspective. In addition, many hours of fieldwork were spent closely coordinating efforts between agencies.

The primary objectives of design grew out of the solution of planning issues. These can be described as follows:

- (1) Preserve the natural beauty of the landscape by revegetating areas quickly.
- (2) Provide a road alignment that disturbed the least possible high altitude area.
- (3) Use as many old roadbed areas in the new design as possible. Making a bikeway of the old road in the Lake Marie area is example of implementation of this philosophy.
- (4) Consider all recreation users. For example, designing a snowmobile parking area at Green Rocks picnic areas as just part of the road maintained a recreational scenic aspect of the road for summer users.

Managing human use in alpine areas and relating the human to the natural environment so that impacts were minimized was an important goal of project design. Effective barrier design was one element in successful implementation of this goal. Four types of barriers were used--natural barriers, placed rocks, bollard posts, and (CorTen) prerusted w-beam guard rail.

The bollard posts (Figure 3) served both to identify these to the traveling public and to limit vehicle use of sensitive alpine areas. The design of these facilities provides positive invitations and images to the public to recreate, without the need for signs.

Placement of rocks was also used effectively. Methods of placement were critical to making these appear natural. Machine operators used a ripper claw to drag boulders and



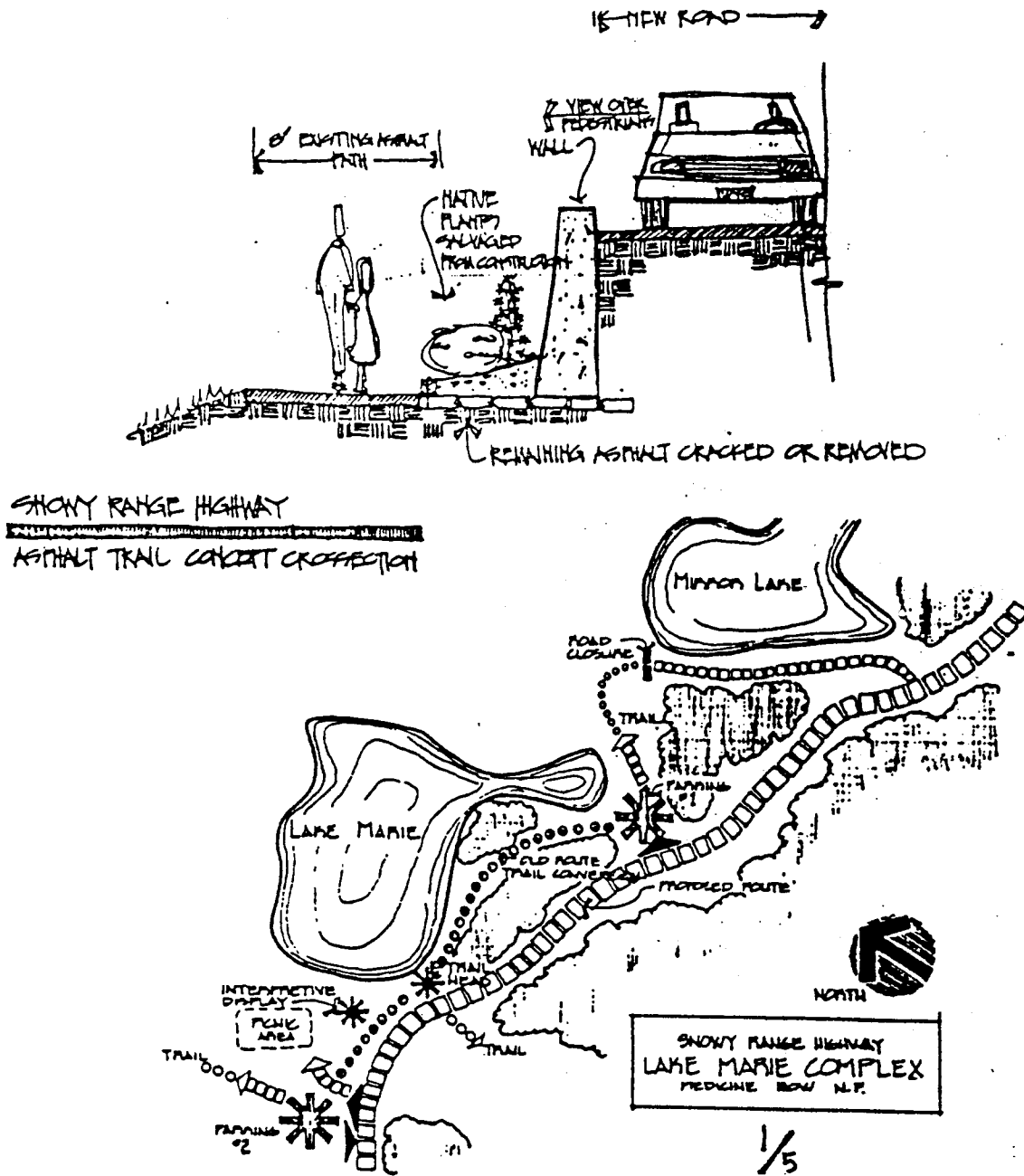
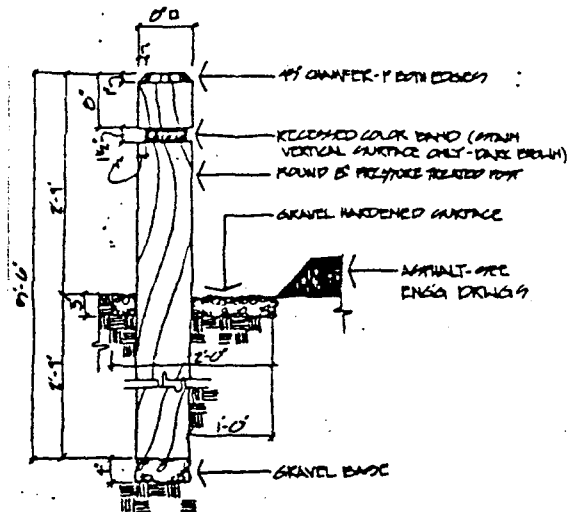
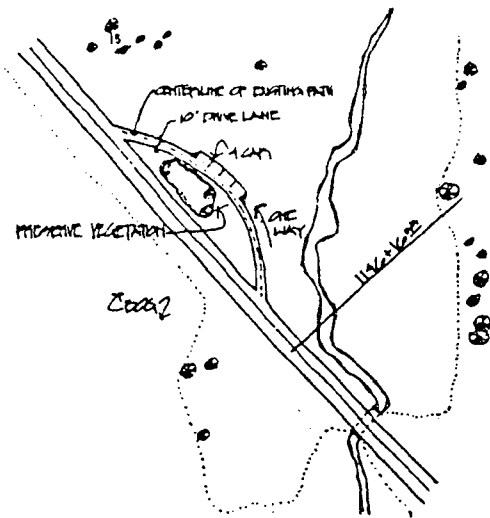


FIGURE 2. Early Concepts of Lake Marie.



⊕ DETAIL 1- BOLLARD

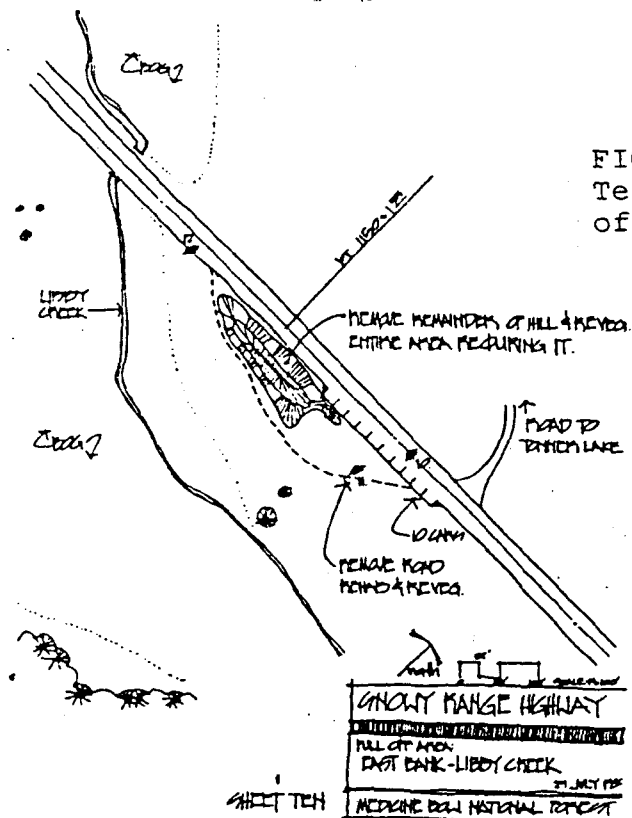
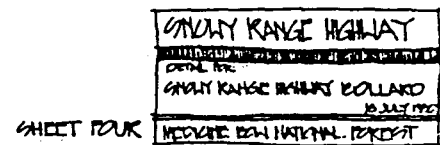
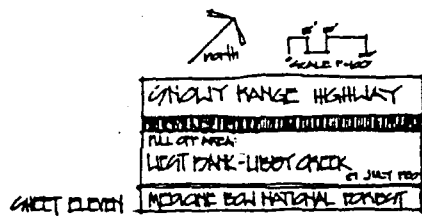


FIGURE 3. Quick Sketch Technique for Communication of Landscape Design Ideas.

press them into the soil during final grading earthwork operations. Landscape design also called for random placement and relating existing rocks to natural features such as contours and the direction of ridges.

All objectives, goals and methods were part of making Snowy Range Highway not just another forest highway, but a western parkway used for both recreation and transportation.

### RECONSTRUCTION

The successful reconstruction of this highway can be directly attributed to the successful integration of teamwork in three areas: planning, design, and reconstruction. Careful implementation of high altitude revegetation techniques, recreation amenity design and reconstruction made the highway what it is today.

A primary objective for revegetation during reconstruction was containment of an area opened to the contractor during any period. Another important objective in minimizing disturbance was maintaining contractor operations within existing clearing limits of the project, or in areas designated by the project engineer.

In addition, the construction engineer for the three separate projects (Mr. Dean Weisbeck, FHWA) played an important role in implementing design strategies. Lines of communication between the FHWA, the US Forest Service, various State agencies, and the University of Wyoming networked to achieve implementation of goals outlined in planning and design.

### REVEGETATION

One of the most important aspects of a high altitude project from a scientific, an environmental, and a recreational standpoint is how fast the impacts of project reconstruction could be eliminated. Two broad goals of the revegetation effort were:

(1) Minimize road alignment changes from the old road. In this way, surface area requiring revegetation would be kept to a minimum.

(2) In areas where revegetation was necessary, use the best known technology. This included tailoring revegetation methods to the sensitivity of the area by dividing the area into low altitude (subalpine) and high altitude (alpine)

sections. The working definition for distinction between these two zones was the 10,000 foot contour. Final methods and recommendations for revegetation were left to the LECAT team.

#### **High Altitude Revegetation Literature and Philosophy.**

Knowledge of revegetation of high altitude and particularly alpine environments is somewhat limited; although there is little doubt as to the high susceptibility of plants in such areas to disturbance. Alpine vegetations occur in what are among the most rigorous terrestrial environments, and without man they seem capable of almost indefinite persistence (Billings, 1973). However, alpine vegetation recovers very slowly after disturbance. Greller (1974) examined alpine tundra which had been denuded in Rocky Mountain National Park during construction of the Trail Ridge Road. He found that 40-50 years after construction of the road, plant coverage on denuded sites was approximately half of that on undisturbed sites. Greller also noted that on a disturbed site which had adequate soil moisture, and which was humus enriched from an upslope community of alpine willow, had developed cover which did approximate that on undisturbed sites. Human caused damage to tundra ecosystems has been documented by several researchers. A study of regional interest was conducted by Willard and Marr (1970). They indicated that wet alpine sites are especially easily damaged by human activities. Other alpine plant environments are usually easily damaged, although alpine turf or sod sites (Cryumbrepts) are the most durable.

Revegetation of alpine sites is a particularly difficult problem because of the shortness of the growing season, the frequent seasonal dry periods of the soil, often low soil fertility, and the absence of mechanized methods for seeding steep alpine areas (Cook, Hyde and Sims, 1974). Another feature of alpine sites which contributes to complexity of revegetation is the mesotopographic gradient described by Billings (1973). This gradient extends from ridgetop to wet meadows or bogs. This gradient includes; (1) windward slope which tend to be quite dry; (2) ridge crests which are somewhat more mesic than the windward slopes; and (3) sites of deep snow accumulation on the leeward slope of ridges which will certainly have plenty of available moisture but have a very short effective growing season. Also considered part of this gradient are (4) meltwater meadows downslope from snow drifts, which are probably the best sites for plant development, and (5) depressions occupied by bogs, often a product of long periods of organic matter accumulation. The lateral dimensions over which this gradient occurs may range in scale from several miles to a few hundred feet. Such heterogeneity of landscape further exacerbates revegetation.

Several authors address techniques and plants which have potential for use in revegetation at high altitudes. One of the earliest studies was performed in Rocky Mountain National Park by Harrington (1946). In this study, native plants were seeded and establishment was evaluated after five and six years. His report suggests that for sites above 10,400 feet in elevation Deschampsia caespitosa, Penstemon shippleanus, Phacelia sericea and perhaps Trisetum spicatum and Thermopsis divaricarpa had high potential for revegetation. Lists of additional plants recommended for alpine revegetation can be found in Kenny and Cuany (1978) Brown and Johnson (1980), Guillaume (1980), and Laycock (1982). Only a portion of those recommended are native plants. Kenny and Cuany (1978) indicate that native plants should receive more emphasis in revegetation of alpine sites. They indicate that Lupinus argenteus has received some attention, and in Colorado, seed collections have been made at elevations up to 11,000 feet. Berg and Barrau (1978) suggest that native shrub establishment should receive more emphasis in alpine revegetation and further suggest that actinomycete nodulated shrubs (nitrogen fixing shrubs) should have a distinct advantage in alpine areas. White and Williams (1985) have reviewed the possibility of using actinomycete nodulated plants in revegetation, but the treatment these authors present is somewhat conceptual and actual tests of actinomycete nodulated plants at high elevations has not been reported. These researchers report further that actinomycete nodulated plants at high elevation or latitudes are not abundant. Alnus spp. may be of value at high latitudes, but do not exist in alpine areas. Dryas spp. are also noted to be actinomycete nodulated, but there is some controversy as to whether they are nodulated in the Central Rocky Mountains. However, it is well documented that nitrogen fixing plants do have a distinct survival advantage over plants which do not fix nitrogen (Bond, 1974 and Vincent, 1974). It should be noted that stockpiling of topsoil for longer than three years has been shown to decrease the number of nodulating bacteria in high elevation rangeland sites (Singleton and Williams, 1980). Presumably, long period of soil storage at high, alpine locations could have an adverse impact on these organisms.

Other microbial associations which have an influence on survival of plants include mycorrhizal fungi. These fungi form symbiotic association with roots of almost all plants (Gerdemann, 1968) and their presence is crucial in water and mineral uptake by higher plants (Williams, 1979; Loree and Williams, 1984; and Abbott and Robson, 1984). Stockpiling of

topsoil for extended periods of time has also been shown to be detrimental to these organisms (Rives et al., 1980).

Several recommendations have been made concerning general techniques which should be followed in revegetation of alpine zones. Alpine soils tend to be quite deficient in plant available nitrogen. Brown and Johnson (1980) recommend that soil analysis be done on target soils prior to revegetation efforts. They recommend that soils found nitrogen deficient be fertilized with nitrogen. Berg and Barrau (1978) indicate that for best results, nitrogen should be applied at a rate of 60 pounds per acre per year for at least four consecutive years. Soils found to have a pH of less than 5.5 should receive an application of limestone to bring the pH to near 6.0 (Brown and Johnson, 1980). Straw as a surface mulch surface stabilized with netting has been shown to enhance seedling survival (Brown and Johnson, 1980).

Revegetation of the areas disturbed during the Snowy Range Road Project was accomplished via several means. Some relatively conventional methods were used for selection and distribution of seed for direct planting as well as preparation of seed bed material. However, seed bed preparation was hydromulched in steep areas, mulched with native straw in others, and in wind prone areas, jute or in a few cases, plastic netting was used to stabilize mulch and seed. In a few areas, native hay cut from alpine meadows adjacent to the road right-of-way was used as mulch. This material may be a source of native seed.

Another fundamental principle which was followed was conservation of topsoil. Topsoil is a source of nutrients, seed and symbiotic microorganisms. When topsoil was relatively deep, it was stockpiled for short periods of time (1 month) and then spread on cut slopes. When topsoil was shallow, it was mechanically removed and rolled to the edge of the right-of-way, and then respread mechanically.

Much emphasis was given to revegetation using shrubs generated from cutting along the road right-of-way. Many shrubs are difficult to propagate from seed (e.g. Heil, 1971), whereas they are relatively easy to regenerate from cuttings. Further in a controlled setting, shrubs can be inoculated with mycorrhizal fungi. Several researchers have shown enhanced survival of plants so inoculated (Backhaus and Nilsson, 1986; and Ruehle, 1981).

**Soils.** Cryumbrepts, the dominant soils in this area, are frequently thin, and that portion of the soil profile usable in reclamation is generally less than 6 inches in depth.

Despite these limitations, topsoil was salvaged even where it was only a few inches in depth. Soil chemical and biological data from this area can be found in Williams, et al., 1985.

In zones where the soil resource was relatively deep, soil was piled in a centralized location, usually within 300 yards of where it was removed. These stockpiles of soil were seldom more than several hundred cubic yards in size.

In zones where the soil was shallow, such as in the alpine sod zones (usually Lithic Cryumbrepts), the soil was mechanically removed to the edge of the right-of-way and left in windrows. In many cases a bulldozer could be used to accomplish this. The machine could be positioned on the road way, and moving perpendicular to the axis of the road, push the desired topsoil to the edge of the right-of-way. In this manner, soil was removed from the working surface and stored for reuse. This technique seemed to work best in areas which were moderately level, although it was used successfully where slopes were even as steep as 2:1. The windrows of soil adjacent to the road provided some degree of erosion control in that they deflected overland water movement away from the exposed working surface of the road. Also, respread of these soils in preparation for revegetation was relatively easily accomplished.

A key notion regarding soil salvage was the time of soil storage prior to reuse. This time was minimized and never exceeded 6 weeks. Soil storage piles were never allowed to over winter prior to use in revegetation. Soil material was replaced in approximately the area from which it was removed.

**Soil Preparation and Seeding.** In areas of slope less than 2:1, soil was respread and prepared by grading and where necessary using a variety of mechanical devices to break-up soil aggregates. These areas were fertilized, per acre, with 60 lbs. of nitrogen as ammonium nitrate, 30 lbs. of phosphorus as  $P_2O_5$ , and 30 lbs of potassium as  $K_2O$ . In high altitude zones as well as areas of slope 2:1 and greater, soils were respread where possible, and fertilized where possible at the same rates as the less steep environments.

From the plant survey taken (Table 1), a list of plants recommended for seeding was generated. These recommended plants were selected on the criteria that they were relatively abundant in the areas to be disturbed, that germination of the seeds was usually high, and that the seeds were available commercially. The plants recommended as generated from Table 1 were Poa alpina (alpine bluegrass), Poa cusickii var. epilis (skyline bluegrass), Poa secunda

(sandberg bluegrass), Festuca saximontana (sheep fescue), Festuca brachyphylla (alpine fescue), Agropyron trachycaulum (slender wheatgrass), Phleum alpinum (alpine timothy), Trisetum spicatum (spike trisetum), Deschampsia caespitosa (tufted hairgrass), Potentilla spp. (cinquefoil), and Achillea millefolium (common yarrow). Species especially recommended were alpine bluegrass, skyline bluegrass, slender wheatgrass, alpine timothy, tufted hairgrass, and common yarrow.

In the areas of slope less than 2:1, seeding rates per acre were 20 lbs Pure Live Seed (PLS) of slender wheatgrass, 10 lbs PLS alpine timothy and 10 lbs of tufted hairgrass. Seed was drilled at 0.5 to 0.25 inches deep, mulched with 2 tons of straw per acre, crimped, and tacked using 100 lbs per acre of binder (M-Binder) plus 700 gallons of water per acre and 300 pounds of wood fiber per acre.

In areas having slope greater than 2:1 or in alpine areas, hydromulching was used. Hydromulch at approximately 0.75 tons per acre was used. The hydromulch contained exactly the same content of PLS per acre as the areas of slope less than 2:1, except that the slender wheatgrass content was increased to 20 lbs of PLS per acre. Alpine and steep slopes were mulched with straw at 2 tons per acre and covered and staked with jute netting.

**Shrub Research and Plantings.** Research on shrub generation and planting was conducted through the University of Wyoming by the Department of Plant Sciences (now the Department of Plant, Soil and Insect Sciences). Funding for this work originated with the FHWA, but much of these resources were routed through the Medicine Bow National Forest.

The majority of the shrub research involved Ribes montigenum (gooseberry), Potentilla fruticosa (shrubby cinquefoil), and several species of Salix (willow). All of these plants are difficult to generate from seed. Therefore, it was decided to use cuttings made from the Snowy Range adjacent to the road right-of-way as the biological material for regenerating these plants. During three years of research, cuttings were made in the fall as well as in the spring. Fall cuttings were packed in sterilized, dampened vermiculite and stored at just above freezing for usually up to 5 months prior to rooting. Spring cuttings were made as early in the spring as possible. Usually this was in May or June, but some cuttings were made as early as April. The



ideal cutting was a wand of the plant in question which was 4 to 7 inches in length, was composed exclusively of the previous growing seasons' wood, and possessed 3 to 7 dormant leaf buds. Usually these cuttings were taken from the finest order of branching of the dormant shrubs. The actual cut of the wand was made at roughly a 45° angle.

The rooting process was accomplished in a mist bench filled with approximately 8 inches of perlite which had been autoclaved to remove possible pathogens. The excised end of the cutting was dampened and dipped in a rooting hormone (Hormodin II), and placed in the mist bench with a minimum of 2 inches of the wand below the surface of and in direct contact with the perlite. Cuttings were arranged on 3 inch centers in the mist bench. Misting occurred at approximately 3 minute intervals.

Plants were found to develop excellent roots after roughly 2 weeks in the rooting bench. Diseased material was consistently a major problem with cutting taken in the fall. Sometime mortality was as high as 100%. However, disease was seldom a problem with spring cut material. It was possible to get 100% of spring cut willow material to root, but more commonly about 80% of all material was rooted.

Rooted material was transplanted into tube paks of a volume sufficient enough to contain about 5 ounces of rooting medium. The medium used was a sterilized peat, vermiculite, sand mix (1:1:1) which had been inoculated with about 5% topsoil from the Snowy Range Road site. The soil was added to assure inoculation of plant roots with appropriate mycorrhizal organisms.

After from 2 to 4 weeks in the tube paks in the greenhouse, plants were moved to an outdoor environment (lath house, 50% porosity), where they were hardened for at least 10 days prior to out planting.

Survival in the field of outplanted material after one year averaged about 95%. Today, 5 to 7 years later, shrub survival is about 80%.

**Landscape Architecture.** Landscape architectural objectives per se were broadly synonymous with the overall goal to provide a scenic driving experience and low impact recreation access to visitors to the Medicine Bow National Forest. Landscape architectural designs and principles were communicated with quick graphic sketches (Figure 3) to FHWA

engineers during the design phase of the project. This input was crucial to producing a road that responded to recreation as well as transportation users.

Techniques used to illustrate and communicate landscape architectural principles to FHWA engineers, planners, and designers were simple graphic drawings, as well as on-the-ground reviews of road alignment. The following primary landscape architectural principles were used in this project:

(1) Road alignment needed to be blended with natural landscape.

(2) Parking areas needed to be designed to fit both land form and located in areas where human use would not result in adverse impacts.

(3) A conceptual relationship analysis needed to be used to identify recreational functions in a given area. Facilities were located as a result of this analysis.

(4) Pedestrian and vehicular circulation patterns needed to be analysed for proper separation (Lake Marie).

(5) Design details such as slope rounding, rock sculpturing, traffic/pedestrian barrier design, and viewer orientation to recreation and possible interpretive sites needed to be incorporated in the final design.

One area of notable public interest was Lake Marie. The original road was aligned very close to the lake. Parking was overcrowded and did not have handicapped facilities. Pedestrians had difficulty accessing recreation areas because of the existing road alignment.

Lake Marie was a key public issue among opponents to the reconstruction of the highway. Opinions varied widely but most focused on the need to provide adequate parking and pedestrian access to the lake. The alignment ultimately chosen maximized recreational considerations. The new alignment was elevated so that motorists could still see Lake Marie. New parking considered the pedestrian, as well as vehicles (see Figure 2). In addition, handicapped access along the lake shore was recognized. The previous roadbed provided a prime opportunity to incorporate these features. The concept for Lake Marie responded to these issues. The old roadbed was used as a handicapped pedestrian walkway with parking located at each end of Lake Marie. A pedestrian footbridge over French Creek provided the necessary linkage between the two areas. The road was reconstructed along the lines of this concept.

The parking areas provide good access to other recreation activities. These serve as nodal points where the distribution of people in the area can be managed. As such,

they also function as places where managers can relate information about resources, management, and culture. Signs for interpretation have been placed in these areas (Figures 4 and 5). This is an important element in the management of humans in the alpine environment.

Landscape architecture and its principles were used throughout the planning, design, and reconstruction phases of the project, as a guiding source of ideas to provide the necessary balance for recreations users in an otherwise transportation-related project. Primary objectives, as listed throughout this paper, echo landscape architecture principles. The quick communication of ideas in an interdisciplinary approach is an art. Graphic sketches, a thorough on-the-ground review of road alignment, and close coordination during the design and reconstruction phase were key in obtaining satisfactory results. Landscape architectural sketches were used to graphically relate ideas to FHWA engineers. Some of the original drawings are included as examples with this paper (see figure 3).

In addition, the relationship of this road to recreation and cultural resources on the Medicine Bow National Forest is its strongest asset. Parking areas give managers the opportunity to utilize and further interpret the various resources. Recreation management on the Medicine Bow National Forest has followed through with interpretive signing at pulloffs along Snowy Range. This is all part of the total management concept for the road and shows how well-thought-out integration of multiple resource values can be a prescription for success.

#### FINDINGS AND INTERPRETATION

1. Alpine environments and landscapes in the Rocky Mountains have broad scenic diversity and attributes that make them attractive as recreation areas. Where access is provided, managing human use is as important to revegetation as it is to the method and science itself. The goals, objectives, and methods set within this paper are directed towards meshing the human environment with the natural one, and further of finding ways of managing human use within the delicate alpine environment using applied science, aesthetic considerations, design and reconstruction details, and site characterization.
2. An interdisciplinary professional staff with diverse opinions is important to finding good solutions. The use of landscape architecture in relating design elements to the human and natural environment needs to be recognized. Landscape architecture comes from a understanding of three

areas; engineering, biological sciences, and art. The combination of the three makes the landscape architect versatile and important to the successful implementation of design in the natural and human environment.

3. Revegetation can be successfully accomplished using a variety of on site materials such as native hay mulch, cuttings of indigenous plants, and site soil. The soil resource is of particular value because it contains seed microorganisms and nutrients adapted to or generated by the unique combination of parent materials (geological substrates), organisms, topography (aspect and slope), and climate as these factors interact through time at this location.

# LIBBY

## FLATS

Elevation: 3272 meters  
10,800 feet

This area serves as a transition between subalpine forest and alpine meadow. Summers are short and cool with a good chance of freezing temperatures occurring even in July. The alpine climate prevents tree growth by reducing the length of the growing season and by snow-blasting in the winter. The scattered trees -- Englemann spruce and subalpine spruce -- are much larger in the forests at lower elevation even though they may be the same age.

Flagged Tree

Winter  
Wind

Windward  
Side

Leward  
Side

Seedlings  
form here

KRUMMHOLZ

The "tree islands" that you see at timberline are commonly referred to as "krumholz", a German word meaning bent wood. Blowing ice and snow damage the needles and new twigs on the windward (west) side of the trunks, leaving branches to form only on the leeward (east) side of the tree.

At the base of the "flagged tree" is a mat of branches which is more dense because it is protected during the winter by snow cover. These dense mats cause snow to accumulate by reducing the force of the wind. During mid-winter only the "flags" are visible above the snow. Snow is blown away almost to ground level where there are no "krumholz" mats, exposing any new tree seedlings to snow blasting. This partly explains the lack of forest today on much of Libby Flats.

A close examination of the "tree islands" shows that they have more than one trunk. However, all but the main trunk probably developed from low branches that produced roots after being pressed to the ground by heavy snow. This mode of vegetative reproduction is known as "layering" and can occur in subalpine forest as well. As these islands continue to enlarge and come closer together, the trees may be able to grow taller because they will protect one another. The present large, charred logs on Libby Flats suggest that more of the area might have been forested at one time prior to a fire caused by lightning. Hundreds of years may pass before the area is forested again.

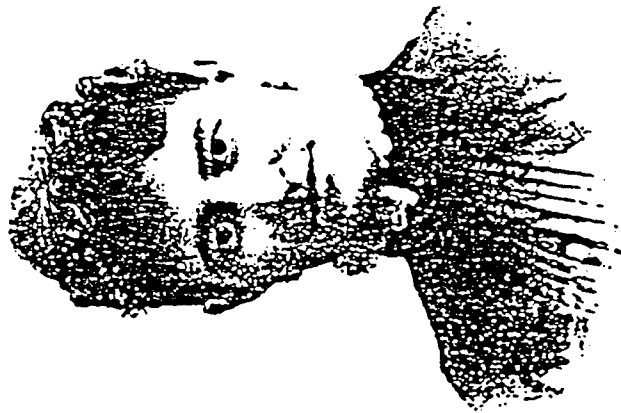
Alpine plants grow very slowly because of the short summers and harsh winters. Scars on the landscape may last for decades. Please don't drive on the alpine meadows.

FIGURE 4. Example of natural history interpretive sign on the Snowy Range Road Project. Sign is currently located on Libby Flats in the Snowy Range.

## *Lake Marie*

Lake Marie was named for Mrs. Mary (Marie) Bellamy [1861 to 1955] by her husband, Charles Bellamy, who was a government surveyor.

After Marie was elected to the Wyoming Legislature, she led the successful suffrage drive that resulted in the passage of the 19th amendment to the United States Constitution.



Mary G. Bellamy was born on December 13, 1861.

After moving to Laramie in 1873 she became one of the three members of the first graduating class of Laramie High School. Starting her teaching career in 1878 in Tybo, Nevada, she returned to Laramie in 1882. Mary married Charles Bellamy in 1886.

After successfully being elected to the office of Albany County Superintendent of Schools in 1902, she became the first woman to be elected to the Wyoming Legislature in 1910.

FIGURE 5. Example of historical interpretive sign on the Snowy Range Road Project. Sign is currently located at Lake Marie.

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RECLAMATION OF EXPLORATION ROADS AND  
MINE-SITES IN NORTHERN NEVADA

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INTRODUCTION

Freeport-McMoRan Gold Company (Freeport) has been involved with mineral exploration in the Independence Range of northern Nevada since 1976, and has been actively mining disseminated gold in this same area since 1981. Most of the Independence Range is managed by the Humboldt National Forest of the U.S. Forest Service (USFS). However, smaller portions of the area are under Bureau of Land Management (BLM) jurisdiction, and scattered parcels of private land are interspersed throughout the area. The mountains vary in elevation from approximately 1,980 m at the edge of the valley floor to over 3,050 m at the highest point. Precipitation varies directly with elevation, ranging from 20 cm to 76 cm, and occurs primarily as snow during the winter months. The Independence Range lies within the northern desert shrub vegetation zone (Tueller 1975). Mixed shrub plant communities are dominated by big sagebrush (Artemisia tridentata) with a perennial grass and forb understory. Small stands of aspen (Populus tremuloides) are scattered, primarily at high elevations and/or areas of high soil moisture. Isolated pockets of conifers, primarily subalpine fir (Abies concolor) are found at higher elevations on concave north slopes. Riparian vegetation is found along the perennial and ephemeral streams in the area.

Successful concurrent reclamation, ongoing since 1979, has been the result of close cooperation between Freeport and federal land management agency personnel. Reclamation planning procedures and implementation discussed below are an outgrowth of environmental commitment and continuous experimentation.

## EXPLORATION ROAD RECLAMATION

Freeport's reclamation emphasis since 1979 has been on mineral exploration roads (built for drill rig access), approximately 30% of which have been reclaimed. Efforts to reduce impacts of mineral exploration have also included interim seeding of road berms and utilization of track-mounted drill rigs (to minimize road construction) in some areas.

Primary short-range reclamation objectives have been to minimize erosion and invasion of noxious exotic weeds, and to re-establish wildlife habitat and livestock forage. The major long-term objective is to enhance productivity through the gradual advancement of native vegetation (secondary succession), which in turn contributes to the recovery of esthetic values.

Road reclamation has consisted of recontouring and seeding the disturbed sites. Partial to full recontouring has been accomplished primarily by two methodologies: (1) with large dozers, by pushing the fill slope up onto the roadbed and "walking" the machine perpendicular to the road bed over the redistributed fill, and (2) with track-mounted backhoes, by "pulling" the fill slope up into the roadbed with successive sweeps of the bucket as the machine backs along the road. The former method has the disadvantages of slope limitations, wider zone of disturbance area (than the backhoe), excessive wear on machinery, and operator safety limitations. Advantages include equipment availability and good "safe-sites" for seeds created by cleat-mark depressions perpendicular to the hill slope. Plummer et al. (1968) pointed out the advantage of these depressions, especially for shrub seeds. A disadvantage of the backhoe is less compaction of redistributed fill (i.e., more chance for soil movement on steep slopes). In steep terrain (>30% slopes) backhoes are typically more economical than large dozers.

Recontoured roads have been most effectively seeded soon after recontouring when the fill material is still comparatively soft and loose. Because steep slopes preclude the use of a rangeland drill, the roads have been typically seeded with hand-held broadcast seeders. Where slopes are less severe, seeding has also been accomplished with electric seeders mounted on pick-up trucks and small dozers. More recently, we have used a 4-wheel drive all terrain vehicle (ATV) with electric seeder attached. However, this method has slope limitations as well, based partially on skill of the operator. Covering seeds is the biggest problem on recontoured roads. Hand raking works, but is obviously labor intensive. By seeding soon after recontouring takes place, we rely on gravity, wind, and water to move soil and cover

seeds. This method has proven especially successful in areas with dozer cleat marks. On less steep slopes ATV's, small dozers, and even pick-up trucks have been used to pull various drags.

Reclaimed roads were seeded for several years with a USFS and BLM approved mixture of 4 perennial grass species and 1 nitrogen-fixing legume. Seeding success was good to excellent in most cases, varying of course with soil type, precipitation zone, elevation, seed depredation, and grazing pressure. In many cases, percent basal herbaceous cover of vegetation on reclaimed sites after two growing seasons has been similar to that measured in nearby "ecologically equivalent" undisturbed sites.

The soil placed over the road beds during recontouring often contains viable native seed, thus enhancing native plant establishment (Glass 1989). The proximity of unaltered vegetation also serves as a source of volunteer species. These species, often including forbs which are palatable to wildlife, begin colonizing these sites within the first two growing seasons after reclamation.

We are currently conducting a study of this secondary succession on reclaimed roads. Major community types being sampled are low sage (A. arbuscula), mountain big sagebrush (A. tridentata vaseyana), and scrub aspen/chokecherry (Prunus virginiana). Establishment of native species varied with soil type, plant community, precipitation zone, aspect, and competition with seeded species. Preliminary results show that succession proceeded most rapidly in the more mesic sites, with up to 37 native species recorded in scrub aspen/chokecherry within 5 years after reclamation. Although seeded perennial grasses were still dominant in most sites, native forbs and shrubs were major habitat components (as measured by percent cover and/or stem density). Many of the invading species have been identified previously as important summer forage species for mule deer (Odocoileus hemionus) in the Independence Range (Selby, 1986). The resulting plant diversity has elicited regular use by mule deer, sage grouse (Centrocercus urophasianus), white-tailed jackrabbits (Lepus townsendi), and nongame birds. An increase in wildlife species utilizing seeded areas may be expected as plant succession proceeds (McAdoo et al. 1989a).

#### MINE-SITE RECLAMATION

Mine-site reclamation is just beginning in the Independence Range. Separate and detailed reclamation plans, the result of Freeport-USFS cooperation, have been written for

each of three mine project areas. Reclamation planning for these projects was based on site-specific post-mining land use goals which were identified during the formal environmental reviews (Environmental Impact Statement and Environmental Assessments). These goals were related directly to pre-mining land uses. Thus, goals for wildlife habitat, watershed, livestock forage, etc., were an integral component of each reclamation plan. Specific goals for the recovery of habitat for mule deer and the threatened Lahontan cutthroat trout were emphasized (McAdoo et al. 1989b).

The planning effort for each project area involved the input, cooperation, and occasional "head-butting" of USFS resource specialists and several company representatives (including a project mining engineer and an ecologist). Each reclamation plan contained five major categories which were discussed in detail: (1) general site conditions and situation, (2) land uses and derivative land-use goals, (3) reclamation objectives and standards, (4) reclamation procedures, and (5) vegetation sampling considerations for determining acceptable ground cover.

The real "meat" of the reclamation plans was contained in the "reclamation objectives and standards" portion. Objectives were determined for nine categories: (1) mass stability, (2) final configuration of the disturbed areas, (3) air and visual quality, (4) erosion, sedimentation, and post-mining hydrology, (5) topsoil management, (6) acceptable plant species, (7) ground cover, (8) concurrent reclamation, and (9) fence management. Objectives in each of these categories were related to one or more of the post-mining land use goals identified in the reclamation plan. Each category received detailed attention by both Freeport and the USFS. A more thorough discussion of this reclamation planning process has been outlined by Thiel (1988).

The reclamation planning process detailed the need for topsoil recovery and stockpiling. For reclamation purposes, we have adopted the definition of topsoil as material that can serve as plant growth medium without continued additions of soil amendments (Cook 1976). Our topsoil typically consists of A-C soil horizons. Each plan specified requirements for annual reporting of topsoil recovery amounts and outlined details for retrieval, stockpiling, and application. Emphasis was also placed on site-specific seed mixtures of adapted plant species. We developed objectives for basal herbaceous cover, shrub stem densities, and forb cover on reclaimed sites. The objectives were made contingent upon results obtained from study plots. Plans were also developed for tree planting in some areas.

Currently, approximately 800,000 cubic yards of topsoil have been stock-piled, and topsoil inventory reporting is proceeding according to plan. Many stockpiles have been seeded to keep them biologically active and to minimize erosion.

Each year, areas for proposed concurrent reclamation are outlined in Freeport's annual work plan. Accomplishments to date include: back-filling of 1 small pit and ongoing partial back-filling of 3 others, reclamation of 3 waste-rock dumps and a portion of another, and reclamation of several segments of abandoned haul-road.

### Pits

Although pits are not typically back-filled due to economical constraints and geological and logistical considerations, Freeport employs this practice when practical. Most of our "pits" are actually side-hill cuts, for which back-filling results in angle of repose talus slopes similar to those of planned waste-rock dumps.

Other types of pit reclamation we are implementing or considering include revegetating pit bottoms, revegetating pit benches, and alternate land-use options. Concave pit bottoms sometimes hold water and are difficult sites on which to establish vegetation. Depending on pit size and configuration, bottoms can sometimes be re-shaped with partial back-filling, then enhanced with growth medium if available, and seeded. This method has been described in our reclamation plans for one project area.

We have recently experimented with revegetating portions of pit benches where site modifications can be made before the areas become inaccessible. Volunteer species have been observed advancing onto some benches, particularly where sluffing has provided pockets of growth medium. Because we have observed use of inaccessible pit benches by several raptor species, we are also considering methods to enhance these areas for nesting by raptors and cavity-nesting birds. Use of pit walls by birds has been recorded in other areas of the West (Steele and Grant 1981, Parrish 1989).

An alternate land use for one of our true pits, as a reservoir, is being considered as a contingency reclamation plan. If water quality is maintained and if the pit is excavated below the karst topography, then letting the area fill with water to create a reservoir may be a viable alternative. The reservoir would be used for fish and wildlife habitat, and would have potential for use by recreationists and livestock. Reservoir development as an

alternate land use has been successful in other mined areas (Proctor et al. 1983).

#### Waste-Rock Dumps

Freeport's dump reclamation varies according to natural topography of sites and dump types (e.g., valley fill, side-hill, etc). Our basic reclamation methodologies are as follows: (1) leaving dump faces at angle of repose and reclaiming horizontal dump surfaces, and (2) reshaping dumps to approximately 3:1 slopes to facilitate growth medium application. In either case, primary goals are long-term mass stability and proper drainage, with productivity goals secondary. Waste-rock dumps in drainages are engineered to ensure sufficient drainage of peak water flows.

We recently reclaimed two dumps for which final reclamation plans specified leaving angle of repose slopes. Minimum standards for coarse durable rock content on dump faces were required for stability and in order to reduce sedimentation potential. Flat surfaces of these dumps were graded to eliminate water impounding. Reclamation of these surfaces consisted of ripping, applying topsoil, and seeding. The angle of repose slopes were also broadcast seeded. We have observed native vegetation, including big sagebrush, rabbitbrush (Chrysothamnus spp.), and bitterbrush (Purshia tridentata) becoming naturally established on older dump slopes over time.

In 1989, we reshaped one waste-rock dump to an approximately 3:1 slope. This was followed by application of topsoil, then seeding. Tree and shrub seedlings will be planted soon on portions of this dump to accelerate vegetation establishment.

In the future, we plan to improve both waste-rock dump and pit reclamation by creating topographic diversity, particularly where wildlife habitat enhancement and/or esthetics are reclamation goals. According to Steele and Grant (1981), establishing such diversity with rock piles, gullies, depressions, and so on, especially where islands of natural vegetation are left, can result in benefits for native birds and mammals. Done properly, we anticipate that this could also result in cost savings during reclamation (Grant and Monarch 1989).

#### Haul Roads

Haul road reclamation in the Independence Range is difficult due to steep terrain. Among the methods we have utilized successfully to reclaim these wide (15-30m) roads

are the following: (1) constructing proper drainage, pulling in fill slopes and/or ripping the road bed, applying topsoil, then seeding, (2) "plug dumping" with waste rock placed against cut slopes to facilitate recontouring and eventual placement of topsoil, then seeding, and (3) recontouring with large backhoes, followed by seeding. Some of our access haul roads (vs. "in-pit" haul roads) are scheduled for width reduction and partial reclamation, with a narrow road being left for public access at the request of the USFS.

In general, our haul road reclamation methodologies vary according to road construction type, steepness of terrain, environmental constraints (e.g., stream proximity), and site-specific goals.

#### SEEDING MIXTURES

Currently, a total of twenty different seed mixes are being used for reclamation, based on reclamation goals and site-specific characteristics (habitat, precipitation, aspect, etc.). These mixtures were developed with rationale to include the following: (1) adapted species, (2) diversity of species (typically grasses, forbs, and shrubs), and (3) species which enhance succession (Booth 1985, Ogle and Redente 1988). In those areas with vegetation diversity goals for wildlife habitat or esthetics, emphasis is placed on rapidly establishing species which hold the soil and compete minimally with native species that may naturally invade the site. Heavy seeding of introduced grasses is avoided where wildlife goals are a priority, because these grasses are often highly competitive with native shrubs and forbs which may either be in the mix or are "volunteer" species.

Seed mixtures currently in use are the result of pre-disturbance site vegetation surveys and our secondary succession study. Preliminary indications are that seeded perennial grass species only serve to slow down secondary succession in relatively mesic sites (e.g., scrub aspen). Smooth brome (Bromus inermis) is especially competitive. However, some sites require rapid establishment of grasses and other vegetation to minimize erosion and/or alien weed invasion.

#### EXPERIMENTAL RECLAMATION, STUDY PLOTS, AND MONITORING

We have not discussed in detail the many techniques and methodologies which are currently being used experimentally at our various mine-sites. A partial listing follows: (1) indigenous seed collecting to improve establishment of native



species (Millar and Libby 1989), (2) planting of shrub wildings, bare-root shrubs, and containerized shrubs to supplement seeding efforts, (3) planting of trees on appropriate sites to increase vegetation diversity, (4) using willow stem-cuttings and "wattling" to stabilize steep slopes and provide diversity, and (5) using erosion control blankets to stabilize steep slopes.

In addition to our secondary succession study, we have established study plots for assessing various growth medium depths, soil amendments (fertilization and mulching), and wildlife use of reclaimed sites, etc. We are also carefully monitoring reclamation results (vegetation establishment) over time. Experience and information gleaned from these experimental efforts and study results, combined with the basics of what we already know about plant-soil-water relationships, will provide the basis for future reclamation efforts.

#### CONCLUSION

Concurrent reclamation in the hard-rock mines of the Great Basin is accelerating out of environmental, social, and legal necessity. As we look to the future, we must approach reclamation as a cost of doing business. But we believe that reclamation can be both economically feasible and effective in restoring land productivity. Continuing development of reclamation "success stories" will require the close cooperation of land managers, mine managers, engineers, renewable resource specialists, and equipment operators, all with a far-sighted understanding of post-mining land-use goals.

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RECLAMATION OF AN OPEN PIT/HEAP LEACH OPERATION  
IN THE NORTHERN BLACK HILLS OF SOUTH DAKOTA

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BACKGROUND

Wharf Resources operates a modern open pit gold mine and heap leach process facility in an historic gold mining district in the northern Black Hills of South Dakota. The operation was first permitted in 1982 and has been in continual operation since that time.

When first permitted, the mine plan involved one open pit and one heap leach pad. The ore was prepared by a 1500 ton per day crushing facility in a 3,000 ounce per week pyrometallurgical gold refining system. Since that time, the Annie Creek Mine has produced nearly 250,000 ounces of gold through development of the Foley Ridge ore deposit, four reusable heap leach pads, a 10,000 ton per day crushing facility and a 8-10,000 ounce per week gold refinery. Currently, the mine level disturbance consists of 410 acres with another 190 acres of associate level disturbance. The final reclamation plan identifies a post-mining land use of livestock grazing; however, additional planning was incorporated to create a secondary beneficial land use of interim or transitory wildlife habitat.

Geologically, the Black Hills are the eastern most extension of the Rocky Mountains. Topographically, the hills are steeply dissected with few valleys and open meadows, the overstory vegetation in the area is dominated by Ponderosa pine. The northern hills receives approximately 25-27 inches of precipitation on an annual basis. The soils are typical of forest soils and the predominant soil at the mine is classified as a Eutroboralf.

RECLAMATION STRATEGIES

The primary goals of the reclamation program at the Annie Creek Mine are to minimize localized impacts to the surrounding area through interim revegetation, and ultimately to create a permanent stable vegetative and edaphic environment, capable of supporting a properly managed livestock grazing system. In the non-backfilled mine pit area, the primary goal is to achieve an aesthetically pleasing, stable land form, that will have a beneficial use to recreationists and wildlife. In order to develop a plan that will allow us to achieve the specified goals it is imperative that the reclamation ecology of both the soil and vegetative environment in the area be fully understood. This information can then be incorporated with numerous on site specific

field studies as well as the utilization of a variety of field implemented reclamation techniques to produce the most stable and desirable reclamation product.

## Soils

The native soils associated with the mine area are typically shallow, rocky, undeveloped, young soils. The parent material associated with these soils is primarily Cambrian Age sedimentary formations. The average textural characterization of these soils is loamy, however clay substrates are often found. The soils are not acidic and, in fact, generally are neutral in pH. Cation exchange capacities generally range from 15 to 30 meq/100g and the predominant cation is calcium. Soil is salvaged at the Annie Creek Mine in a single lift operation utilizing bulldozers, trucks and shovels or scrapers. Due to the high density of mature trees in the area, after logging, it is necessary to grub the remaining root balls from a soil salvage area prior to removal of the thin topsoil layer. The soil is then stored in one of many soil stockpile locations, as direct haul of soil to reclaimed areas is generally not feasible. While direct haulage of a cover-soil media is clearly advantageous, the open pit hard rock mining method usually precludes a large amount of reclamation concurrent with disturbance.

As designed, the post-mining cover-soil will be deposited at a depth of approximately four inches. However, due to limited availability and the potential for site specific needs for additional cover-soil application, Wharf Resources has begun investigations of the use of sedimentary based waste material as a cover-soil. Roughly, 60 percent of the geologic material mined is sedimentary in origin. Except for nitrogen, the macro and micro nutrients, CEC, and pH appear to make this sedimentary overburden material suitable as a plant growth medium. The results of investigations performed on field test plots utilizing sedimentary waste rock material have indicated no observable difference between fertilized and non-fertilized plots when considered in both vegetation establishment and growth; provided that the initial seed mixture incorporated perennial legumes.

Due to the lack of suitable salvageable native soil, it is critical that investigations such as these are performed. Additional studies will concentrate on depths of cover-soil required for revegetation (i.e. soil wedge investigations to determine optimum cover-soil depths), long term vegetative performance, long term fertilization requirements, adjustment of the plant species composition to attain vegetative diversity and permanence, surface erosion control, and surface manipulation techniques for optimization of plant species diversity and water usage.

## Revegetation

As previously stated, an objective of the reclamation program at the Annie Creek Mine is to establish an immediate or interim vegetative coverage to minimize impacts to the surrounding area as a result of a large scale disturbance. Typical of early revegetation efforts, the initial success of each seeded species was not readily apparent. Therefore, widely used and often aggressive species were incorporated into the original seed mixture. For example, in the early 1980's smooth brome grass was a significant component of both the interim and final plant species seed mixture. The results of field investigations and general observations revealed that smooth brome grass compiled a significant percentage of the established vegetative component within two to three years after seeding. While this species has its place in forage based agricultural related environments, vegetative diversity was being sacrificed for the sake of vegetative production and cover. Therefore, to maintain an objective of relative species diversity in the post-mining landscape, smooth brome grass was omitted from the mixture.

Subsequent to the elimination of smooth brome grass from the herbaceous seed mixture, investigations were performed on native undisturbed vegetative communities adjacent to the mine area. Results of those observations revealed that a significant portion of the native vegetative community consisted of introduced perennial species such as Canada bluegrass and smooth brome grass. Because South Dakota does not currently have a native species criteria for reclamation bond release, Wharf Resources began to utilize adapted as well as native plant species in both the interim and final herbaceous seed mixture. Criteria for plant species selection into the final seed mixture was based on species adaptability to the reclaimed environment (based on field test studies, experience, and literature review), and functionality in regard to the post-mining land use. Table 1 lists the species currently in use at the Annie Creek Mine. These species are being tested at the mine in a number of reclamation study plots. More than likely, within the next five years the species that appear on this list will be revised according to results of studies conducted on areas that have been treated with native cover soil as well as sedimentary waste material as a plant growth medium. It is further envisioned that site specific seed mixtures will be constructed to attain specific goals within differing physiographic areas. As results of field studies are analyzed, Wharf Resources will propose to the regulatory authority to use a variety of species in a variety of settings based on the test results and professional discretion. Eventually, Wharf Resources may propose a species list from which select species can be taken to accomplish desired results. This technique will be in lieu of utilizing rigid and set species lists based on regulatory mandate. Wharf Resources feels that the optimum post-mining environment can be attained only through a flexible and objective approach to developing a plant species seed mixture. A number of species have been field tested at the Annie Creek Mine. Future seed mixtures will incorporate data derived from field tests of these species.

**SEED MIX FOR REVEGETATING WASTE SITES AND MINE BENCH AREAS  
AT THE ANNIE CREEK MINE**

<b>SPECIES</b>	<b>PLS*/ACRE</b>
Legume (Vetch)	1.5
Legume (Clover)	1.0
Slender Wheatgrass	3.0
Thickspike Wheatgrass	2.0
Hard Fescue	5.0
Timothy	2.0
Bearded or Bluebunch Wheatgrass	3.0
Russian Wild Rye	4.0
Canada Bluegrass	3.0
<b>TOTAL</b>	<b><u>24.5</u></b>

\*PLS = Pounds Pure Live Seed

Vegetation establishment can often times be accelerated by remodification of micro-climates associated with the seedling environment. The objectives of micro-climate modifications are site specific in nature.

Generally, seedbed preparation in areas that have received salvaged cover-soil is not an elaborate procedure at the Annie Creek Mine. Erosion and soil compaction are not significant problems in the northern Black Hills. Therefore, seedbeds are typically prepared by spreading cover-soil with a small bulldozer. Experience has shown that the dozer tracks provide optimum seedbed firmness and configuration. Other methods of seedbed preparation have been tested at the mine and have proven to be less effective than utilizing the dozer to both spread cover-soil and prepare the seedbed. Additional tests are planned for the use of modified cultipackers. Traditional seedbed preparation equipment is not feasible in the reclaimed environment at the Annie Creek Mine due to slope steepness and the extensive amount of rocks in the native soil material.

Seeding is accomplished exclusively by the hand broadcast method. Field experience has shown that brillion type seeders or drill type seeders were proven ineffective in seed distribution, due to the rough and steep terrain.

Hydromulching is a technique familiar to high elevation hard rock mining reclamation programs. However, cost analysis at the Annie Creek mine combined with subsequent seedling establishment investigations have revealed that hyromulching is not as efficient as compared to other means of modifying the seedling establishment environment. It was found at the Annie Creek Mine that hydromulching requires additional roads to be constructed in and around the areas to be reclaimed, resulting in increased reclamation costs and unnatural post-mining contours. Alternatives to hydromulching include straw mulching which can be performed concurrent with seed bed preparation and seeding. Straw mulch applied at a minimum rate of one ton/acre was, however, complicated by the inability to keep the straw on the reclaimed slopes. High winds peculiar to high elevation environments were found to contribute to a loss of straw from the reclaimed slope. Therefore, investigations were initiated in 1989 using straw mulch covered with a loose solar degradable netting material (3/4 inch square grid). The majority of the cost associated with the netting material involves the labor associated with installation. Preliminary cost analysis indicate that straw mulching and netting over a seeded area is essentially the same as hydromulching. The advantage of using the straw mulch and net is that netting does not require additional roads and the net can be applied by unskilled mine labor.

The use of cover or nurse crops was investigated at the Annie Creek Mine. Results obtained from numerous field test plantings and specifically designed test plots revealed that nurse crops of small



grains (millet, oats, winter and spring wheat) are of questionable assistance in the establishment of a perennial herbaceous cover. Nurse crops have been used in two ways: 1) in combination with a perennial seed mixture; and, 2) seeded prior to the additional seeding of the perennial species.

Limited rainfall during three previous growing seasons has undoubtedly had an effect on the establishment of the nurse crop species. However, test results reveal that Fall seeded perennials established more rapidly than perennials seeded with a companion nurse crop. The perennial species were seeded at roughly a one-third higher rate than were the companion or nurse crop test plots. Cost analysis indicated that the straight perennial seeded areas would support a one-third higher seeding rate when compared to the seed cost of the nurse crop plus the perennial species. The additional labor involved with reseeded into a nurse crop and the loss of production involved in waiting an additional growing season after the nurse crop species are seeded may have significant long term cost effects. Additional investigations are currently being performed to analyze the effect of nurse crops seeded concurrently with perennial species. Initial observations of a 1989 nurse crop/perennial species seeded area on a slope of 2.3:1 indicated that the small grain species provided rapid establishment of a vegetative component; however, the final results of this experiment will not be available for another two years. Once the final investigations are complete in this regard, a modification of the seeding technique may be warranted.

Aesthetically and politically it is necessary in South Dakota to incorporate a woody species component into the final reclaimed scenario. Therefore, Wharf Resources has conducted field investigations on the establishment of transplanted containerized and bareroot shrub and tree species during the last five growing seasons. A list of those species tested is found in Table 2. The results of woody species viability investigations revealed that tree and shrub establishment in the reclaimed environment is complicated by wildlife predation. It is certainly not a new revelation that wildlife are drawn to reclaimed environments. This appears to be accentuated in the northern Black Hills due primarily to the creation of new and diverse ecotypes within a general overstory monoculture of ponderosa pine. Furthermore, it appears that wildlife are opportunistically seeking the younger and potentially more palatable herbaceous and woody species planted in the reclaimed areas. Because the reclaimed environment seems to have created a virtual smorgasbord for a variety of wildlife species, Wharf Resources has investigated the use of physical and chemical wildlife deterrents when trying to establish woody species. During the 1988 and 1989 growing seasons, tree and shrub species were placed inside plastic containers designed to protect the plant from predation and desiccation. The preliminary results of these tests indicated that predation was reduced and viability slightly increased; however, a more long-term investigation is warranted. During the 1989 planting season, bareroot stock was treated with a systemic chemical designed to deter wildlife

predation. Test plots were constructed in an area that deer were known to frequent. Initial observations were encouraging but inconclusive and are awaiting further investigation during 1990. Future investigations will concentrate on the longevity of the chemical application as well as the overall effectiveness in regard to tree and shrub establishment and growth as effected by wildlife predation.

The difficulty experienced in establishing a viable rapidly growing tree and shrub component in the reclaimed environment prompted the review of alternative techniques for establishment of a tree and shrub component. During the 1989 growing season, reclamation specialists at the mine investigated the use of transplanted native tree and shrub pads into the reclaimed environment. To accomplish this, a recipient reclaimed area was prepared for the transplantation of a native tree and shrub pad. The pads were roughly four foot by six foot and two to three feet deep. To prepare for the pad, the area was excavated, (roughly to those same dimensions) in the reclaimed area. The pad was extracted with a small track mounted crawler loader that could maneuver in the natural terrain without causing additional disturbance. The pads were selected for transplant based on the primary woody species present in the pad, the age of the tree, and the overall health of the tree and shrub species. Once removed from the native environment, the pad was quickly taken to the reclaimed area to minimize the potential for desiccation of the root systems. The pads were then placed in the prepared area and compacted using the tracks from the crawler/loader. The pads were watered twice after transplanting and were evaluated weekly throughout the summer. Results of those evaluations revealed that ponderosa pine was not as initially susceptible to this type of program as was the deciduous trees and shrubs. However, these plants have not gone through an entire growing season and will be subject to further evaluation for winter hardiness during the spring of 1990.

The criteria for selection for the primary species in each transplant was based on aesthetics and the ability of that species to further propagate in the reclaimed environment. For instance, Aspen trees were selected due to their rhizomatous nature. Shrub species were also selected based on their ability to reproduce vegetatively as well as their potential for sexual reproduction. The primary objective in undertaking this project was to add a more mature tree component to the reclaimed area for primarily for aesthetic purposes; however, the advantage of applying a native seed source to the reclaimed area was also evaluated as a potential benefit.

An additional technique employed in 1989 involved the direct haul of native cover-soil material to a reclaimed area. A section of undisturbed aspen forest was targeted for the direct haul of soil to a waiting recontoured slope. The objective of this salvage operation was to effectively transplant aspen rhizomes to the reclaimed landscape. While we have no results on the success of this operation, it has been observed in the reclaimed area that native shrubs and forbs were

Table 2. Bareroot tree and shrub species planted at the Annie Creek/Foley Ridge Mine between 1985 and 1988.

Shrubs (deciduous)

American Plum	Honeysuckle
Amur Maple	Lilac
Buffaloberry	Mayday
Caragana	Nanking Cherry
Cotoneaster (Peking)	Nannyberry
Cottonwood ((Robust)	Sand Cherry
Crabapple	Scarlet Mongolian Cherry
Dogwood (Red osier)	Silver Buffaloberry
Golden Current	Snowberry
Golden Willow	White Willow

Trees (deciduous)

Burr Oak  
 Green Ash  
 Hackberry  
 Harbin Pear  
 Mid-west Crabapple  
 Russian Olive  
 Siberian Crabapple  
 Western Chokecherry

Trees (coniferous)

Colorado Blue Spruce  
 Eastern Red Cedar  
 Ponderosa Pine  
 Rocky Mountain Juniper  
 Scotch Pine

beginning to become reestablished. It is our hope that aspen will also follow this pattern.

#### Surface Manipulation

The two most critical components to revegetation of a disturbed site are soil and water. Conservation and control of both these parameters is paramount to both the establishment and maintenance of a vegetative component in reclamation. While in the northern Black Hills we are blessed with an abundance of moisture in normal years, it is absolutely critical that we conserve and maintain an adequate soil environment for vegetative establishment. This charge is complicated by irregular terrain as well as steeply constructed slopes. Therefore, we have modified a concept of soil and water control utilizing regular mine equipment.

In 1987, we began a program to investigate the use of waste material as a cover-soil. To maximize the slope roughness and increase the amount of water retained on the reclaimed slope, we instituted a program of surface manipulation utilizing a D-3 Caterpillar bulldozer to create strategically placed water catchment basins. Steep slopes that have a high erodibility potential will have deeper and more frequent dozer basins than those of a more gently sloping contour. The basins are designed to catch water, and potentially eroding soil into the bowl of the basin. Overflow water from the basin would exit on the sides and drain directly into another receiving basin. Figure 1 illustrates a typically designed pattern of dozer basins disseminated across a slope of something less than 3.0:1. The advantages to these surface manipulation techniques are numerous. Aside from the obvious conservation of soil and water, the dozer basins provide deviations in localized microclimates that will, in time, provide for the development of a more diverse vegetative species component. The bowl or bottom of the basin receives the majority of the surrounding moisture and therefore creates a more mesic environment when compared to the crest of the basin, which is naturally more xeric. In addition, the bowl of the basin also provides an excellent location for the planting of bareroot or containerized tree and shrub stock. The crest, or the berm of the basin, also provides a climate modifier for both sun and wind. Furthermore, the basins will work as modified wind fences and allow snow to build in the bowl of the basin, thereby protecting newly established vegetation during the more hostile winter seasons.

To the untrained eye, the dozer basins initially appear as an unordered attempt at soil recontouring. However, experience has shown that over time and dependent on soil types, the basins will naturally fill with sediment from surrounding basins. Eventually, the basins will reach equilibrium with the vegetative community to reduce the amount of soil translocation and ultimately develop a more modified and less hummucky appearing landscape.

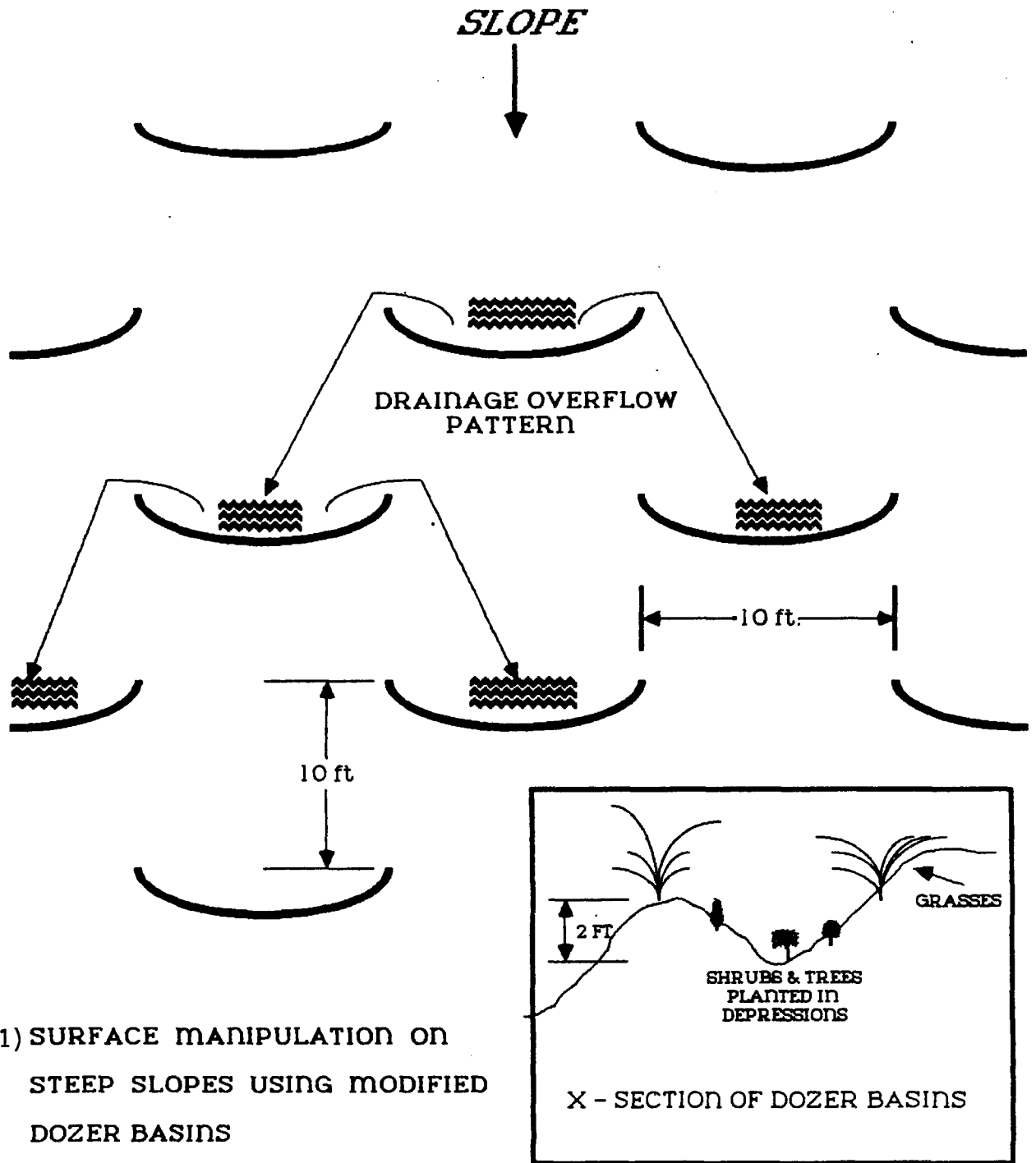


Fig. 1) SURFACE MANIPULATION ON  
STEEP SLOPES USING MODIFIED  
DOZER BASINS

At the Annie Creek mine, the use of this type of surface manipulation has proven to be effective in controlling erosion, and establishing vegetation on fairly steep slopes. However, due to the extreme cost involved in implementing these features, their use is restricted to those most difficult to reclaim slopes. We have modified the design of this technique using larger bulldozers on steeper slopes to create a site specific desired effect. We have also compared the results of this type of surface manipulation to a more conventional terrace or horizontal berm and found that the long term effectiveness of this type of surface manipulation is ecologically and economically more cost effective.

Other types of surface manipulation techniques employed at the Annie Creek mine are oftentimes traditional and seemingly unimaginative, but are equally as effective in certain conditions. When discussing recontouring with an equipment operator, we have found that it is imperative to emphasize that roughness is more desirable than smooth. This is often a difficult task, especially with operators that are not familiar with reclamation techniques. We have also, in the past utilized a very simple technique that is restricted to more gently sloping recontoured areas. That technique involves the equipment operator maneuvering the tractor along the contour in a serpentine pattern. This technique has been effective in establishing a sufficiently rough terrain so as to assist in the establishment of tree and shrub plantings as well as herbaceous cover. Aside from the cost involved with this operation, it proved to be exceptionally hard on the equipment and it was not uncommon for the dozer to lose its track during this maneuver. The replacement of the track is both time consuming and difficult and over time, creates an undue wear on the equipment. Therefore, this technique is no longer employed.

Lastly, we also stress the salvage of small twigs and tree parts with the cover-soil. Once reapplied, the area becomes difficult to negotiate from a human standpoint, however, the added debris has proven beneficial for the establishment of vegetation and as hiding cover for small mammals and birds.

#### MINE BENCH RECLAMATION

Backfilling in an open pit operation such as the Annie Creek mine is not always a feasible option. Therefore, it was critical to design a reclamation plan that would incorporate as aesthetically pleasing natural conditions as possible. The Black Hills are full of large rock outcroppings and canyons of exposed rock, therefore, in designing a reclamation plan for the mine bench areas, we investigated numerous natural rock outcrops and highwalls. The overall height, stability and extent of these natural features was investigated. The results of those observations were then incorporated into a design for the reclamation of the mine benches left in the post-mining landscape. Natural highwalls are commonly bordered by grass or tree-covered slopes and are generally quite unevenly dissected. Talus slopes are often associated with less

stable rock formations. All of these areas provide specialized habitat for a variety of terrestrial and avian wildlife species. Therefore, to facilitate the aesthetics of highwall configurations in combination with wildlife habitat improvement areas. The mine pit benches were constructed to provide natural ties with the surrounding topography and an undulating diversity in highwall faces. Talus slopes will be left in those areas of less stable rock formations to provide vertical access to horizontal benches for terrestrial wildlife. The rock formation diversity will be created through selective blasting techniques employed during the final push-back phase of open pit mining. This technique provides an economical method of accelerating natural weathering processes to facilitate natural appearing, aesthetically pleasing final land forms. This type of land sculpting in combination with revegetation along the borders of the mine benches yields an attractive, natural appearing, stable land form.

#### SUMMARY

The Wharf Resources Annie Creek Mine, located in the Northern Black Hills of South Dakota actively pursues a diverse reclamation scenario designed to meet ecological, economical and political mandates required to actively mine in a highly scrutinized environment. Revegetation investigations designed to test both native and introduced plant species are continually being evaluated so as to develop a diverse, permanent vegetative component to the reclaimed landscape. Reclamation techniques such as the selective use of native and naturalized cover-soil combined with an aggressive reclamation testing program have revealed numerous reclamation techniques designed to coexist with the dynamics of the Black Hills ecology. Specialized recontouring and surface manipulation utilizing regular mine equipment has increased slope water-holding characteristics and decreased the loss of precious natural cover-soil while increasing vegetative establishment. Creative land sculpting techniques combined with the manipulation of topographic diversity in mine bench areas has produced an aesthetically pleasing and ecologically sound post-mining feature. The reclamation program at the Annie Creek Mine will continue to investigate new and creative dimensions in reclamation to produce an economically viable and ecologically stable reclamation product to design to facilitate designated primary and secondary post-mining land uses.

**POSTER SESSION PAPERS**



**In vitro multiplied Poa alpina  
(alpine bluegrass) as seed source  
for high altitude revegetation**

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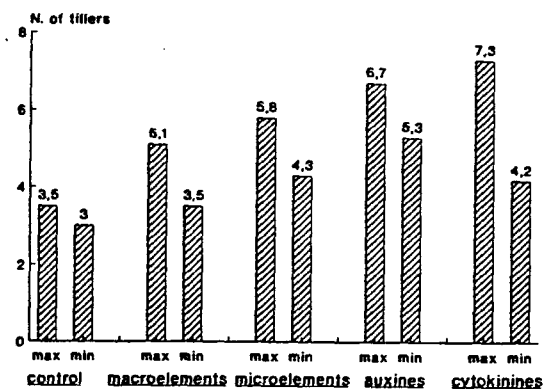
- Division Natural Hazards and Upland Erosion Control -  
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Alpine bluegrass is very successful in pioneer alpine sites. Its utilization as seed material in high altitude revegetation requires large seed harvest. To produce many seed-bearing plants, in vitro multiplication was studied.

In laboratory trials an optimal culture medium for Poa alpina has been worked out : the resulting multiplication rates corresponded to ca. 6 tillers per initial plant within five weeks.



*single tillers of Poa alpina  
cultivated in vitro*



**Multiplication of Poa alpina  
in various culture media**

On the whole, the results obtained were very satisfactory in all series, but the best seed yield occurred at ca. 3700 ft in sunny sites with rich soil. In these conditions ca 4cwt/acre have been harvested : this yield corresponds to French commercial norms.

The seeds developed at lower altitudes were lighter than those produced in high-alpine sites, but their viability was not impaired.

The seed material obtained from in vitro multiplied alpine bluegrass will be used in mixture with commercial varieties for high altitude revegetation in the French Alps esp. on machine-graded ski runs.

In this way, exceedingly large amounts of plants can be obtained independently of season/weather conditions, and then used either for seed production or directly as implants.

The individuals issued from in vitro multiplication were tested for general performance and seed output in various experimental plots.

## NATIVE LEGUMES OF THE SWISS ALPS IN HIGH ALTITUDE REVEGETATION RESEARCH

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Legumes play an important role in biological erosion control because they fix nitrogen in their root nodules and thus stimulate biological soil activity.

Our research program includes 14 native Alpine taxa. Their behaviour is exemplified here by *Trifolium alpinum*, *T. nivale* and *Astragalus alpinus*.

### Seeding experiments:

Germinating behaviour, early life-phases and development of plants were studied in laboratory and field trials which included both scarified and non-scarified seeds. Scarified seeds of all taxa germinated very well, while non-scarified seeds behaved differently: only few seeds of *T. alpinum* germinated, whereas the seeds of the other taxa germinated well but less rapidly.

The development of *T. nivale* was very rapidly. *A. alpinus* developed not so fast and *T. alpinum* very slowly. However, in the field trials only *T. alpinum* showed a good survival and establishment.

### Planting experiments:

The legumes originating from natural populations were multiplied according the SRC-method; the clonal modules developed were then planted onto ski run plots.

The taxa studied responded differently to the SRC-treatment; these differences may be related to the root morphology. *T. alpinum* had a big mortality rate and formed hardly new roots; in *T. nivale* and *A. alpinus*, the rooting followed quickly and after 6 weeks of cultivation well-developed root nodules appeared.

Behaviour of the clonal modules in field trials was marked by their good survival, but growth and onset of flowering differed from one taxon to another. Species which formed a considerable root system (including root nodules) after SRC-treatment, distinguished good growth and quick flowering. So, *T. nivale* and *A. alpinus* flowered and produced seeds already one year after planting.

## Plant Materials - New Releases

by

Wendel G. Hassel and Sam E. Stranathan  
USDA Soil Conservation Service

New varieties spell out opportunities for revegetation success. Documentation compiled by Plant Material Centers in the Western United States and Alaska support the performance and use of a growing list of successful plant materials.

Support information is provided with the formal release of each new material. Release criteria differ somewhat in each state, but you can be assured that each material can stand on its own. Release information is the best guide you have as a potential user of the new plant material product.

You must be alert to two major areas of concern relative to new releases. The first relates to the area of adaptability. Release information describes rather elaborately the specific region of the plant's origin and its tested area of adaptability.

Often the total area of adaptability cannot be determined in order to get new, good materials out to the public on a timely basis. The testing process concentrates on the most significant area of use and reflects the areas financially supported by the testing facility. The testing of each new plant material encompasses a period of ten to fifteen years.

What does this mean to you, the user? If you have an interest in a species and there is a released variety, you will help yourself by obtaining the release information. Often you are dealing with a site not specifically described in the area of adaptability, yet you feel comfortable that the species has application to your job. We suggest you take some risks, and try the product. Another option is to encourage the expansion of trials through your relationship with your local Soil Conservation District.

The second area of concern deals with commercial availability. The information on new varieties may reach the user groups before the production can meet even a minimal demand. Until the plant is released, there is no reasonable method to predict the market. More importantly, there is no buyer commitment that might stimulate a producer to gamble.

Where does this leave the interested user? It is appropriate to first contact your commercial seed/plant supplier. This fortifies to him that a market exists. Secondly, most commercial seed production is handled by the Seed Certification Agency listed on the release. The option beyond the commercial market is to learn from the Seed Certification Agency if growers exist for the product. Again, your contact encourages grower interest.

You can contact the primary agency responsible for the testing and release of each plant material. The testing facility will be tracking production, and their name will be listed on the release notice/information. They are interested in the success of the product.

For some products you may find it feasible for you or your company to increase the materials on a small scale basis.

## RECENT RELEASES

## Cultivar: "PETE" Eastern Gamagrass

Scientific Name: *Tripsacum dactyloides*

Uses: "Pete" is suited for pasture, hay, wildlife plantings, and reestablishment of native prairie on sites where eastern gamagrass occurred naturally. It can be grown farther west on irrigated or subirrigated sites.

Primary Agency: Manhattan Plant Materials Center (PMC) - Kansas

## Cultivar: "Pronghorn" Prairie Sandreed

Scientific Name: *Calamovilfa longifolia*

Uses: "Pronghorn" is suited for revegetating sandy sites in the Nebraska sandhills and northwest Kansas.

Primary Agency: Manhattan PMC - Kansas

## Cultivar: "Forestburg" Switchgrass

Scientific Name: *Panicum virgatum*

Uses: It is used singly or in warm season mixes for livestock forage on rangeland, pasture and hayland. It is excellent for wildlife habitat, critical area seedings, roadside cover, and erosion control.

Primary Agency: Bismarck PMC - North Dakota

## Cultivar: "Dakota" Switchgrass

Scientific Name: *Panicum virgatum*

Uses: It is used singly or in warm season mixes for livestock forage on rangeland, pasture, and hayland. It is excellent for wildlife habitat, critical area seedings, roadside cover, and erosion control.

Primary Agency: Bismarck PMC - North Dakota

## Cultivar: "Tomahawk" Indiangrass

Scientific Name: *Sorghastrum nutans*

Uses: It is used singly or in warm season mixes for livestock forage on rangeland, pasture, or hayland. It is excellent for wildlife habitat, critical area seedings, roadside cover, and erosion control.

Primary Agency: Bismarck PMC - North Dakota.

## Cultivar: "Bonilla" Big Bluestem

Scientific Name: *Andropogon gerardi*

Uses: It is used singly or in warm season mixes for livestock forage on rangeland, pasture, or hayland. It is excellent for wildlife habitat, critical area seedings, roadside cover, and erosion control.

Primary Agency: Bismarck PMC - North Dakota.

## Cultivar: "Bison" Big Bluestem

Scientific Name: *Andropogon gerardi*

Uses: It is used singly or in warm season mixes for livestock forage on rangeland, pasture, or hayland. It is excellent for wildlife habitat, critical area seedings, roadside cover, and erosion control.

Primary Agency: Bismarck PMC - North Dakota.

## Cultivar: "Goldar" Bluebunch Wheatgrass

Scientific Name: *Pseudoroegneria spicata* (*Agropyron spicatum*)Uses: It is used for livestock forage on rangelands, critical area seedings, weed control (particularly *Bromus tectorum*), vegetation firebreaks, and mine spoil reclamation.

Primary Agency: Aberdeen PMC - Idaho

## Cultivar: "Pryor" Slender Wheatgrass

Scientific Name: *Elymus trachycaulus* (*Agropyron trachycaulum*)

Uses: It is used for livestock forage in short rotations, for hay or pasture. It is ideal in mixtures for conservation and reclamation plantings. It does well on areas of moderate salinity.

Primary Agency: Bridger PMC - Montana

## Cultivar: "Egan" American Sloughgrass

Scientific Name: *Beckmannia syzigachne*

Uses: It is used for reclamation or erosion control plantings in seasonally wet areas such as ditches, streambanks, or fresh water shorelines. It is recommended for waterfowl habitat.

Primary Agency: Alaska PMC - Palmer, Alaska.

## Cultivar: "Service" Big Bluegrass

Scientific Name: *Poa ampla*

Uses: It is used for erosion control, reclamation, stabilization, habitat enhancements and landscaping.

Primary Agency: Alaska PMC - Palmer, Alaska.

## Cultivar: "Gruening" Alpine Bluegrass

Scientific Name: *Poa alpina*

Uses: It will be used for erosion control, highway revegetation, and reclamation on a range of sites from streambanks to gravelly alpine sites.

Primary Agency: Alaska PMC - Palmer, Alaska.

## Cultivar: "Regal" Desertwillow

Scientific Name: *Chilopsis linearis*

Uses: It can be used for landscaping and erosion control on streambanks.

Primary Agency: Agriculture Exp. Station, N. M. State University, Las Cruces, New Mexico.

## Cultivar: "Centennial" Cotoneaster

Scientific Name: *Cotoneaster integerrima*

Uses: It is used in multi-row and single row windbreaks, recreational developments, plantings on transportation and transmission corridors. It provides food and habitat for wildlife.

Primary Agency: Bismarck PMC - North Dakota

## Cultivar: "Caiggluk" Tilesy Sage

Scientific Name: *Artemisia tilesii*

Uses: It is used for reclamation achieving erosion control and plant diversity. It tolerates a broad pH spectrum and a range of heavy metals.

Primary Agency: Alaska PMC - Palmer, Alaska.

Cultivar: "Oliver" Barren Ground Willow

Scientific Name: *Salix brachycarpa*

Uses: It is used for landscaping, reclamation, windbreaks, and erosion control. It's an important source of food and shelter for wildlife.

Primary Agency: Alaska PMC - Palmer, Alaska.

Cultivar: "Wilson" Bebb Willow

Scientific Name: *Salix bebbiana*

Uses: It is used for landscaping, screenings, living fences and windbreaks. It's an important source of food and habitat for wildlife.

Primary Agency: Alaska PMC - Alaska.

Cultivar: "Long" Barclay Willow

Scientific Name: *Salix barclayi*

Uses: It is used for landscaping, windbreaks, and reclamation. It's an important source of food and shelter for wildlife.

Primary Agency: Alaska PMC - Palmer, Alaska.

Cultivar: "Roland" Pacific Willow

Scientific Name: *Salix lasiandra*

Uses: It is used for landscaping, riparian protection and restoration, screening windbreaks, and reclamation. It's an important source of food and cover for wildlife.

Primary Agency: Alaska PMC - Palmer, Alaska.

Cultivar: "Rhode" Feltleaf Willow

Scientific Name: *Salix alaxensis*

Uses: It is used for, streambank restoration, erosion control and windbreaks. It is an important source of food and cover for wildlife.

Primary Agency: Alaska PMC - Palmer, Alaska.

## SEED DORMANCY IN NATIVE ALPINE PLANTS AND IMPORTANCE OF THE SEED PRETREATMENT TO HIGH ALTITUDE REVEGETATION

Martin Schuetz, Geobotanical Department, Swiss Federal Institute of Technology, Zurich, Switzerland

Reproduction by seed in alpine plants involves various risks; seed dormancy occurs thereby frequently preventing seeds from germination under unfavourable conditions. One of the most common types of innate dormancy is related to a hard seed coat restricting water and/or gas exchange. This dormancy can be broken by scarification.

The following germination responses after scarification often are representative of families both under laboratory conditions and in the field:

**Leguminosae:** All seeds germinate after scarification. The seed coat is the only cause of innate dormancy.

**Caryophyllaceae:** Some scarified seeds germinate rapidly, the others remain dormant. The seed coat represents but one of numerous factors influencing dormancy. Innate dormancy is created by seed coat impermeability to water and inactive embryos.

**Compositae:** Germination accelerates after scarification, but the percentage of germinated seeds remains unaltered. The seed coat apparently does not cause dormancy, but affects the absorption of water and/or radicle development. Innate dormancy is probably created by inhibitors in the embryo.

The understanding of dormancy mechanisms is very important in preparation of the seed material for high altitude revegetation.

Seedling emergence from scarified seeds is successful in species in which the seed coat is the only cause of dormancy (e.g. Leguminosae). Scarified seeds of Caryophyllaceae and Compositae therefore are not suited to seedings above timberline.

**Leguminosae:** Sowing of scarified seeds is effective only after the snowmelt, but not at the end of the season; non-scarified seeds may be sown at any time.

**Caryophyllaceae:** Emergence and seedling establishment of non-pretreated seeds usually is more successful when seeds are sown at the end of the vegetative period. These differences are exemplified by *Silene wildenowii*, where seedling emergence in early summer seedings corresponded to 44 percent, but was considerably better (76 percent) in late summer seedings.

## Single-ramet-cloning (SRC) and multi-ramet-cloning (MRC): an example of basic AND applied revegetation research

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### Alms:

- basic - Study on regeneration of plants after a considerable damage  
 applied - erosion control of alpine ski runs and economical use of native plant material

Regeneration in plants is understood here as building anew of organs and tissues of an individual after a dieback or a seasonal damage)\*. Regeneration of populations and/or ecosystems shall not be dealt with.

### Questions:

- basic - How big is an individual regeneration capacity?  
 - Is the regeneration capacity genetically fixed or depending on ecological conditions?  
 - Is the regeneration capacity recognizable independently in growth and reproduction, i.e. Is there a trade-off between both mechanisms?  
 applied - Which species and which methods are optimally suited to revegetation purposes (Fig. 1)?  
 - Which hazards are decisive for failure and success of revegetation, and how can plants be protected against them?

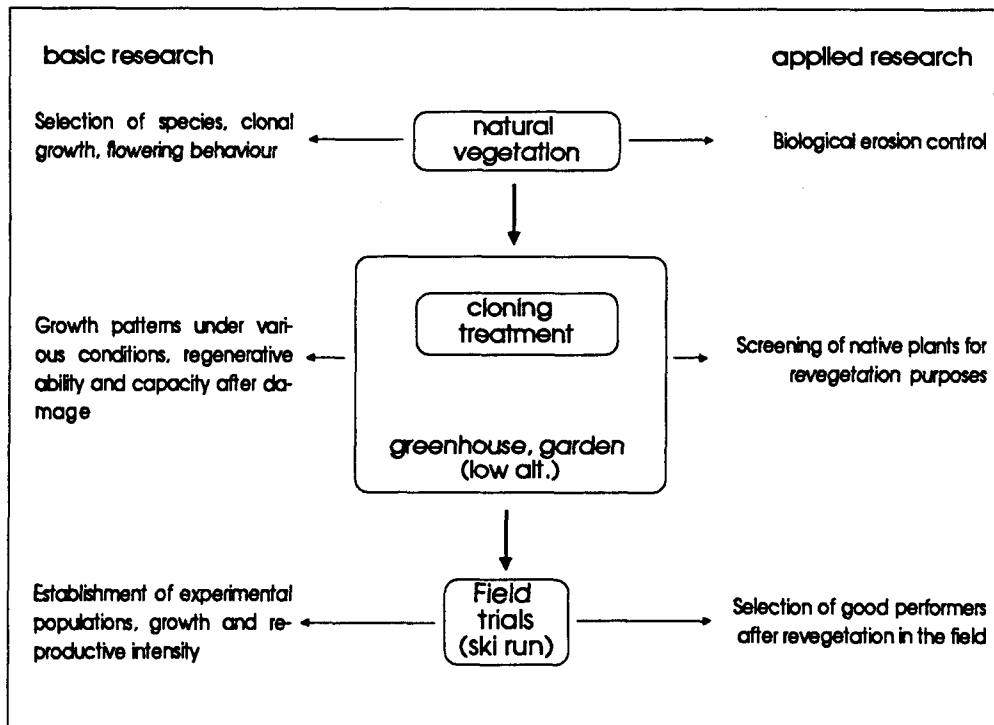


Fig. 1 Basic and applied research as complements.

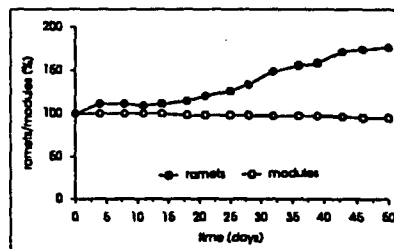


## - Cloning treatment -

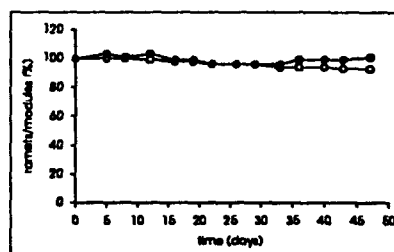
### Basic aspects

Cloning results in separation of a whole clone or a clone part into single ramets (SRC-treatment) or ramet groups (MRC-treatment). The following patterns of regenerative growth were observed after only one SRC-treatment (Tschurr 1988):

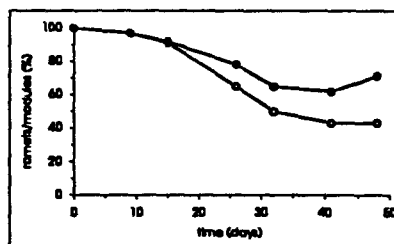
I Increase of rametnumber:  
*Campanula cochlearifolia*



II constant number of ramets:  
*Myosotis alpestris* (Ca<sup>\*\*</sup>)

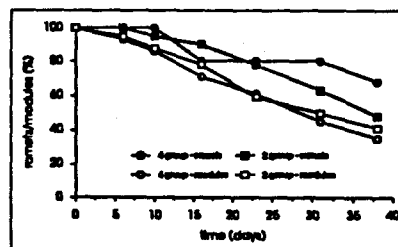


III Decrease of rametnumber:  
*Helictotrichon versicolor* (Si<sup>\*\*</sup>)



The regenerative behaviour of the plants cloned is mostly influenced by particular growth strategies as well as ecological factors. It does not depend on taxonomical rank. The taxa with clonal growth of the "guerilla"-type apparently are better suited to cloning than the "phalanx"-plants\*.

One MRC-treatment is supposed to be less extreme than an SRC-treatment, it was applied specially to plants with growth type III.



MRC-treatment: *Helictotrichon versicolor* (Si<sup>\*\*</sup>)

Similarly to the SRC-series, the behaviour of plants in the MRC-trials shows a great diversity and variability. MRC-treatment doesn't seem to be advantageous.

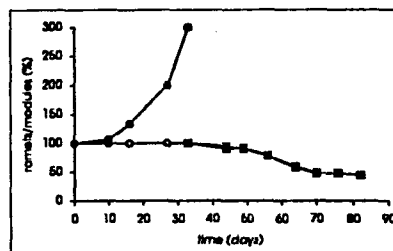
\* for classification see Lovett-Doust 1981

\*\* Ca = carboniferous, Si = siliceous soil

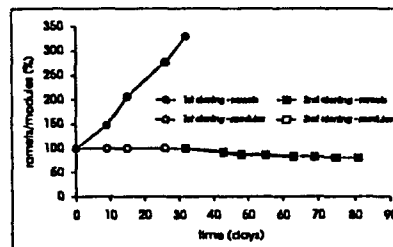
## - Cloning treatment -

Repeated SRC-treatment was applied to estimate the limits of individual regeneration capacity.

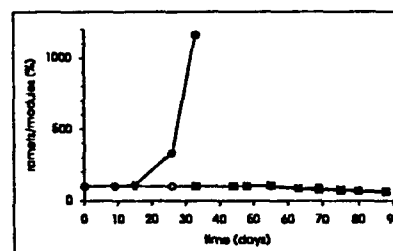
Repeated SRC: *Senecio carnolicus*



Repeated SRC: *Myosotis alpestris* (Ca)



Repeated SRC: *Chrysanthemum alpinum*



Already the second SRC-treatment wasn't tolerated well. Apparently it is important for the plants to produce many ramets within a short time, even at the expense of future performance, than to ensure good fitness.

### Applied aspects

Of 24 studied taxa 11 performed sufficiently well to be utilized on ski runs. Modules of these 11 taxa could be multiplied on average 1.6-times. With  $1 \text{ m}^2 = 840$  cloned modules,  $16 \text{ m}^2$  ski runs can be revegetated.

Multi ramet cloning is not worthwhile, as the same amount of revegetation material can be obtained from SRC-treatment. With repeated SRC-treatment there is no better number of modules receivable, too.

## - Field trials (ski run plots) -

### Basic aspects

**Tab. 1** Survival and growth in the field plots

species groups	number of modules/ramets		
	4.8.87	11.8.88	24.7.89
<i>Gramineae</i>	120/	93/603	94/850
<i>Cyperaceae</i>	80/	66/158	66/202
<i>Ranunculaceae</i>	80/	73/99	75/117
<i>Cruciferae</i>	40/	32/144	27/119
<i>Boraginaceae</i>	75/	75/196	75/194
<i>Campanulaceae</i>	40/	30/182	29/253
<i>Compositae</i>	165/	119/231	103/213
Total modules/ramets	600/	488/1613	469/1948



**Fig. 2** Field plot (Ca)

Survival on both soil types is good, on carboniferous soil a further growth has been observed. In several taxa flowering occurred already in the first season after planting. Ecological factors strongly influence plant behaviour in the field trials.

### Applied aspects

Several taxa manifested an intensive clonal growth and self-seeding in natural conditions. This behaviour supports the revegetation of ski runs. To save plant material, a minimum density, that still offers enough safe sites for immigrants, was figured out. Safe site conditions were simulated with Curlex®, too. A direct-cloning treatment as a second application after the SRC-treatment was tested. No fertilizer and additional treatments were applied.

### References

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- Tschurr F.R. 1988: Regeneration in some alpine plants. *Ber.Geobot.Inst.ETH, Stiftung Rübel, Zürich* 54, 111-140.
- Urbanska K.M. 1985: Some life history strategies and population structure in asexually reproducing plants. *Bot.Helv.* 95(1), 81-97.

## **Revegetation of overgrazed alpine and subalpine areas in South Tyrol/Italy**

Thomas Wilhalm, Department of Botany, University of Innsbruck/Austria and Florin Florineth, Regional Service of Soil Protection and Avalanche Control, Bozen/Italy.

### **Erosion danger**

The extensive erosion in Alpine areas of South Tyrol results from deforestation and overgrazing, and is further promoted by easily-weathered substrata and the steep slope relief. Revegetation at ca. 6100 - 8400 ft. (subalpine-alpine belt) is supervised by Regional Service of Soil Protection and Avalanche Control, Bozen, Italy (RSSPAC).

### **Revegetation work**

Earlier revegetation included commercial non-native seed material only; the resulting plant cover had to be constantly maintained. From 1978 on, seeds of some native species, harvested in the wild and further multiplied in a Service-owned facility, are used in mixture with commercial varieties (Fig.1).

The current revegetation programme of RSSPAC includes as well native species implants. The single-ramet cloning (SRC) introduced by URBANSKA (1986) is followed to obtain large quantities of clonal modules. Two different revegetation techniques were applied so far:

- A. In suitable large surfaces, mixtures of commercial and native seed were sown. The gaps in the resulting plant cover were then planted with clonal modules.
- B. In steep bare slopes particularly exposed to erosion, seeding was unsuccessful. In these areas considerable amounts of clonal modules were thus planted by hand, covered by loose straw, and then stabilized with jute nets.

The combined seeding-planting method proved to be optimally suited to the difficult site conditions. About 50,000 clonal units were planted throughout the summer 1989 (Fig.2).

### **Successful revegetation**

In areas revegetated 12 years ago with commercial seed mixed with a single native species, numerous native plants spontaneously immigrated. The erosion control is assured, yet the commercial varieties still represent the main vegetation component. However, the aim of our revegetation work is to obtain a plant cover closely resembling a natural vegetation. The commercial plant material, if and when used, should help to establish a pioneer plant cover and subsequently be replaced by native species.

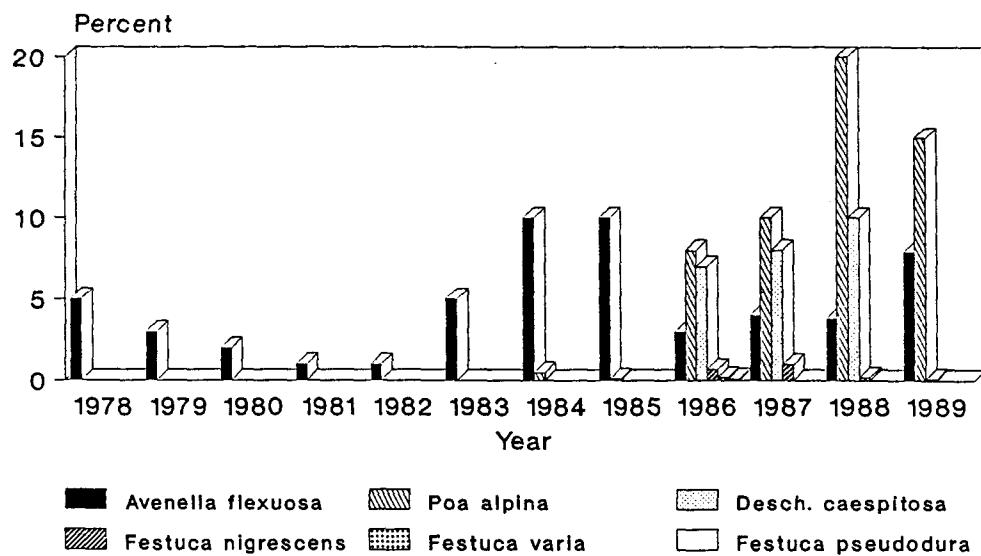


Fig. 1 Percentage of native species in the seed mix. Variability of seed composition is due to availability.

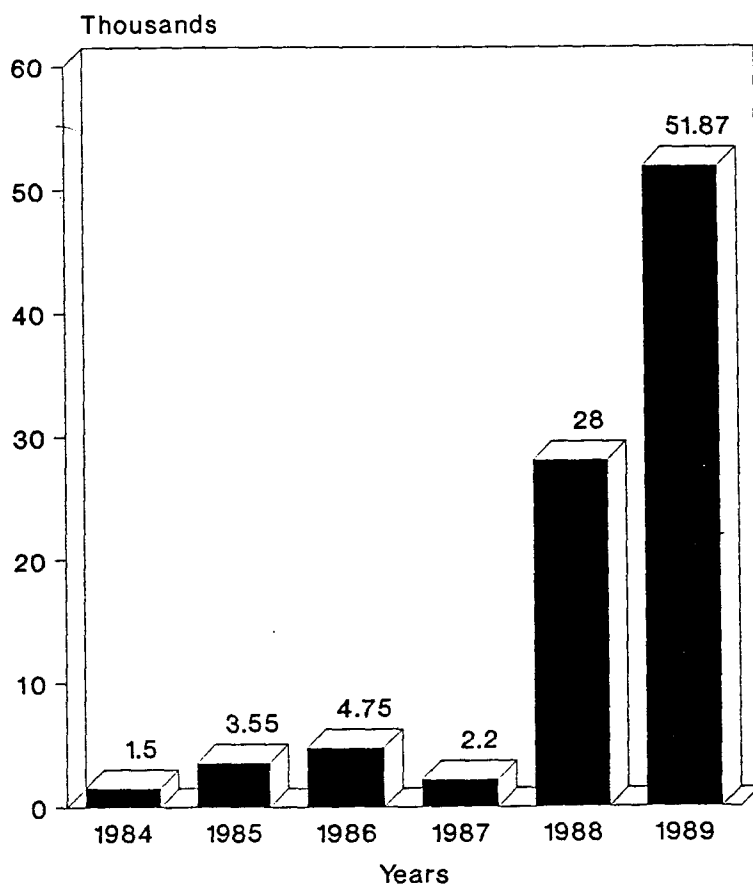


Fig. 2 Number of clonal modules planted.

## PARTICIPANT LIST

We were pleased to have a total of 247 participants at the Ninth High Altitude Revegetation Conference. Participants included attendees from 22 states and four foreign countries (Table 1). While most of the participants came from Colorado (66 percent), it is a pleasure to note that most regions of the country were represented.

For all of you that came, thank you for your participation in the conference. Your presence makes the conference a success. Make your plans for attending the tenth conference in March 1992, and pass the word to your fellow workers so that the 1992 conference will be a great success.

Editors

Table 1. Geographical distribution of participants at the Ninth High Altitude Revegetation Conference.

Geographic Entity	Number of Participants	Percent of Total Participants
United States		
Alaska	1	0.40
Arizona	3	1.21
California	10	4.05
Colorado	163	65.99
Georgia	2	0.81
Idaho	4	1.62
Indiana	1	0.40
Montana	7	2.83
New Mexico	2	0.81
Nevada	4	1.62
North Dakota	2	0.81
Ohio	2	0.81
Oregon	1	0.40
Pennsylvania	1	0.40
South Carolina	2	0.81
South Dakota	10	4.05
Tennessee	1	0.40
Texas	2	0.81
Utah	8	3.24
Washington	1	0.40
Wisconsin	1	0.40
Wyoming	8	3.24
INTERNATIONAL		
Austria	1	0.40
Canada	4	1.62
France	1	0.40
Switzerland	5	2.02
TOTAL	247	

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MARCH 1 -2, 1990

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90. MARK A. HEIFNER  
37 E. COLORADO AVE.  
DENVER, CO 80210  
303-722-9067
91. ROLLAND L. HEIN  
COLORADO MOUNTAIN COLLEGE  
P.O. BOX 244  
LEADVILLE, CO 80461
92. THOMAS HENDRICKS  
HENDRICKS MINING CO.  
3000 N. 63RD ST.  
BOULDER, CO 80301  
303-443-1502
93. DAVID B. HERRINGTON  
NATIONAL PARK SERVICE  
BOX 25287  
DENVER, CO K80225  
303-969-2014
94. JAMES HERRON  
CO MINED LAND RECLAMATION DIV.  
1313 SHERMAN, #215  
DENVER, CO 80203  
303-866-3567

95. LOREN R. HETTINGER  
DAMES & MOORE  
1125 17TH ST., SUITE 1200  
DENVER, CO 80202  
303-299-7836
96. DON HIJAR  
GARRISON SEED COMPANY  
P.O. BOX 1604  
GREELEY, CO 80632
97. JANINE HIJAR  
GARRISON SEED COMPANY  
P.O. BOX 1604  
GREELEY, CO 80632
98. STEVEN HOLDSAMBECK  
U.S. FOREST SERVICE  
2015 N. POPLAR  
LEADVILLE, CO 80461  
719-486-0749
99. TERRY J. HUGHES  
UNITED STATES FOREST SERVICE  
2250 HWY. 50 S.  
DELTA, CO 81416  
303-874-7691
100. BRUCE HUMPHRIES  
MINED LAND RECLAMATION DIV.  
1313 SHERMAN ST., RM. 215  
DENVER, CO 80203  
303-866-3567
101. SUE INGRAM  
LEADVILLE CORPORATION  
P.O. BOX 933  
LEADVILLE, CO 80461  
719-486-0722
102. CHARLES JACKSON  
AMAX, INC.  
1626 COLE BLVD.  
GOLDEN, CO 80401  
303-234-9020
103. LINDA KAY JAMES  
JAMES RANCHES LANDSCAPING, INC  
33800 HWY. 550 N.  
DURANGO, CO 81301  
303-259-0301
104. KAY JAMES  
FLATIRON COMPANIES  
P.O. BOX 229  
BOULDER, CO 80306  
303-444-2151
105. LEE JOHNSON  
BUCKLEY POWDER CO.  
42 INVERNESS DR. E.  
ENGLEWOOD, CO 80112  
303-790-7007
106. LARRY JOHNSON  
TRIPLE L CONSTRUCTORS  
BOX 1079  
DELORES, CO 81323  
303-882-4814
107. SUSAN JONES  
LAMBDA BIOREMEDIATION SYSTEMS  
2840 FISHER RD., COMPLEX E  
COLUMBUS, OH 43204  
614-278-2600
108. JAY JONES  
HENDERSON MINE & MILL  
P.O. BOX 68  
EMPIRE, CO 80438  
303-569-3221
109. WILLIAM R. JORDAN, III  
UNIVERSITY OF WISCONSIN  
ARBORETUM, 1207 SEMINOLE HWY.  
MADISON, WI 53711  
608-263-7889
110. ROBERT D. JUDY  
CYPRUS COPPER COMPANY  
9100 E. MINERAL CIR.  
ENGLEWOOD, CO 80112  
303-643-5082

111. ROBERT JUMP  
COLORADO STATE UNIVERSITY  
AGRONOMY DEPARTMENT  
FORT COLLINS, CO 80523  
303-491-5061
112. ROY KARO  
PEABODY COAL COMPANY  
BOX D  
HAYDEN, CO 81639  
303-276-3707
113. DEBORAH KEAMMERER  
KEAMMERER ECOL. CONSULT., INC.  
5858 WOODBOURNE HOLLOW RD.  
BOULDER, CO 80301  
303-530-1783
114. WARREN KEAMMERER  
KEAMMERER ECOL. CONSULT., INC.  
5858 WOODBOURNE  
BOULDER, CO 80301  
303-530-1783
115. RICHARD KEIGLEY  
ROCKY MOUNTAIN NATIONAL PARK  
ESTES PARK, CO 80517  
303-586-2371
116. TOM KELLY  
BOWMAN CONSTRUCTION SUPPLY  
2310 S. SYRACUSE WAY  
DENVER, CO 80231  
303-696-8960
117. JOHN C. KIRK  
SD DEPT. GAME, FISH & PARKS  
445 E. CAPITOL  
PIERRE, SD 57501  
605-773-4501
118. BOB KIRKHAM  
CO MINED LAND RECLAMATION DIV.  
1313 SHERMAN, #215  
DENVER, CO 80203  
303-866-3567
119. KENNETH S. KLCO  
DOMTAR GYPSUM  
P.O. BOX 180  
COALDALE, CO 81222  
719-942-4200
120. CRAIG KNOCK  
K & K HYDRO TURF  
R.R. 1, BOX2580  
RAPID CITY, SD 57702  
605-342-6220
121. DANIEL M. KOSZUTA  
MT DEPT. STATE LANDS  
1625 11TH AVE.  
HELENA, MT 59620  
406-444-2074
122. PAUL KRABACHER  
CO MINED LAND RECLAMATION DIV.  
1313 SHERMAN, #215  
DENVER, CO 80203  
303-866-3567
123. KELLY KRABBENHOFT  
NORTH DAKOTA STATE UNIVERSITY  
AN & RANGE SCIENCE, BOX 5727  
FARGO, ND 58105  
701-237-7130
124. JIM LANCE  
CO DIVISION OF HIGHWAYS  
P.O. BOX 2107  
GRAND JUNCTION, CO 81502
125. LISA LARSEN  
WESTECH  
P.O. BOX 6045  
HELENA, MT 59604  
406-442-0950
126. JOHN E. LAURSEN  
CHEVRON CHEMICAL  
MANILA STAR ROUTE  
VERNAL, UT 84078  
801-789-7795

127. JOHN LAWSON  
WHARF RESOURCES, INC.  
P.O. BOX 446  
DEADWOOD, SD 57732-0446
128. JOHN LEAHY  
PINON MESA NATIVE SEED  
329 MT. PRINCETON  
LEADVILLE, CO 80461  
800-367-1163
129. PHIL LINGERICH  
COLORADO MOUNTAIN COLLEGE  
821 HARRISON  
LEADVILLE, CO 80461  
719-486-2850
130. TONY LEONARD  
AMERICAN EXCELSIOR COMPANY  
6475 N. FRANKLIN  
DENVER, CO 80229  
303-287-3261
131. MICHAEL LINDENBAUM  
SANTA FE SKI COMPANY  
1210 LUISA ST., #10  
SANTA FE, NM 87501  
505-982-4429
132. CHARLES J. LOGAN  
SOIL CONSERVATION SERVICE  
BELLE FOURCHE, SD 57567  
605-859-2284
133. MARK LOYE  
JEFFERSON COUNTY PLANNING DEPT  
183301 W. 10TH AVE.  
GOLDEN, CO 80401
134. GARY A. LUDWIG  
PLEASANT AVENUE NURSERY  
P.O. BOX 257  
BUENA VISTA, CO 81211  
719-395-6955
135. TRACEY MAAS  
SNO-ENGINEERING, INC.  
P.O. BOX 1726  
PARK CITY, UT 84060  
801-649-4777
136. CARL MACKEY  
MK-ENVIRONMENTAL SERVICES  
1700 LINCOLN ST., STE. 4800  
DENVER, CO 80203  
303-860-8621
137. DAVID MAHLER  
ENVIRONMENTAL SURVEY CONSULT.  
4602 PLACID PLACE  
AUSTIN, TX 78731-0446
138. WARREN T. MAIERHOFER  
THE BF GOODRICH CO./PROMAC SYS  
921 E. 13TH AVE., #PH  
DENVER, CO 80218  
303-839-9143
139. CLIFFORD MANN  
MAMMOTH/JUNE SKI RESORT  
P.O. BOX 24  
MAMMOTH LAKES, CA 93546  
619-934-2571
140. CHRISTOPHER C. MARVEL  
NATIONAL PARK SERVICE  
P.O. BOX 25287  
DENVER, CO 80225  
303-969-2828
141. MADELINE R. MAZURSKI  
UTAH STATE UNIVERSITY  
147 CROOKED SPUR  
BOULDER, CO 80302  
303-442-3758
142. J. KENT MCADOO  
FREEPORT-MCMORAN GOLD CO.  
134 W. MAPLE ST.  
ELKO, NV 89801



143. JOHN MCBRAYER  
CMC ENVIRONMENTAL TECH.  
COLORADO MOUNTAIN COLLEGE  
LEADVILLE, CO 80461  
303-486-3048
144. JOHN MCCARTY  
COLORADO DEPT. OF HIGHWAYS  
P.O. BOX 1430  
GLENWOOD SPRINGS, CO 81623  
303-945-0493
145. RICHARD S. MCCULLOCH  
1224 POMONA ST., UNIT D  
FORT COLLINS, CO 80521  
303-498-9247
146. SALLY MCLEOD  
BOND GOLD COLOSSEUM, INC.  
P.O. BOX 94078  
LAS VEGAS, NV 89199  
702-367-3383
147. JEREMY MCMAHAN  
EAGLE COUNTY GOVERNMENT  
P.O. BOX 179  
EAGLE, CO 81631  
303-328-7311
148. FLOYD A. MCMULLEN, JR.  
3111 S. JASMINE WAY  
DENVER, CO 80222  
303-844-3104
149. GARY L. MCNALL  
MCNALL RECLAMATION  
504 W. MAIN  
LEAD, SD 57754  
605-584-2603
150. R. L. MEDLOCK  
UNION PACIFIC RESOURCES  
8774 YATES DR., STE. 100  
WESTMINSTER, CO 80030  
303-650-7205
151. RAY MERRY  
EAGLE COUNTY GOVERNMENT  
P.O. BOX 179  
EAGLE, CO 81631  
303-328-7311
152. CAMILLE M. MEYER  
COLORADO MINED LAND  
RECLA. DIV 1313 SHERMAN RM 215  
DENVER, CO 80203
153. LOU MILLER  
WATER WASTE AND LAND, INC.  
2629 REDWING RD., STE. 200  
FORT COLLINS, CO 80526  
303-226-3535
154. CAROL MINAR  
221 S. EUDORA ST.  
DENVER, CO 80222  
303-322-6663
155. PETE MOLLER  
COLORADO MOUNTAIN COLLEGE  
TIMBERLINE CAMPUS  
LEADVILLE, CO 80461  
719-486-2015
156. NICK NAGLE  
SOLAR ENERGY RESEARCH INST.  
1617 COLE BOULEVARD  
GOLDEN, CO 80401  
303-231-1173
157. ROBERT NESTEL  
FEDERAL HIGHWAY ADMIN.  
P.O. BOX 25246  
DENVER, CO 80225  
303-236-3468
158. MIKE NEUMANN  
UNION PACIFIC RESOURCES  
8774 YATES DR., STE. 100  
WESTMINSTER, CO 80030  
303-650-7206

159. GAIL NEWTON  
DAMES & MOORE  
9300 TECH. CENTER DR.  
SACRAMENTO, CA 95826  
916-364-8698
160. STANLEY NIELSON  
COLORADO ANALYTICAL LAB  
P.O. BOX 507  
BRIGHTON, CO 80601  
303-659-2313
161. GEORGE NIX  
COMINCO AMERICAN RESOURCES  
P.O. BOX 847  
CARLIN, NV 89822  
702-744-4211
162. GARY NOLLER  
UPPER CO ENVIR. PLANT CENTER  
P.O. BOX 448  
MEEKER, CO 81641  
303-878-5003
163. SUSAN NORMAN  
LAKE TAHOE BASIN MGMT. UNIT  
P.O. BOX 731002  
SOUTH LAKE TAHOE, CA 95731-7302
164. STEVE O'NEILL  
SHARP BROS. SEED COMPANY  
101 E. 4TH STREET RD.  
GREELEY, CO 80631  
303-356-4710
165. JOHANN OBERLOHR  
ROCKY MOUNTAIN BIO-PRODS., INC  
P.O. BOX 608  
EDWARDS, CO 81632  
303-926-1025
166. TIM OLSON  
SD DEPT. OF WATER & NAT. RES.  
523 E. CAPITOL AVE.  
PIERRE, SD 57501  
605-773-4201
167. MERLYN PAULSON  
COLORADO STATE UNIVERSITY  
REC.RES. & LANDSCAPE ARCH DEPT  
FORT COLLINS, CO 80523
168. JEFFREY L. PECKA  
LANDSCAPE ARCHITECT  
5973 E. IRWIN PL.  
ENGLEWOOD, CO 80112
169. JIM PERRY  
BUREAU OF LAND MANAGEMENT  
P.O. BOX 25047, NERA  
DENVER, CO 80225  
303-236-4399
170. T. H. PETERS  
T. H. PETERS CONSULTING SRVCS.  
BOX 607  
COPPER CLIFF, ON POMINO  
CANADA  
705-682-1185
171. MARK PHILLIPS  
PHILLIPS SEEDING  
11843 BILLINGS  
LAFAYETTE, CO 80026  
303-665-2618
172. ROGER L. PIPER  
BOX 536  
LEADVILLE, CO 80461  
303-486-2678
173. PAT PLANTENBERG  
MONTANA DEPT. OF STATE LANDS  
CAPITOL STATION  
HELENA, MT 59620  
406-444-2074
174. KEVIN B. POWELL  
WYOMING HIGHWAY DEPARTMENT  
P.O. BOX 1708  
CHEYENNE, WY 82002-9019  
307-777-4210

175. ROBIN RALPHS  
RBI  
4901 S. WINDERMERE  
LITTLETON, CO 80120  
303-795-2582
176. PENNY RAMSEY  
BLUE MOUNTAIN SEEDING  
2013 BLUE MOUNTAIN AVE.  
BERTHOUD, CO 80513  
303-776-6013
177. RON RAMSEY  
BLUE MOUNTAIN SEEDING  
2013 BLUE MOUNTAIN AVE.  
BERTHOUD, CO 80513  
303-776-6013
178. DAVID M. RANGE  
EXXON COAL AND MINERALS CO.  
BOX 580  
GLENROCK, WY 82637  
307-265-7600
179. ED REDENTE  
COLORADO STATE UNIVERSITY  
RANGE SCIENCE DEPARTMENT  
FORT COLLINS, CO 80523  
303-491-6542
180. JEAN D. REEDER  
USDA - ARS  
P.O. BOX E  
FORT COLLINS, CO 80525  
303-221-0578
181. ROY RENKIN  
YELLOWSTONE NATIONAL PARK  
P.O. BOX 168  
YELLOWSTONE, WY 82190
182. STEVE RODIE  
SUNDESIGNS ARCHITECTS  
901 BLAKE  
GLENWOOD SPRINGS, CO 81601  
303-945-2201
183. JOSEPH C. ROESSER  
BRECKENRIDGE TOWN ENGINEER  
P.O. BOX 168  
BRECKENRIDGE, CO 80424
184. ROBERT ROMERO  
THE FEED BIN  
1202 W. ALAMEDA  
SANTA FE, NM 87501  
509-982-0511
185. THOMAS E. ROOT  
BRADLEY, CAMPBELL, CARNEY & MA  
1717 WASHINGTON AVE.  
GOLDEN, CO 80401  
303-278-3300
186. JIM ROSE  
AMERICAN EXCELSIOR COMPANY  
6475 N. FRANKLIN  
DENVER, CO 80229  
303-287-3261
187. LARRY ROUTTEN  
MINED LAND RECLAMATION DIV.  
1313 SHERMAN ST., RM. 215  
DENVER, CO 80202  
303-866-3567
188. MIKE SAVAGE  
MINED LAND RECLAMATION DIV.  
1313 SHERMAN ST., RM. 215  
DENVER, CO 80203  
303-866-3567
189. JAMES J. SCHERER  
U.S. ENVIR. PROT. AGENCY  
999 18TH ST., STE. 500  
DENVER, CO 80202-2405  
303-293-1603
190. KIM SCHULTZ  
UPPER CO ENVIR. PLANT CENTER  
P.O. BOX 448  
MEEKER, CO 81641  
303-878-5003

191. GERALD E. SCHUMAN  
HIGHPLAINS GRASSLANDS RES. STA  
8408 HILDRETH RD.  
CHEYENNE, WY 82009  
307-772-2433
192. MARK SCHUSTER  
HIGH ALTITUDE COMMITTEE  
910 COVE WAY  
DENVER, CO 80209
193. MARTIN SCHUTZ  
GEOBOTANICAL INSTITUTE, ETH  
ZURICHBERGSTRASSE 38  
ZURICH, 8044  
SWITZERLAND  
011411256430
194. DAVE SCOTT  
ALPINE MEADOWS SKI AREA  
P.O. BOX 5279  
TAHOE CITY, CA 95730  
916-583-4232
195. ROBERT J. SENN  
ROCKY MOUNTAIN BIO-PRODS., INC  
P.O. BOX 608  
EDWARDS, CO 81632  
303-926-1025
196. JIM SHARKOFF  
COLORADO STATE UNIVERSITY  
AGRONOMY/ PLANT SCIENCE BLDG.  
FORT COLLINS, CO 80523  
303-491-1004
197. DAVID SHARROW  
NATIONAL PARK SERVICE  
BOX 25287  
DENVER, CO 80225  
303-969-2017
198. STEVE S. SHUEY  
COLORADO MOUNTAIN COLLEGE  
1821 RIDGEVIEW DR.  
LEADVILLE, CO 80461  
719-486-2539
199. WILLIAM SIMON  
ALPINE MINE CONSTRUCTION  
P.O. BOX 401  
SILVERTON, CO 81433  
303-387-5496
200. ROBERT SMITH  
CONSTRUCTION PRODUCTS DIVISION  
4019 INDUSTRY DR.  
CHATTANOOGA, TN 37416  
615-892-8080
201. TIMOTHY SMITH  
COTTER CORPORATION  
12596 W. BAYAUD AVE., #350  
LAKEWOOD, CO 80228
202. BRIAN SMYTHE  
SUNSHINE VILLAGE CORP.  
BOX 1510  
BANFF, AB TOLOCO  
CANADA  
403-762-6511
203. DAN SOKAL  
BUREAU OF LAND MANAGEMENT  
P.O. BOX 1009  
GLENWOOD SPRINGS, CO 81602  
303-945-2341
204. SCOTT SPACKEEN  
GRANITE SEED COMPANY  
P.O. BOX 177  
LEHI, UT 84043  
801-768-4422
205. STEPHEN J. SPAULDING  
COLORADO STATE FOREST SERVICE  
P.O. BOX Y  
WOODLAND PARK, CO 80866  
719-687-2921
206. DARRELL E. SPILDE  
AMERICAN MINE SERVICE  
14160 E. EVANS AVE.  
AURORA, CO 80014  
303-696-2000

207. GREGG R. SQUIRE  
CO LAND MINED RECLAMATION DIV.  
1313 SHERMAN ST., RM. 215  
DENVER, CO 80203  
303-866-3567
208. MIKE STAHL  
HOMESTAKE MINING COMPANY  
P.O. BOX 875  
LEAD, SD 57754  
605-584-4985
209. ROBERT STEINHOLTZ  
NATIONAL PARK SERVICE DSC-TNG  
P.O. BOX 25287  
DENVER, CO 80225  
303-969-2190
210. RON STEVENSON  
STEVENSON INTERMOUNTAIN SEED  
P.O. BOX 2  
EPHRAIM, UT 84627  
801-283-6639
211. RICH STEWART  
SUMA PACIFIC  
P.O. BOX 1251  
GRANTS PASS, OR 97526  
503-479-1461
212. CLINT STRACHAN  
WATER WASTE AND LAND, INC.  
2629 REDWING RD., STE. 200  
FORT COLLINS, CO 80526  
303-226-3535
213. SAM STRANATHAN  
SOIL CONSERVATION SERVICE  
655 PARFET  
LAKEWOOD, CO 80225
214. PETE STRAZDAS  
MONTANA DEPT. OF STATE LANDS  
CAPITOL STATION  
HELENA, MT 59620  
406-444-2074
215. JEFF SUNDERMAN  
BUCKLEY POWDER CO.  
42 INVERNESS DR. E.  
ENGLEWOOD, CO 80112  
303-790-7007
216. CRAIG TAGGART  
EDAW, INC.  
240 E. MOUNTAIN AVE.  
FORT COLLINS, CO 80524  
303-484-6073
217. MARC S. THIESEN  
TENSAR EARTH TECHNOLOGIES  
1210 CITIZENS PARKWAY  
MORROW, GA 300260  
404-968-3255
218. GARY L. THOR  
COLORADO STATE UNIVERSITY  
AGRONOMY DEPARTMENT  
FORT COLLINS, CO 80523  
303-491-7296
219. JEFF TODD  
AMAX, INC.  
1626 COLE BLVD.  
GOLDEN, CO 80401  
303-231-0396
220. DAVID K. TRAPPETT  
BUREAU OF LAND MANAGEMENT  
764 HORIZON DR.  
GRAND JUNCTION, CO 81506
221. FLORIS B. TSCHURR  
GEOBOTANICAL INSTITUTE, ETH  
ZURICHBERGSTRASSE 38  
8044 ZURICH,  
SWITZERLND  
011411256431
222. LARRY TURK  
TAHOE NATIVE PLANTS  
P.O. BOX 13196  
SOUTH LAKE TAHOE, CA 95702  
916-577-5011

223. CHRISTINE TURNER  
REVEK, INC.  
P.O. BOX 157  
LOUISVILLE, CO 80027  
303-666-4050
224. MAX UNDERWOOD  
COLORADO MOUNTAIN COLLEGE  
1852 SILVER EAGLE CT.  
LEADVILLE, CO 80461  
719-486-2928
225. KRYSZYNA M. URBANSKA  
SWISS FED. INST. TECHN. ZURICH  
GEOBOT. DEPT. SFIT  
ZURICHBERGSTRA. 38 ZURICH, CH-8044  
SWITZERLAND  
01/2564308
226. IVAN URNOVITZ  
COEUR D'ALENE MINES  
2417 BANK DR., #302  
BOISE, ID 83705  
208-385-0373
227. DODE VANDEMARK  
CLIMAX MOLYBDENUM COMPANY  
CLIMAX MINE  
CLIMAX, CO 80429  
719-486-2150
228. FEARN R. VEST  
PEABODY COAL COMPANY  
P.O. BOX 605  
KAYENTA, AZ 86033  
602-677-3201
229. LAUREL E. VICKLUND  
CORDERO MINING COMPANY  
P.O. BOX 1449  
GILLETTE, WY 82717-1449  
307-686-5505
230. JULIE VIKRE  
COLORADO MOUNTAIN COLLEGE  
ENVIRONMENTAL TECH. DEPT.  
LEADVILLE, CO 80461  
303-486-2015
231. BOB VILOTTI  
ARKANSAS VALLEY SEED COMPANY  
4625 COLORADO BLVD.  
DENVER, CO 80216  
303-320-7500
232. RICHARD VINCENT  
WDEQ-LAND QUALITY DIV.  
122 W. 25TH, 3RD FL., HERSHEY  
CHEYENNE, WY 82002
233. JAMES P. WALSH  
JAMES P. WALSH & ASSOCIATES  
1002 WALNUT  
BOULDER, CO 80302  
303-443-3282
234. MICHAEL K. WARD  
USDA FOREST SERVICE  
2250 HIGHWAY 50  
DELTA, CO 81416  
303-527-4131
235. SHERRY WEINSTEIN  
JEFFERSON CTY. PLANNING COMM.  
18301 W. 10TH AVE., STE 220  
GOLDEN, CO 80401  
303-278-5845
236. CHRISTINE L. WHITTAKER  
MONTGOMERY ENGINEERS  
161 MALLARD DR.  
BOISE, ID 83706  
208-345-5865
237. DALE WIBBENMEYER  
CLIMAX MOLYBDENUM COMPANY  
CLIMAX MINE  
CLIMAX, CO 80429  
719-486-2150
238. THOMAS WILHALM  
UNIVERSITY OF INNSBRUCK  
STERNWARTESTR 15  
INNSBRUCK, 6020  
AUSTRIA

239. TOM WILLIAMS  
STEFFEN ROBERTSON AND KIRSTEN  
3232 S. VANCE ST., STE. 210  
LAKEWOOD, CO 80227  
303-985-1333
240. STEPHEN E. WILLIAMS  
UNIVERSITY OF WYOMING  
P.O. BOX 3354  
LARAMIE, WY 82070
241. NANCY C. WINDHOLZ  
COLORADO MOUNTAIN COLLEGE  
ENVIRONMENTAL TECH. DEPT.  
LEADVILLE, CO 80461  
303-486-2015
242. JON F. WINTER  
WHARF RESOURCES, INC.  
P.O. BOX 446  
DEADWOOD, SD 57737  
605-584-1441
243. BILL WOLVIN  
WINTER PARK SKI AREA  
BOX 36  
WINTER PARK, CO 80482  
303-726-5514
244. JAMES C. WOODS  
NATIONAL PARK SERVICE  
12795 W. ALAMEDA PARKWAY  
LAKEWOOD, CO 80225  
303-969-2093
245. DARIN WORDEN  
HECLA MINING COMPANY  
802 N. 3RD, STE. 200  
MCCALL, ID 83638  
208-634-3848
246. RICHARD WRENN  
ALPINE MEADOWS SKI AREA  
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