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HIGH ALTITUDE REVEGETATION WORKSHOP NO. 3

Edited by

S. T. Kenny

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Edited by

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Colorado State University

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PREFACE

The papers in this volume were presented at the Third High Altitude Revegetation Workshop sponsored by the Committee for High Altitude Revegetation and have been rearranged from their original order. Committee members Larry Brown, Wendell Hassell, Mark Schuster, and Paul Wilderman donated many hours contacting and organizing the speakers, and made this a cohesive workshop. I thank them and many others for their efforts toward making this workshop the best yet. I thank also the many speakers who contributed their time in attendance and participation.

The Committee will continue to sponsor workshops on a biennial basis, and summer field tours annually. The forth workshop is tentatively scheduled for March, 1980 at the Colorado School of Mines in Golden.

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Stephen Kenny
Fort Collins
May, 1978

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J. R. LaFevers and D. P. Groeneveld and P. S. O'Boyle were unable to attend the workshop.

C. C. McCall, Director, Mined Land Reclamation, Colorado Department of Natural Resources, presented a disucssion on current events in reclamation happening on the state, regional, and Federal levels at the workshop. He thought a written paper would be of little practical value.

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ASPECTS OF THE ECOLOGY OF ALPINE AND SUBALPINE PLANTS

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INTRODUCTION

Alpine or high mountain environments stretch from the equator to the Arctic and Antarctic. The most diverse array of high mountain ecosystems exists in the American Cordillera extending from the Southern Andes of Tierra del Fuego 55°S latitude to the Brooks Range of Alaska (68°N). The relatively old Rocky Mountains constitute the heart of this system in western North America from New Mexico to Alaska; the geologically young Andes assume the same role from one end of South America to the other. The Sierra Nevada and Cascades are also geologically young and represent important secondary mountain systems in western North America.

In some mountain ranges there are relatively sharp boundaries between what might be called "alpine" and those systems which lie slightly lower in elevation and are referred to as "subalpine." In many mountains, though, sharp lines between alpine and subalpine zones do not exist. Upper timberline is frequently used as the boundary between subalpine and alpine vegetation in North America. However, on most mountains of the earth it is not a particularly good boundary, and it is not a very good boundary on most North and South American mountains either. Timberlines almost always exist at much higher elevations than the lowest patches of alpine vegetation. This is often true around glacial valleys, both those with and those without glaciers at the present time. For example, timberline around the Athabaska Glacier in the Canadian Rockies is fully 675 m (2,215 ft) above the terminus of the glacier where, in the morainal gravels, there are a number of arctic-alpine plant species, but no trees. The reasons for this common phenomenon are rather simple: those factors which define the lower limits of alpine species are not necessarily those which limit the upward distribution of trees.

Gradients

Since mountains vary in elevation and latitude, it is not surprising that, in spite of sharing many environmental characteristics in common, their environments do differ. These differences are more easily seen along gradients of various kinds and lengths. The most obvious of these gradients are latitudinal (from equatorial to polar regions) and elevational (from the lower slopes to the summits). These "macrogradients" have a great deal of influence on the amounts of solar radiation received, length of day, temperatures, and amounts of precipitation. Such gradients have considerable control over the kinds of plants and animals which are available in a region as potential members of alpine biological communities and ecosystems.

Within these large gradients are smaller environmental gradients which exist on every mountain. These, along with bedrock differences, control almost all the local distribution patterns of plant and animal species within the constraints set by the elevational gradient on the mountain. The smaller gradients are determined primarily by topography. Topography, in itself, does not control growth and distribution of alpine organisms but does moderate those factors which interact directly with the organisms: solar radiation, soil moisture, soil and air temperatures, wind, and both the blasting and protecting aspects of snow. Ridges, slopes, valley and cirque floors act together along a "mesotopographic" gradient (Billings, 1973) as diagramed in Figure 1. A mesotopographic gradient is essentially a combination of an alpine moisture gradient with a length-of-growing season gradient caused by differential snowmelt. A single mesotopographic gradient can be utilized as a "mesotopographic unit." Environmental patchiness, so apparent in alpine regions, can be related to vegetational pattern and structure by studying a number of mesotopographic units in fairly close proximity to each other.

Within mesotopographic gradients, boulders, rock outcrops, and patches of krummholz produce small, elongated snowdrifts in their lee. Small depressions also catch blowing snow. Even these small drifts produce miniature environmental gradients which are "microtopographic" gradients. The captured snow, because of the winter protection it affords, is reflected in vegetational patches consisting of species needing such protection, and those, such as *Kobresia*, which do not.

If a single alpine area has different kinds of bedrock, it is also possible to compare mesotopographic units based upon different geologic substrata. This allows us to go one step farther in understanding the dependence of vegetational composition on adaptations and competition since certain edaphic factors (soil moisture availability, soil temperature, nutrient availability) will favor some taxa, including ecotypes, over others (see Mooney, 1966). Such information not only has significance in the realm of pure science but has practical applications as well. These applications are apparent in understanding: 1) carrying capacity of alpine rangelands, 2) recreational carrying capacities in alpine areas, 3) alpine water yield, 4) the revegetation of tailings from alpine mining operations since such alpine tailing dumps often form classic, but relatively small, mesotopographic units.

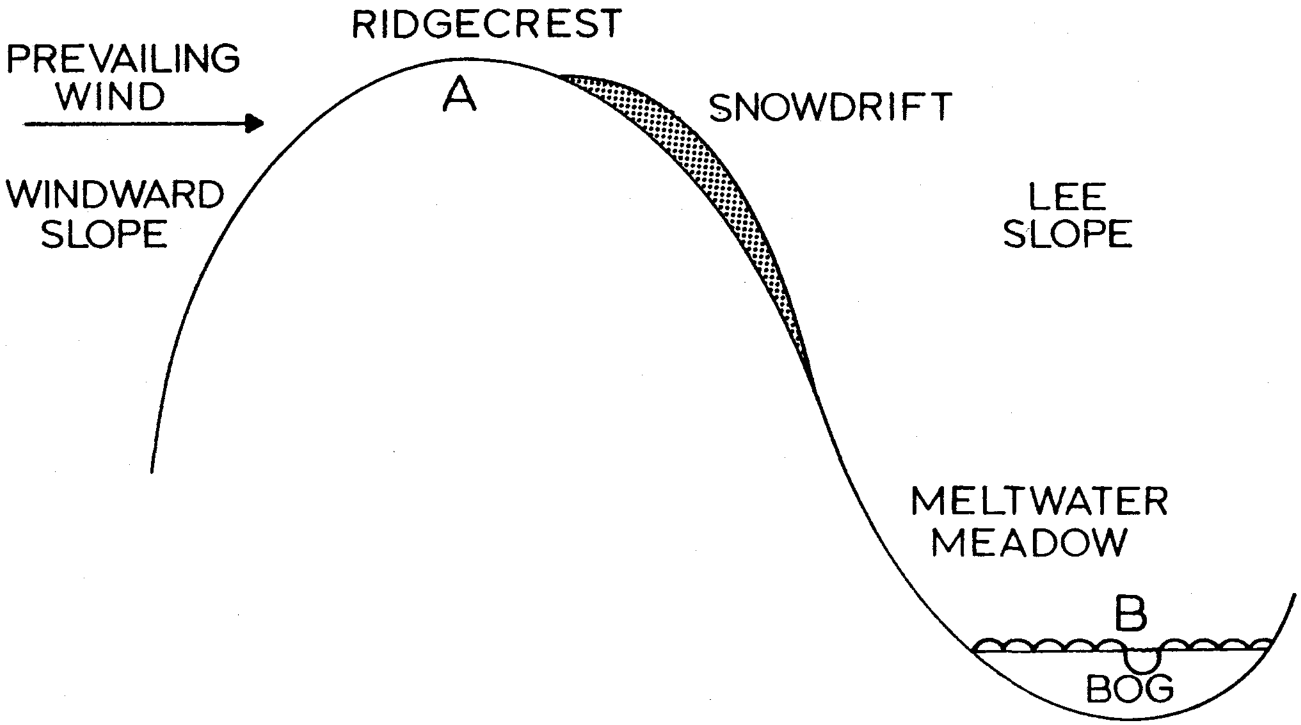

Figure 1. Diagram of a typical alpine or arctic mesotopographic unit with its environmental gradient from the upper windward slope to the lee valley. The scale would vary from about 50 m (160 ft) from A to B up to perhaps 1,000 m (3,280 ft) (from Billings, 1973).

Physical Versus Biolgical Aspects

The soil moisture available to plants along a mesotopographic gradient is derived from two sources: snowbank meltwater and summer rainfall (Billings and Bliss, 1959; Holway and Ward, 1963). As a first approximation, one could assume that the vegetational differences due to water availability and use between the ridgecrest and the meltwater meadow would be accentuated where winter snowfall is great and summer rainfall is rare or lacking, as in the Sierra Nevada.

In alpine environments, it appears to be the physical factors which dominate and control the growth, reproduction, and distribution of organisms. Plants and animals occur in patterns determined by local gradients in solar ultraviolet and visible radiation, net radiation, low soil and air temperatures, snow distribution, wind speeds, length of "growing" or snow-free season, steepness of slope, type of rock, and soil characteristics, including soil frost action and needle ice. Plants are small in these cold, windy environments; such vegetation cannot modify or "soften" the environment as does a subalpine forest. Consequently, the biological portion of the environment appears at first glance to be less important than physical factors in determining patterns and growth rates in alpine communities. This all may be a bit deceptive though. We know that large native and introduced herbivores can have marked effects on alpine vegetation and soils. In some alpine ecosystems, insect predation can be very intense on both vegetative and reproductive systems of the plants. In this regard, the puna of the central Peruvian Andes comes to mind. Perhaps we just do not know alpine environments and ecosystems well enough yet - even in their relatively natural states. When one adds people to the picture, the biological part of the alpine environment becomes very important indeed, and destruction of alpine ecosystems can and does occur.

Evalution and Ecotypes

Alpine and subalpine plants belong to a species which can evolve relatively easily to fit cold, short growing seasons. There is a certain amount of pre-adaptation involved. This is probably the case in the origin of much of the Sierran alpine flora from *winter* annuals and perennials of the cold deserts on the east (Chabot and Billings, 1972). The same thing could easily have occurred earlier (and certainly continues today) in the evolution of the old Rocky Mountain alpine flora from the surrounding grasslands and semi-deserts. Once adapted to alpine conditions, some of these new species can easily migrate back and forth to the Arctic by long-distance dispersal of seeds as climates change. Others are much more conservative for various physiological and reproductive reasons and tend to remain localized or endemic to certain mountain regions. There are many widespread arctic-alpine species and many regional endemics in the Rocky Mountains. The Sierran alpine flora is relatively new and has fewer arctic-alpine species and a greater percentage of endemics.

As evolution progresses and mobility of propagules increases, adaptation of local populations to regional and local environmental gradients results in genetically based latitudinal and elevational ecotypes and ecoclines of arctic-alpine species (Mooney and Billings, 1961; Billings and Mooney, 1968; Billings *et al.*, 1971; Billings, 1973; Billings, 1974). Within regional and latitudinal ecotypes, there is a somewhat variable ability for acclimatization both physiologically and morphologically (Billings *et al.*, 1971). The understanding of acclimatization mechanisms is extremely important to an understanding of successful adaptation of alpine plants to environmental stress along all gradients, including the mesotopographic gradient.

The genetic differences between the uppermost plants of a species on a mountain and the lowermost can be considerable. These differences should be taken into consideration in any revegetation scheme. The same thing holds true for edaphic ecotypes on different geologic substrata and for seasonal and, perhaps, drought stress ecotypes along a mesotopographic gradient.

ADAPTATIONS OF PLANT POPULATIONS OT ALPINE ECOSYSTEMS

Alpine vegetation consists almost entirely of perennial plants. Practically all perennial graminoids in high mountains have much more living tissue belowground than above. Some, but not all, dicots also have most of their biomass within the soil. However, this is not usually true of dwarf shrubs. Annual species are absent or rare. Alpine annual plants are miniature; they contribute little to vegetational cover or productivity.

The following list of plant life forms is arranged in approximate order of importance in high mountain vegetation outside the tropics.

- Perennials
  - Graminoids
  - Herbaceous dicots
    - Single-stemmed dicots
    - Cushion plants
    - Small basal rosette plants

Dwarf shrubs, either evergreen or deciduous
Giant rosettes and cacti
Mosses
Lichens

Annual graminoids or dicots

Vegetational Structure

As indicated earlier most alpine vegetation is dominated by perennial graminoids. Associated with these grasses and sedges are herbaceous dicots and dwarf shrubs, both envergreen and deciduous: willows, heathers, and the like. The vegetational gradient and any given elevation is closely correlated with and controlled by amounts of snow cover and water available in different segments of the mesotopographic unit. The most productive alpine vegetation is that in the meadows below melting snowdrifts. The least productive and most sparse vegetation lies under the snowdrift itself and is exposed only in later summer, if then. Here, a few dwarf perennial dicots are the only plants scattered over barren rocks, gravel, and sometimes a bit of soil.

Plant Processes

a. Dormancy. Alpine plants of the middle latitudes and arctic regions are dormant 9 to 10 months of the year. During this time, temperatures of the surrounding air and soil are usually well below freezing. The plants are snow-covered except on the windward slopes and ridges where snow-cover is sporadic. Several kinds of plants on these ridges or upper windward slopes cannot tolerate protective snow-cover and occur only where high winds keep the ground bare and frozen. Among these are a sedge, *Kobresia*, certain plants, such as members of the genus *Saxifraga*, with the small rosette life form, and cushion plants. Such plants, in dormant condition, are adapted to environmental conditions which are extremely cold and dry because of exposure. The perennating or live parts of alpine plants in long-winter mountains are in the buds, roots, rhizomes; in evergreen plants, the younger leaves also remain alive.

b. Early growth. The perennial life forms of alpine plants enable them to break dormancy rather rapidly after snowmelt or after soil thaw on snowfree ridges. This usually occurs in late May or June in the Northern Hemisphere but can be somewhat later in areas around late-melting snowbanks. Rapid growth of shoots and leaves is accomplished by translocation of carbohydrates and lipids from roots, rhizomes, and/or evergreen leaves. Respiration rates are high at this time; such high rates are associated with the speeding up of most metabolic processes. Photosynthesis, however, starts out slowly as compared to respiration due partly to the time it takes for

Dark respiration rates of whoe plants of 17 arctic and alpine ecotypes of *Oxyria* showed no apparent differences in temperature acclimatation among ecotypes; homeostasis was almost "ideal" to temperature changes in all ecotypes (Billings *et al.* 1971). However, alpine populations, in general, showed less respirational loss of carbon when grown at warm temperatures than did plants from arctic populations.

Photosynthesis rates of alpine plants as measured in the field are difficult to interpret and compare because of the use of different measurement techniques (infrared gas analyzer, $^{14}CO_2$, etc.). The CO_2 uptake also can be calculated on different bases including mg CO_2 per dm^2, per dry wt, or per g fresh wt. In the Alps and in the Rocky Mountains, maximum rates between 4 and 13.5 mg $CO_2 \cdot dm^{-2}$ (two surfaces)$\cdot hr^{-1}$ have been reported for several species. In these studies, whole plants were used; average maximum values were around 10 mg $CO_2 \cdot dm^{-2} \cdot hr^{-1}$. In other studies, single leaves have been used. Such different combinations of methods sometimes have made it difficult to know what reported field photosynthesis rates mean and how comparable they are. For example, it is known that some species will have apparent net photosynthesis rates higher than others if expressed on a leaf area basis and lower than others if expressed on a dry weight basis. Standardization is badly needed in field techniques for measuring photosynthesis and respiration.

d. Storage compounds. The photosynthate produced by alpine plants is used not only in current growth and reproduction but as storage compounds in roots, rhizomes, and evergreen leaves. A very large proportion is stored in this way, particularly late in the growing season, and is utilized in early growth the following year (Mooney and Billings, 1960). In most alpine plants, these storage compounds are carbohydrates, but lipids are also stored, particularly in the leaves of small evergreen rosette plants and in the evergreen leaves of very small shrubs such as *Ledum groenlandicum* and *Diapensia lapponica* (Hadley and Bliss, 1964).

e. Translocation. The translocation of carbon from starch photosynthate in the chloroplasts to other parts of the plant during low temperatures appears to be one of the adaptations of true high mountain plants. This degradation of starch to sucrose or other compounds in the chloroplasts of *Oxyria digyna* can take place during cold alpine nights in the Sierra Nevada (Chabot and Billings, 1972). The same process of starch degradation to sucrose occurs in leaves of *Encelia virginensis*, a species of warmer lower slopes of the eastern Sierra Nevada at higher temperatures (20-23^oC, 68-73^oF). However, if *Encelia* plants are exposed to cold nights (8-11^oC, 46-52^oF) in which *Oxyria* successfully degrades starch to sucrose, starch grains still remain in the *Encelia* chloroplasts the next morning. Such starch accumulation not only reduces photosynthesis chlorophyll synthesis. The result is net dry weight loss for the first week or so after snow release (Bliss, 1966).

c. Photosynthesis and respiration. Positive net photosynthesis takes over during the daylight hours as soon as the plants develop chlorophyll. The photosynthetic pathway apparently is C_3 in all alpine graminoids, and probably for almost all dicots also. I do not know of any truly alpine graminoids which have the C_4 photosynthetic mode. However, A. T. Harrison (personal communication, August 23, 1977) has found a C_4 *Muhlenbergia* in the subalpine zone of the Laramie Mountains in Wyoming. Teeri and Stowe (1976), using multiple regression with 32 grass floras in North America and 19 environmental variables or combinations of such variables, found that mean daily minumum temperature in July was the best predictor of the percentage of C_4 graminoid species in a flora. No C_4 species occurred in those places where the mean daily minimum was below 8^{o} (46^{o}F). In a linear regression of actual percentage of C_4 grass species against "normal" mean daily minimum teperature in July, the percentage of C_4 species becomes zero at about 7^{o} (45^{o}F). The "r" value for this regression was .972. Since temperatures in middle-latitude alpine areas go below 7^{o} almost every night, this pretty well rules out the presence of C_4 graminoid species. Admittedly, more basic research is needed on this point. But even if a C_4 species is found in an alpine area, it would likely be so rare as to have almost no effect on the productivity or structure of alpine vegetation.

For alpine dicots, there is little or no information on the presence of C_4 species. It seems probable that alpine dicots are almost entirely C_3 species also. There is a slight possiblility that C_3 dicots might be found in alpine regions of high mountains which are in or near deserts.

Since most all alpine plants appear to be C_3 plants, this means that some organic compounds are lost in photorespiration in addition to those used in dark respiration. It is known that dark respiration rates of alpine plants are relatively high at low temperatures but little or nothing is known about their rates of photorespiration. If high, photorespiration could be involved in decreasing net photosynthesis rates and, thus, net primary productivity in alpine ecosystems.

Alpine weather is known for its rapid changes in temperature and light. At least some alpine species show the ability to adjust photosynthetic and dark respiration rates rather quickly to such environmental changes. Alpine ecotypes of *Oxyria digyna* have shown "ideal" homeostasis in adjusting net photosynthetic rates to temperature changes while arctic ecotypes of the same species in the same experiment showed only a low degree of partial homeostatic adjustment (Billings *et al.*, 1971).

but can lead to the breakdown of chloroplasts themselves. This ability to degrade starch to sucrose at low temperatures and to translocate sucrose to storage organs at the same low temperatures may be one of the principal steps in the evolution of adaptations of plants to alpine environments. It is probable that the great majority of other plants cannot do this. Much more research on this apparent adaptation is needed; it would be particularly helpful in the understanding of success or failure in high mountain revegetation.

f. Drought stress. Alpine areas are more prone to late season drought than are arctic regions except for polar desert locations. Teeri (1973) has shown that *Saxifraga oppositifolia* has polar desert ecotypes that are extremely drought resistant and can develop water potentials to below -40 bars. It should be possible to find such drought-resistant ecotypes in the drier parts of alpine mesotopographic gradients. In fact, Klikoff (1965) found that photosyntheis in the moist site *Calamagrostis breweri* from the Sierra Nevada decreased to almost -10 bars. On the other hand, *Carex exserta* from drier sites on the same gradient was still photosynthesizing at 25% maximum at water potentials as low as -20 bars. Studies of water relations and drought stress in alpine plants continue. But, much more needs to be done since successful revegetation in these severe environments depends to a large extent upon water.

g. Mineral nutrition. Another research area in need of considerable work is that of mineral requirements and nutrient cycling in natural alpine ecosystmes. More information seems to be available for introduced grass communities than for the native alpine communities. For example, Grable, Willhite, and McCuistion (1965) found that nitrogen supplied by legumes or fertilizers increased hay production and nutrient uptake in high elevation mountain meadows in Colorado. Nitrogen and other nutrients may be limiting in other alpine communities too. For example, Brown, *et al.* (1976) found that application of 15-40-5 granular fertilizer to plots at the Iron Mountain and McLaren Mines on the Beartooth Plateau resulted in about 100 times greater productivity than on control plots. What is needed in alpine areas is more of this kind of research and also the kind being done by Chapin, McKendrick, and others in the Alaskan Arctic on the uptake and cycling of nitrogen, phosphorus, and other mineral nutrients.

h. Growth. Vegetative regrowth of shoots in alpine plants can be very rapid from the perennating bud which almost always is very close to the ground surface. This growth begins as soon as the snow melts and the soil temperature rises $0^{o}C$ ($32^{o}F$). In certain species, such as *Erythronium grandiflorum* whose bud is in a relatively deep bulb, regrowth begins even before snowmelt. Once a leaf of this species has penetrated above the shallow, old snow, its thermal reradiation and/or respiratory heat make the hole in the snow greater in diameter. This allows penetration of more solar radiation to the soil surface thus speeding regrowth even more.

The growth of root systems and rhizomes in alpine plants is almost unknown. There is little reason, however, to believe it to be much different than that occurring in arctic species. Billings *et al.* (1976, 1977) found that root growth in certain species of tundra graminoids can take place at rates of 1 to 2 mm per day at temperatures of $0^{o}C$. Studies of alpine plant water relations and nutrient requirements would be aided by considerably more knowledge of the below-ground structure, growth rates, and activities of these plants.

i. Reproduction. Flowering in alpine and subalpine plants takes place almost entirely from flower bud primordia formed the year before or even earlier. Such pre-formed flower buds enable alpine plants to bloom rather soon after breaking of dormancy. If the season continues favorably, seed set can occur in middle to late summer. Successful seed-set depends not only upon the availability of pollinators but the weather at the time of flowering. A blizzard or unusually cold weather at this time can result in no viable seed being formed. Once seed is produced, it is available for short-or long-distance dispersal mainly during the latter part of the growing season. Because of environmental constraints at this time or intrinsic dormancy is some species, germination in seeds of most species does not occur until at least the following year. There are only a few exceptions to this. Many of these plants also reproduce vegetatively by bulbils, rhizomes, stolons, or bulbs.

Seedling establishment occurs only occasionally in most alpine species. Even so, the availability of viable seed makes such establishment much more common in alpine regions than in the Arctic where many species produce seed only rarely and vegetative reproduction is the rule. Seedling growth is very slow. Much of the first year's photosynthate goes into the development of a root system which is insurance against drought death and serves as a carbohydrate bank. Very small true leaves may be produced the first year, but cotyledons often carry the plant through the first season by their photosynthesis. Several years may elapse before the young plant is firmly established.

j. Onset of dormancy. Near the end of summer, alpine plants go into vegetative dormancy rather quickly. In *Oxyria*, arctic ecotypes begin to form perennating buds at photoperiods as long as 14 to 15 hr. Alpine ecotypes under the same temperature conditions do not do this until the photoperiod is down to 12 to 13 hr. No matter what the temperature, all *Oxyria* plants will be dormant when a decreasing photoperiod reaches about 11 hr. Photoperiod may be the principal dormancy cue in *Oxyria*, but it is not independent of low temperatures and drought; this may be true of most alpine species. Without this dormancy or hardening, alpine plants would be in no condition to withstand the rigors of winter. This is especially true of those species such as *Kobresia* which exist on snowfree ridges. But so little is known of these mechanisms in plants of high mountains. Again, more is known of such processes in arctic vegetation than in alpine plants. For example, Shaver and Billings (1977) have found that in certain tundra graminoids in Alaska shortening photoperiods is more important than decreasing soil temperatures in stopping the growth of roots near the end of the growing season.

k. Ecological adaptations. The real answers to questions concerning adaptations of plants to alpine conditions lie in finding out how the populations of a species fare in alpine ecosystems. Studies of morphological, physiological, and reproductive traits are essentially analytical, even though many of the observations are made in the field. Using such information, both from the field and from controlled conditions, it is necessary to synthesize some sort of model of how the local population of a species fits into an alpine ecosystem.

A successful population will be one that by having the right combination of vegetative and reproductive characteristics at times of environmental stress will survive and reproduce. The acid test of adaptation must be made in the mountains with the populations under the stress of predation, and in competition with other vegetation for energy capture, water, nutrients, and pollinators. Nothing replaces simple field experimentation on natural populations within the context of whole alpine ecosystems in constructing and testing adaptational models. Alpine adaptations are as varied and numerous as the heterogeneity of alpine environments and the wealth of genetic systems preserved in these environments allows. There is no single "best" adaptational "strategy" among alpine plant species.

EFFECTS OF ENVIRONMENTAL PERTURBATIONS ON HIGH MOUNTAIN ECOSYSTEMS

Until the last few thousand years, high mountain ecosystems and biota evolved in the absence of man. Primitive people played only a minor role, if any, in the environmental screen governing natural selection. Such freedom from human impact allowed plants and animals to develop adaptations to the precarious environments of alpine regions where physical factors dominate.

Before the coming of people, there were natural environmental perturbations in high mountain ecosystems: floods, earthquakes, extended droughts, glaciation, and lightning-caused fires. These still occur. But people have brought new changes: lumbering, grazing, mining, road consturction, atmospheric changes such as the breakdown of stratospheric ozone with possible increase in solar ultraviolet radiation in alpine areas, and the increase in atmospheric CO_2 with possible warming of these cold, snowy ecosystems. In addition to these perturbations, it is the increase in sheer numbers of people in mountains through tourism and recreation which have multiple direct and indirect impacts on montane ecosystems.

As man has moved into these natural mountain systems, the susceptible biota and soils have become increasingly exposed to injury, and often to irreversible ecosystemic change and extinction of species. It seems that, in spite of the relative severity of alpine physical environments, such high mountain ecosystems are "fragile" only in the presence of man and his use of the land. Only a few mountain regions, mostly polar, have escaped severe damage by people.

Both natural and man-induced perturbations in alpine ecosystems result in long-term changes in environments and biological communities. These include:

a. changes in local wind direction and force
b. changes in patterns of drift snow
c. changes in soil characteristics including nutrient status, pH, compaction, and erosion
d. changes in soil mositure and runoff
e. changes in vegetation composition including extinction of some native species, invasion of weeds, introduction of exotic species by certain kinds of revegetation attempts
f. possible changes in ecosystem secondary productivity triggered by introduced plant species which are overly susceptible to fire or contain poisonous compounds.

RECOVERY FROM PERTURBATIONS

Natural vegetational succession and recovery of soils in alpine areas is very slow. Some perturbations are so severe as to eliminate the possiblility of recovery entirely because of the complete destruction of soil. Examples can be seen seen in all high mountain regions, but the introduction of hooved animals into the mountains of New Zealand (where they had not existed before) caused such severe erosional damage that original ecosystems have literally gone down-hill, and only rubble and rock are left. The moral, of course, is not to let the situation in regard to carrying capacity get so far out of line before doing something about it. If closed to use before the soil is gone, there are species in the native "climax" vegetation which can act as pioneers in natural revegetation or succession. Such a process will take time, but it will work if initiated before severe soil changes occur.

Man-aided revegetation can speed up the process of plant succession in alpine and subalpine sites. But, it must be remembered that revegetation is not equivalent to total ecosystem recovery. For this it is necessary to restore the environment and biological community, including decomposers, into a functional alpine ecosystem with adapted species at each trophic level.

How does this get done? I do not have the answers; you may. Certainly, site preparation including contouring, and restoration of nutrients is the place to start. Then, I would strongly advise using mixtures of native pioneer alpine species of plants, including mosses, rather than short-lived introduced species for planting. If wide-ranging alpine species are to be used, it would be wise to try to obtain seeds or sods of those ecotypes from the region in which the work is being done. I would even go so far as to suggest those species and ecotypes that best fit the various segments of the local elevational and mesotopographic gradients. In other words, there is not one kind of alpine adaptation among plant species, but many. This array is due to the complex selective screen provided by the overlapping high mountain environmental gradients.

To restore alpine and subalpine ecosystems, then, one must know the genetic, physiologic, and ecologic characteristics of the native species in their native ecosystems. This not only includes plants (vascular and non-vascular) and animals in the grazing food chain but algae, fungi, bacteria, and animals (invertebrate and vertebrate) of the detrital food chain, and those involved in nutrient cycling. All of this will require research and the money to support it.

In the restoration of alpine ecosystems, we must realize that after a rather long period of protection from people, the are eventually going to be used again by people. Such renewed systems must be used rationally in the future so that their integrity can be maintained. This can be done by making small compromises in time, space, and use. These compromises will have to depend upon a knowledge of the particular alpine ecosystem in question. As Jernelöi and Rosenberg (1976) conclude: "Ecosystem stress-tolerance should be made a top priority in ecological research." In quantitative terms, we know little of such stress-tolerance in mountain systems, but in qualitative terms the low stress-tolerance to man in such systems is readily apparent.

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DISCUSSION

WILLARD: What do we know about the effects of fertilizer on the growth of alpine plants; the need for fertilization?

BILLINGS: We know very little. We know a great deal more in the Arctic than in the alpine vegetation. Much of the work in this area of research has been done by Terry Chapin and Gus Shaver.

QUESTION: What kind of soil information do you have along the Cordillera?

BILLINGS: We are looking into the effect of unusual substrates such as dolomite and andesite. There needs to be more work on the influence of geologic substrates.

PROBLEMS IN THE IDENTIFICATION OF THREATENED AND ENDANGERED PLANT SPECIES

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INTRODUCTION

The purpose of this paper is not to provide details on physically identifying particular threatened or endangered plants, but rather to discuss the philosophy and principles by which it can be decided whether and how rare plants should be regarded as deserving of protection. In this discussion, the term "endangered" will mean simply "in danger of extinction," except as specifically indicated. "Threatened" will mean "likely to become endangered in the foreseeable future."

VALUE OF RARE PLANTS

What then is the point of being concerned with rare plants? There is, for many people, an aesthetic value attached to many of our rare native plants, though often they are not showy. There is also an aesthetic value in the minds of many in maintaining our native flora as intact as possible because it represents an inheritance of considerable antiquity. Perhaps the most commonly cited reason for the preservation of rare plants is their value as a genetic resource. This is a persuasive reason because the loss of unique genetic material is irrevocable and removes an alternative in the future when that genetic resource may have been of value to man. Of what conceivable value could the very rare plants ever be to human needs of the future? Occasionally cited along these lines are potential values as food or medicinal crops or as genetic material for the development of such plants. These uses are perhaps relatively unlikely for most of our rare western plants. Probably the single most important potential use of the genetic resources of the rare plants of our region will stem from the interests of people such as those who are concerned with revegetation. Since many of the rare plants grow in extreme sites, the potential value of their fitness on disturbed sites is very high. In the interest of keeping all alternatives open in the development of revegetation science, it is obvious that as much as possible of the genetic variety of our native flora should be preserved.

APPROACHES TO PRESERVATION OF UNIQUE PLANTS

If it is then desirable to preserve the rare plants, how do we determine which plants are truly endangered and, thus, in need of protection? At this point, it may be useful to compare the situation of threatened and endangered animals with rare plants. In general, consideration of threatened and endangered animals entered the public consciousness and the legal statutes before similar consideration for plants (Melville 1970). A great many of the animals on Threatened or Endangered lists compiled by governmental agencies were once widespread and have been brought to the brink of extinction by direct or indirect human destruction of the organisms themselves, their prey, and/or critical parts of their habitat. In general, most of the very rare plants of the western U.S. have probably been very restricted in their distribution since a time predating the presence of our culture. Of course, many animal species have long had restricted distributions and some plant species such as the Tulip Gentian *Eustoma grandiflorum*, or, more famously, the Yellow Lady Slipper Orchid, *Cypripedium calceolus*, have been reduced from much more widespread occurrence. However, as a rule, inherently restricted distribution has characterized our rare plants, whereas the bulk of threatened or endangered animals have distributions and numbers which have been greatly reduced in recent times. It should be noted that some plants that have long had relatively restricted distributions have recently had them restricted further through the effects of disease, horticultural collection, grazing, or destruction of their habitat.

What principles should be used in determining which plants merit endangered status? Perhaps the most conservative approach is to limit designation to plants in danger of extinction over their entire known range. This is essentially the approach used in compilation of lists of proposed endangered plants by the U.S. Fish and Wildlife Service. Another approach is the inclusion of locally rare disjunct plants. An example of this in Colorado is *Rhododendron albiflorum* in the Park Range; this plant is indeed rare in Colorado but is much more widespread in the Pacific Northwest. An even more liberal interpretation of endangered status could allow inclusion of plant populations at the edge of a relatively large range if it can be shown that the range is being reduced.

Both these latter approaches extend the concept of protecting rare plants from protecting a species world- or nation-wide to protection within a smaller geographic unit. Protecting disjunct or marginal populations may be unnecessary if the species is well-established elsewhere and the goal is preservation of the species, *per se*. However, if the purpose of the protection is the preservation of genetic variability, then preservation of marginal or disjunct populations is well-founded. Such populations are frequently those with genetic makeup differing from the central part of the species range because of adaptation to environments at the extreme of the ecological amplitude of the species.

Another potentially valuable approach may be the preservation of plants rare within political boundaries such as states or even smaller units. This type of approach could find support in locations where the populace had acquired a sense of pride and/or responsibility for the unique botanic features that political unit may have inherited. In this manner, for example, plants such as *Rhododendron albiflorum*, *Trillium ovatum*, or many other rare plants in the Park Range of Colorado which are disjuncts from the Pacific Northwest could be protected. Under Federal rules, these plants could not be listed as Endangered or Threatened because they are not so rare in all parts of their range of occurrence. Yet, they represent a unique botanic feature which may be important to the people of Colorado.

In further consideration of the criteria for the identification of imperiled plants, some attention should be given to those plants which are not yet extremely rare but which, because of over-exploitation, have experienced great reductions in populations and face further reduction. These plants include those showy plants of horticultural interest such as cacti and orchids which have been collected in large quantities by private and commercial collectors as well as people casually picking flowers. Under the classification used by the International Union for Conservation of Nature and Natural Resources (IUCN), these plants would be placed in the "Depleted" category, meaning that the "species is sufficiently abundant for survival, but is in decline as a result of natural causes or human activity" (Melville 1970). As human populations in this region increase, pressures on horticulturally interesting plants will only increase. For aesthetic as well as scientific reasons, these plants may deserve protection along with rarer plants.

VALIDITY OF TAXONOMIC UNITS IN GENETIC PRESERVATION

There is another matter crucial to the establishment of a truly useful system for recognizing and protecting endangered plants. This is the matter of the plant units to be addressed in the system. Very often, "endangered species" are actually sub-specific units, that is, subspecies or varieties. This technicality is not of great importance except that, as one passes below the species level, disagreement among experts on the taxonomic validity of the units increases. This means that one man's subspecies or variety may be another man's unnamed forma or not regarded as a separate unit at all. In some cases, taxa established from one or a very few localized collections and never collected again may cause controversy as to whether they were valid taxa or were sterile forms or were within the natural variability of a higher taxonomic unit. Such disagreements are doubtless confusing to legislators and agency administrators charged with arranging for the protection of endangered plants.

This brings up the question of whether current taxonomic units are an adequate base from which the goal of genetic preservation can be conscientiously reached. While the morphological characteristics underlying traditional plant taxonomy do usually reflect genetic differences, other genetic differences correlating with differing ecological conditions are found within species and are referred to as ecotypes. Ecotypes have different physiological potentials that are often not accompanied by sufficient morphological differences to merit taxonomic separation. Dr. W. D. Billings has been responsible for much of the work demonstrating the nature of ecotypic variation in arctic and alpine plants. His work along with that of other plant ecologists, plant physiologists, and geneticists has demonstrated that significant variations in site adaptation can exist within a taxonomic species. The genetic variation of ecotypes could be of particular importance in the development of species adapted to high altitude disturbed sites, such as is currently being pursued by Dr. Robin Cuany of Colorado State University and others. It is suggested, then, that a useful system for the preservation of rare plant genetic resources should include a means of incorporating accumulated knowledge of restricted ecotypes and protecting them, even though they may be regarded as parts of wide-spread and non-endangered species.

CURRENT EFFORTS IN RARE PLANT PROTECTION

What is the current state of affairs regarding threatened and endangered plants in Colorado? At the Federal level, there has been a list published including plant taxa proposed for Endangered status. This list (U.S. Fish and Wildlife Service 1976) includes 32 plant taxa with known distributions in Colorado. There has been no official proposed list of threatened species; however, on the original list (designated a "Review of Status") which was generated by the Smithsonian Institution for the U.S. Fish and Wildlife Service (1975), fifteen additional plant taxa with known distributions in Colorado were listed as Threatened. At present, there are no officially designated Endangered or Threatened species in Colorado or any adjacent states.

At the state level in Colorado, there are no officially recognized threatened or endangered plants either, although the state flower, *Aquilegia caerulea*, does have some legal protection. The recently formed Colorado Native Plant Society is in the process of producing a list of plant taxa which they consider to be endangered or threatened. This list is based largely on information present in a checklist of Colorado plants produced by the University of Colorado Museum (Weber and Johnston 1976). The criteria used in selecting plants for the C.U. Museum list were more liberal than those used in making the Federal lists. Thus, about 146 taxa are regarded as endangered and 418 taxa are regarded as rare (more or less equivalent to "threatened").

Although no official list of endangered plants exists for the State of Colorado yet, the means for protecting them through identification and protection of critical habitat does exist within the provisions of the Colorado Natural Areas Act, passed into law last year and administered through a Natural Areas Council under the Department of Natural Resources.

Finally, let me turn briefly to problems I see in implementing programs for the protection of rare plants in the field. First of all, establishing the exact ranges of many of these plants will be difficult because of the lack of existing information and the difficulty of identifying some of these plants. Botanists with experience sufficient to identify the more obscure plants are relatively few in this region. Information concerning the precise distributions of our rare plants will accumulate slowly; the rate of accumulation may well relate directly to the rate of development of advanced amateur botanists.

Once localities have been determined, there is often a very real dilemma at hand regarding how many people should know exactly where a rare plant grows. The dangers of unscrupulous exploitation by collectors may be great if precise localities are publicized. Many of our rare plants are found in remote areas where future development is highly unlikely. In these cases, it may be that by involving the rare plant in a program intended to protect it, and consequently directing public attention toward it, the plant may face far greater endangerment than it ever would had no one ever tried to protect it.

On the other hand, protecting most truly endangered plants is likely to be simpler than protecting many endangered animals because the needs of animals are typically more complex due to their mobility and higher position in the food chain. Often they are critically dependent on large scale environmental factors which may already have been greatly altered. Because endangered plants are so restricted, preserving them is not an extensive obstacle to human developments (Jenkins 1975).

CONCLUSION

In conclusion, there is benefit to be realized from the continued existence of rare populations of plants with unique genetic variations, especially those adapted to extreme sites, whether or not this is reflected in taxonomic status. Attempts to protect these resources should include an inventory and a thorough investigation of their distributions, but may best succeed by doing little else except as actual endangerment of individual populations becomes apparent, necessitating legislative or administrative action.

Although I have not spoken as an official representative, let me encourage anyone interested in the native flora of Colorado to become involved with the Colorado Native Plant Society. This group is concerned not only with endangered and threatened plants but also with the use of native plant materials in horticulture and land rehabilitation and the general furthering of the appreciation of and, when necessary, the protection of our native flora. Membership information can be obtained by contacting Sue Martin, Membership Chairman, Colorado Native Plant Society, 4700 Venturi Lane, Fort Collins, Colorado 80521.

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DISCUSSION: BILLINGS, BUCKNER, McCALL

PECKA: How might the state plan and organize development so that it occurs in an orderly manner? What type of time table do we need to follow to be adequately prepared?

BILLINGS: We need an inventory of ecosystems now before they become over-stressed. Once an ecosystem is over-stressed, it rapidly deteriorates. We need to know at what point the ecosystem becomes stressed.

BUCKNER: We are already behind in our inventory process and need an integrated inventory process.

McCALL: From the government view point, we try to coordinate with other state agencies involved in the reclamation review process--water quality, water resources, air pollution, wildlife. If an applicant's activities will affect these areas, we try to have him present his application to all agencies involved. In this way the agencies involved can collectively and consistantly work with the applicant. In Montana, the state sent out a questionnaire on the state's future. In which direction should the state administrators lead the state? Inventories are needed on natural resource carrying capacities.

WILLARD: Does the Colorado reclamation act call for inventory of ecosystems?

McCALL: I don't believe that the reclamation act calls for the operator to inventory these areas. Rare and endangered animals have been considered. I think that the Mined Land Reclamation Board would be willing to consult and work with groups interested in the plant systems, too.

MARR: Does the endangered species act require protection of habitats outside those which contain endangered species?

BUCKNER: To my knowledge it does not. A pending federal law (the diversity act) is directed towards identification of unique ecosystems or habitats and is similar to the Colorado Natural areas act.

BILLINGS: The fundamental unit of preservation may not be at the species level, but at the ecosystem level. If certain ecosystems are rare or unusual, then the whole ecosystem including the edaphic environment, the topographic environment, and the biological environment need to be preserved as a whole. If you change a part, then the whole system may disintegrate.

COMMENT: The U. S. Fish and Wildlife Service is preparing a flora of threatened and endangered species.

BILLINGS: The preservation of ecotypes from individual areas is also necessary. The germplasm of such ecotypes is important for application to revegetation.

RECLAMATION: A POLITICAL VIEW

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I thought it would be appropriate to approach the field of reclamation from a political and historical perspective. Revegetation, of course, is the crossroads of the environmental movement, requiring by definition a disturbance of the natural environment and a program of repair. However, the reclamation movement in the western states had a curious and far different beginning. I suspect that John Wesley Powell, as much as any man, was responsible for its start. He pointed out the great potential of the Colorado River for agriculture, the rivers for commerce and the deserts for oases of economic and social growth. Reclamation in this historic sense came to us with reverse English. It meant the process of altering a natural landscape by impoundments, diversions and the leveling of land to create an economic and settlement opportunity for immigrants. The Bureau of Reclamation not only symbolizes this historic definition, but, indeed was created in 1902, as you recall, to generate it. In a peculiar sense one can argue that the very success of the philosophy of old-time reclamation--the alteration of nature for economic and settlement benefits--gave rise to the movements in the sixties and the seventies to curtail it.

The meaning of reclamation today is an outgrowth of, or a reaction to, the anti-reclamation movement. Instead of seeking to alter nature for economic gain, to which it seems to me the pioneers quite justifiably subscribed, reclamation today has become the movement to repair change wrought by man upon the land. The reverse of the earlier definition, modern reclamation is a movement to return land to its natural setting--to move the pendulum from economic value to environmental integrity of the natural landscape.

Now I confess to having, by circumstance and appointment, a foot in both camps. My grandfather came west at the turn of the century about the time the formal reclamation program was gaining steam: when economic units were assembled from the public lands. Our living today in northern Wyoming is dependent upon the use of diverted, though not impounded, waters for the production of alfalfa and native hay.

My responsibilities in the Department of the Interior included both the Bureau of Reclamation, then still defending, if not always successfully, the old reclamation ethic, and the Bureau of Land Management (BLM), then in the early stages of developing a new concept. I suppose the demise of the old definition was best noted in my office when in the early months following my appointment, the Bureau of Reclamation asked for an *ad hoc* meeting to brief me on the reclamation mission. They started the briefing by thanking me for the opportunity to present an "odd hack" briefing on the substance of their program.

My first year in Interior was in 1969 as a staffer to the Under Secretary Russell Train. This was the year that the National Environmental Policy Act was passed. It was also the year that the BLM completed a study indicating that although the rate of leasing Federal coal lands, measured in acres, had risen dramatically in the sixties, the rate of production had fallen rapidly. Let me use this program to illustrate the changing policies of reclamation in the late sixties and early seventies.

Because of the imbalance between rising acreages and declining production of Federal coal, the BLM informally stopped issuing coal leases in 1970 and '71. In 1972 a formal moratorium was imposed by Secretary Rogers C. B. Morton to assure that fair market value was being obtained and, most notably, to examine and upgrade the environmental stipulations required in a federal coal lease. Simultaneously, efforts were underway in the Congress to draft and promote the strip mine legislation which would require, as a condition of all coal mining, that the lands be reclaimed and revegetated. Although the Federal Energy Administration opposed this initiative with the eventual concurrence of the White House, the Interior Department under Mr. Morton strongly supported this national legislation. That support was based upon two broad principles: ethically, because the legislation reflected changing views of land as a resource to protect, as well as, a commodity to use; and, politically, because national legislation was necessary to guarantee against another Appalachia from happening in the West and to compromise between the economic and environmental interests in the nation.

It seems probable to me that the Interior argument would have prevailed if the bill in Congress had not been "Christmas treed" with issues and provisions neither essential nor germane to reclamation proper. These provisions established mineral institutes at all state universities, the expense of which the Office of Management and Budget opposed, and citizen suits, which the Justice Department opposed.

The failure of our voice in Interior to influence the posture of the Administration stimulated Secretary Morton to establish in 1974 an internal task force to develop a set of reclamation standards for application to the public lands under the BLM. These are the present BLM 3041 and the Geological Society 211 regulations that were published in 1976. These are now in the process of revision in order to comply with the Surface Mining Act. These BLM regulations require that what was eventually written into the strip mine bill for all lands: returning mined land to approximate original contour, setting aside topsoil, preventing acid mine drainage, requiring revegetation with native grasses, requiring irrigation, establishing the duration of liability and bonding.

The most original of its provisions was the opportunity for states to assume responsibility for the mining of Federal lands. The state must adopt as a minimum the Federal standards and demonstrate an effective administrative program to enforce them in order to assume responsibility. This provision was intensively opposed by the hierarchy of the BLM, who would loose bureaucratic turf, and by environmental groups who thought that the states would be more permissive in their administration and enforcement of the standards. We believed, to the contrary, that the people who would be the most vigilant in the protection of environmental values on the public lands would be those closest and most immediately affected. We hoped to avoid duplication of administrations between Federal and state permitting authorities. Those of us involved with the development of these reclamation stipulations were, I suppose, modestly pleased to see that the heart of the strip mine bill, passed in 1977 by the Congress, was built around, and in many instances, contained nearly verbatum our early Interior requirements.

There were, of course, important differences, both in provision and in language. The approach to alluvial valleys is a case in point. Our language called for the protection of the hydrological regime by the best commercially available technology. An approach that was as unpopular with the mining industry as it was with environmental groups. The Interior regulations called for the designation of lands to be withdrawn from mining with special emphasis being given to agriculture in alluvial valleys. There was not an absolute prohibition of mining in alluvial valleys; the burden of proof was the applicant's to demonstrate that the hydrologic regime could be protected. They did not, as the strip mine bill does, allow for the declaration by the land owner that stripping would not cause more than minimal disruption of his agricultural operations. Such a declaration will make alluvial valley mining much easier for companies who have reached consent agreements with surface owners. The Interior regulations, also, did not allow for trade-offs of alluvial valley coal rights to other areas of the public lands. This was, however, strictly prohibited by the amendments to the coal leasing bill of 1976 which specifically precludes such trade-offs.

It remains an open and fundamental question as to whether trade-offs as provided for in the strip mine bill will ever work for two reasons. One is the appraising difficulties of demonstrating equivalency of value of the two tracts of land. The second is the certain litigation that will ensue from either industrial interests who might themselves desire the coal being traded for or from public interest groups who might oppose the development of either coal site. The "trade-off" provision, I regret to suggest, should be regarded as only a temporary political solution necessary to getting the bill passed. No professional I know believes that within our lifetime there will be a successful application of it on the ground. Thus, it becomes for those land owners holding subsurface rights in alluvial valleys a cruel and tantalizing mirage--promising the realization of the economic values of his property rights by trade-offs, but without the mechanics to accomplish it.

Despite the uncertainty of the trade-off provision of the Surface Mining Bill, it does not change the historic significance of its passage. The coal mining in this country shall be encouraged but only if the land is repaired and revegetated. Economic and environmental interests have been balanced as indicated by the public utterances of dissatisfaction from both industry and environmental groups on its passage. But, its effectiveness has still to be demonstrated in the field. Whether it becomes a mechanism for solving environmental problems or side-stepping them is a matter of two things: the regulations themselves, and the officials who undertake to implement them. The human element is a most significant consideration. The regional director of the Office of Surface Mining (as yet unselected) will have enormous influence over how the program is administered in the field. His guidance over what constitutes satisfactory compliance of, for example, approximate original contour will provide the proof of the pudding.

My intent was to discuss that elusive balance between development and protection with application to western coal. As I have thought upon that balance it has become evident that there is no prescription of forumla for that determination. Because the players and their institutions change over time, as does public opinion, which is indispensible to influencing both, the balance must be drawn in a different place for each action and each time. What seems self-evident to me is that the pendulum in this decade vibrates as much for environmental causes as for economic--a sign of the maturity of this country. The days and the philosophies of J. W. Powell were justified and necessary for the westward expansion and manifest destiny of this country. Equally necessary and inevitable was the growth of the environmental movement.

The only sure prediction is that the success and persuasiveness of any movement guarantees the advent of its counterbalance. It is probable, for example, that over zealous enforcement by the Office of Surface Mining to the point of extending the intent of the Congress will guarantee support for political forces working in the opposite direction. The counterbalance will push the pendulum to a different point.

The one common and essential element is the dedication and the integrity of the people involved. Their perspectives span both sides as is necessary to this country. This is why I believe this workshop is so critical because you exist at the hub of the controversy and necessarily reach to both sides. You, therefore, must be pragmaticists as well as idealists--knowing that we must continue to insist upon a better environment as a matter of principle, but that, for many Americans ourselves included, a better environment means jobs and minerals. It seems to me that this understanding of the balance between development and protection is very critical to both the proper recognition and the proper solution of the reclamation problems.

THE ROLE OF ENVIRONMENTAL CONSULTANTS IN RECLAMATION

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In order to clarify the various services that environmental consulting firms can provide for reclamation efforts, let me first present my conceptual analysis of reclamation itself. Reclamation, like most other planned operations can be broken down into a number of discrete steps along with the operation generating the need for reclamation.

As we look at a breakdown of these process stages, keep in mind that the primary function of an environmental consultant is to complement the capabilities and staff of his client. This may be done by either providing highly specialized capabilities not present on the client's staff or by providing additional manpower more efficiently than can be done with the client's personnel.

First, I would like to illustrate the various major phases of an industrial development requiring reclamation efforts (Figure 1). It should be noted here that although reclamation efforts are typically conducted at the end of the operations on a given site, the whole reclamation program must be planned along with the overall operation. Thus, reclamation planning should be a component of the Major Process Planning and plans developed there should be revised as necessary during the Secondary Planning stage. In short, successful reclamation doesn't just happen; it is carefully planned.

STEPS IN RECLAMATION PLANNING

Now let's turn our attention to the steps in reclamation planning and implementation (Figure 2). The first major task, and one that is too frequently neglected, is to thoroughly characterize and understand the disturbances which must be reclaimed. Many of the past failures in reclamation efforts have resulted from attempts to apply the same set of reclamation procedures to all types of reclamation problems. Thus, it is imperative that any reclamation planning be based on a thorough understanding of the operation

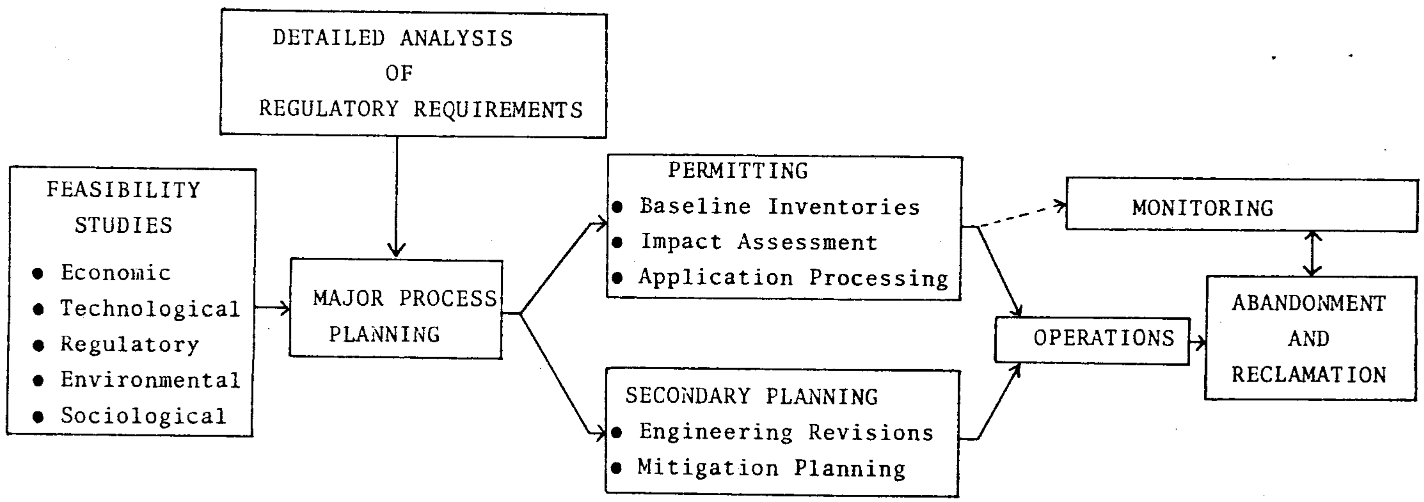

Figure 1. Generalized Diagram of Developmental Phases Common to Industrial Projects.

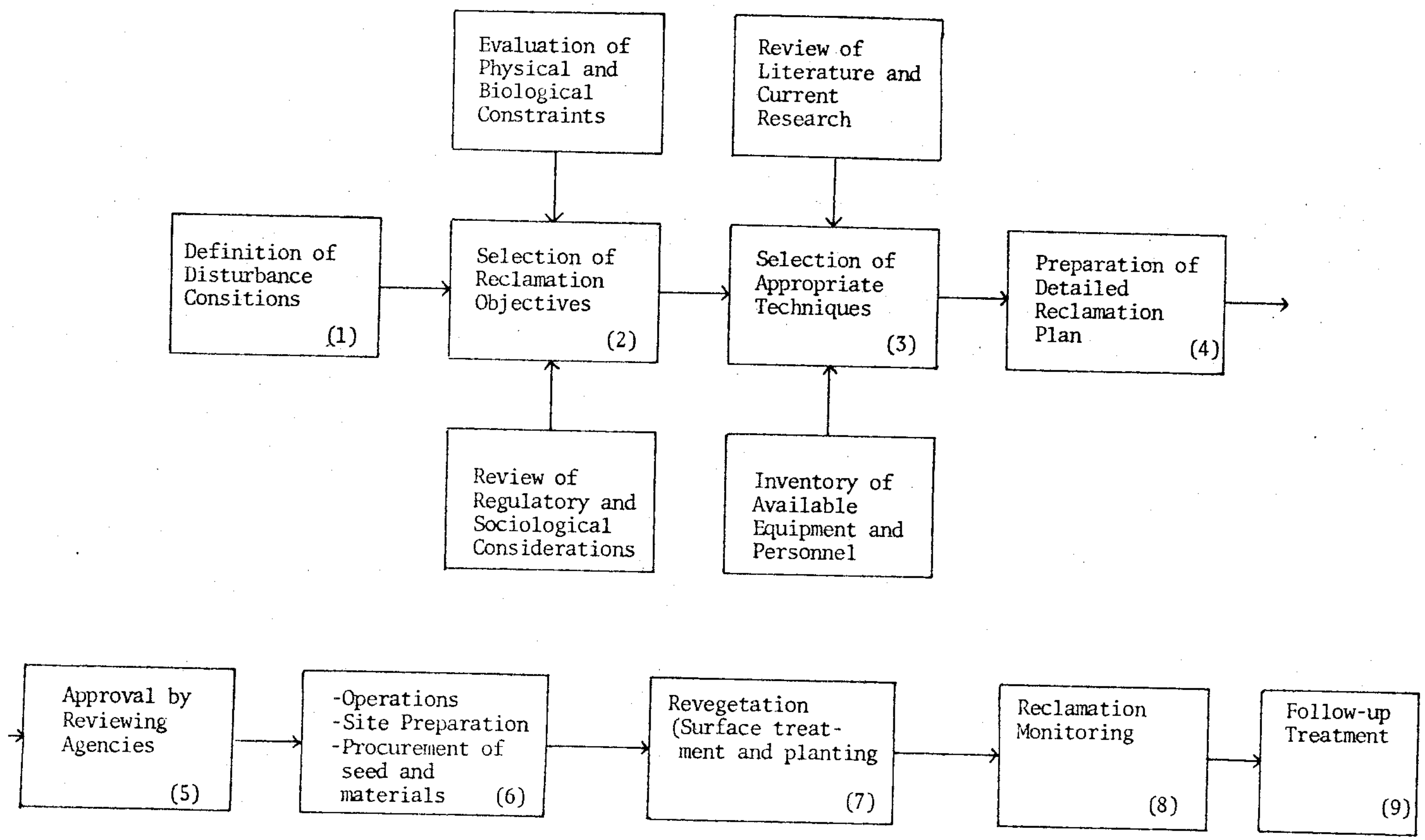

Figure 2. Steps in reclamation planning and implementation.

generating the disturbance; the constraints imposed by local climatology, soils, and faunal populations; and requirements or priorities imposed by governmental regulations, local social needs, and general economics.

Once these various factors are understood, it is possible to establish reclamation objectives for the area. Work to reach this stage is best done jointly by the operating company and its consultants. Certainly, the consultants are seldom in a position to fully appreciate the operating and economic constraints of the client, and conversely, the operating company frequently lacks a thorough perception of the physical and biological constraints. Thus, the cooperative effort helps insure adequate consideration of all pertinent factors.

The next major task, selection of appropriate reclamation techniques, is one of the areas where consultants have historically played an important role. With the operating company defining the availability of equipment and personnel, the consultants are commonly asked to recommend optimal techniques to insure rapid, efficient reclamation. In order to provide this service, the consultants must be familiar with the literature, ongoing research, personnel involved in reclamation efforts on similar areas, and the relative cost versus success relationship of various techniques. Some techniques may automatically be excluded on a given project because they aren't appropriate under specific conditions. More often, however, a variety of procedures are technically feasible with selection being necessary on the basis of efficiency and availability.

Preparation of a Detailed Plan

Once the appropriate array of reclamation techniques are selected, a comprehensive plan should be prepared which clearly describes the procedures to be used, the rationale for their selection, the availability or source of materials, the criteria for determining reclamation success, and contingency procedures for corrective measures if necessary. This plan should contain sufficient detail to allow evaluation by both reviewing agency personnel and concerned laymen.

Unless the operating company has well qualified personnel in the reclamation field, preparation of the detailed plan is probably more conveniently done by the consultant with input and review from the client. If this approach is taken, however, sufficient interaction must occur to allow both parties to be satisfied with the plan, since they will both likely be involved in defending it before the reviewing agencies. Too often, consultants are hired and work performed without the client having a thorough understanding of the product he receives. In many such cases, both the operating company and the consultant end up embarrassed during a critical review. It is imperative that the consultant and client have good communication channels and thoroughly understand what the other is doing.

After the detailed plan has been approved within the organization of the operating company, it is submitted to the reviewing agency. In the case of surface mine reclamation, the reclamation plan is normally submitted along with the mining plan.

Surface mining companies are frequently reluctant to submit a thoroughly detailed reclamation plan, as discussed here, to a reviewing agency. Because of the long life of a given mine, it is undesirable at the outset to become locked into approaches and techniques that may soon be outdated. This is an understandable concern, especially in states where the revision of a mining or reclamation plan entails numerous reviews and approvals. In such cases it is much simpler to submit a reclamation plan covering only the general procedures and required information. This, however, does not justify the absence of a detailed plan. Even if not submitted to a reviewing agency, the operating company should prepare a comprehensive plan for its internal planning and later reference. With the high level of personnel turnover within many companies, this is one way of insuring consistency in the reclamation program for a long term operation.

Revegetation

Mining operations or other land disturbances most commonly cannot commence until the reclamation plan is approved by the appropriate agency. Since reclamation considerations often have bearing on how the site is disturbed in the first place, site preparation for reclamation actually begins with the first turning of earth. Depending on the duration and timing of the operation, it may also be necessary to begin procuring seed, seedling stock, and other reclamation supplies at this point. Procurement of seed for some species may require a year or two-year delay from the initial procurement decision. Here again, the environmental consultant may be of benefit in locating sources or performing collection services.

The earth moving and revegetation activities are quite straight forward and normally performed by the operating company itself. In the case of unusual or complex reclamation procedures, however, additional field supervision may be necessary. This may be provided by either the reclamation staff of the operating company or by the consultant.

Following revegetation, the area should be inspected periodically to insure that reclamation is successful. Again, this service may or may not be assigned to a consultant depending on the client's staff capabilities. While the approach for obtaining personnel to perform this evaluation may change from time to time, the criteria for making the evaluation must remain stable and should be established in the original detailed reclamation plan.

SELECTING A CONSULTANT

In these various steps of the reclamation process the environmental consultant serves a variety of roles, including:

- collector and compiler of data and literature
- coordinator of applications and reports
- reviewer of preliminary operating plans
- liason with technical agency personnel
- "impartial" observer and technical evaluator
- expert witness

If these are the services expected of the consultant, how does one go about selecting a consultant? The first thing that should be done is to decide exactly what services the consultant will have to provide. For example, is it a question of high technical expertise, or manpower, or both that is involved? On the basis of this decision, one can look at consulting companies in terms of their expertise in specific areas and their manpower available. One should also attempt to determine exactly who of the consultant's staff would be assigned to the job. Expert capabilities of a consultant are of no benefit to a client if they aren't involved on his job. The client should also examine the prospective consultant's managerial experience on similar projects and evaluate his "track record."

In some cases the client may not know what services the consultant will have to provide because of unknowns within the operation planning process. In this case the client should also evaluate potential consultants on their ability and experience in developing realistic programs.

While the summary has covered the principle roles of consultants in the reclamation process, there are innumerable other tasks which consultants may perform. The variety of assignments is only limited by the variety of capabilities represented by individuals in the consulting field. In general, where some operating company has a need, one or more of the consulting firms will develop the staff capabilities to handle it.

A REGIONAL PERSPECTIVE ON LAND RECLAMATION ECONOMICS

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INTRODUCTION

The purpose of this paper is to examine some of the factors responsible for variations in reclamation costs and benefits, and to emphasize the significance of economic factors and alternative philosophies to reclamation planning. Actual reclamation cost and benefit data are of great significance to the reclamation program at the site to which they are applicable, and a number of specific cases are examined in this paper. It is recognized that site-specific data often have applicability in the planning of other similar operations and are often used in defense of various reclamation economic philosophies (theoretical approaches to such questions as, "How much should reasonably be spent on a reclamation program?" "Who will pay for the reclamation?", and "How will it be paid?"). The applicability of these data is limited, however, and may be misleading when extrapolating to sites in other regions, to different types of mining operations in similar regions or the same region, or to any site being reclaimed for a different use. The examples given in this paper were chosen for their diversity in order to illustrate the range of costs and opportunities that may be encountered in land reclamation planning.

Despite the technological advances realized in recent years, land reclamation must still generally be considered to be experimental. Current reclamation practices at best result in satisficer conditions. The processes of topsoil removal and replacement, overburden recontouring, and revegetation cannot reproduce pre-mine subsurface physical conditions. As yet, the overall impacts of mining and reclamation on hydrologic conditions and soils ecosystems are unknown. Nor has the long range productivity of reclaimed soils in prime agricultural areas been demonstrated (Doyle, 1976). The fact that the federal government is spending more than $453 million annually on over 2500 energy related environment and safety programs, with 107 of these projects ($20.8 million) related directly to coal land reclamation issues reflects that for any type of surface mining, many reclamation problems still exist (LaFevers and Imhoff, 1977). Not the least of these problems are the economics issues, which are considerably complicated by the fact that no universally accepted definition of the term "reclamation" or any alternative term presently exists. No matter how much resources (capital or otherwise) are expended, therefore, it may not be possible to determine whether an area is acutally "reclaimed." Two 1977 reports state, for example, that in Colorado and North Dakota almost no mined areas had been released from reclamation bonding requirements since the enactment of their reclamation laws in 1972 and 1970, respectively (Rold, 1977 and LaFevers, Johnson and Dvorak, 1977). In other states where land has been released from bond, there is often criticism that the land is not completely reclaimed. This controversy exists at least in part because of the very weak definitions of reclamation written into the existing reclamation laws (for a discussion of the way this definition is handled in various states, see LaFevers, 1977, Carter, *et al*., 1974, and Imhoff, *et al*., 1976).

In addition to the federal government, forty states have reclamation laws that dictate minimum standards which, under most circumstances, must be met or exceeded. This indicates that the citizens of these states want to have a role in the reclamation of their land and that they are willing to pay the price for that reclamation (even though they do not know what the price will be). Alternatively, the thought may prevail that they will be paying a higher price in social and opportunity costs for not reclaiming, or that consumers in other states will ultimately pay for the reclamation through higher commodity prices.

Considering that some of the reclamation cost may be recovered by the mine operator through increased land value, sale of products, public relations values, etc., there are at least two basic philosophies concerning the theoretical maximum that should be spent on reclamation. One of these philosophies, described by Leaming (1977), is that the inputs to reclamation should not exceed the value of the land after reclamation plus a differential to account for direct public interest in the reuse of the site. Leaming states, for example, that "the expenditure of $2,000 per acre to put land into a condition in which it is worth only $500 per acre on the land market, is a misallocation of $1,500 worth of other resources just as much as spending $2,000 to make a $500 motorcycle." The premise is that since only $500 could be recovered, and the public will eventually have to pay the remaining $1,500 in increased commodity prices, perhaps the excess could be more profitably spent on social programs to aid local residents. In addition, if "excessive" reclamation costs have to be added to the price of the commodity, the competitive position of that industry in the commodity market is worsened. In the case of coal, for example, reclamation costs can often be the most significant factor in determining whether the mined product will be competitive not only with coal from other regions, but also with other energy sources. The same is true of copper, which must compete with other metals for portions of the same market, and of most other mineral commodities. The other philosophy is that if the land is to be mined, it must be reclaimed completely regardless of the cost and no matter how it is paid for or by whom. The premise here is that the value of the mineral that can be recovered must be sufficient to pay the reclamation costs in addition to the mining and processing costs or the mineral should not be mined at all.

A compromise philosophy has been adopted as the basis for reclamation laws. In this thesis, an acceptable minimum level of reclamation is established, often by rather arbitrary criteria, and operators are required to meet or exceed these standards regardless of the cost. In most cases, however, if a standard can be shown to cause an unreasonable hardship in a particular case, provisions are made for the granting of a variance (the "doctrine of reasonableness" referred to by Imhoff, *et al.*, 1976). In some cases it is recognized that pre-mining conditions may not be the optimum conditions for the post-mining landscape. In P.L. 95-87, for example, provisions are made for the mining company to check with local planners to see if a reclamation plan conforms with existing land use plans and policies. At the same time, the possibility exists that alternative uses will be identified that may be of more value to the local community, thus increasing the value of the reclaimed site (LaFevers and Imhoff, 1977).

RECLAMATION COSTS

The estimation of reclamation costs is usually a very difficult and imprecise process. Even for a single site, it is an unmanageable task to list all the variables and quantify their relative effects on the overall cost of a reclamation program. Since cost data are often considered proprietary, many companies are not willing to provide access to them. When access is provided, the data are often incomplete because mine operators do not, as a rule, separate reclamation costs from extraction costs in the detail necessary for accurate overall estimations. It may occur, for example, that a dragline operator, whose primary task is excavation, will be directed to selectively place some overburden materials in order to facilitate the reclamation process. In such a case, a portion of the operating cost of the dragline should be counted as a part of the total reclamation cost. The same is true of any portion of the mine planning function that deliberately results in a modification of the reclamation plan. Although mine planning and reclamation planning should be integrated, often some costs relating to both are compiled as mine planning costs. Legal fees and related expenses are an example of costs that are difficult to isolate. In many cases, the costs associated with obtaining data, completing forms, filing plans, and providing public notice for reclamation operations are difficult to separate from the costs relating to the same activities conducted for the extraction operation. Some costs that are not usually quantified include the opportunity costs related to reclaiming land for specific uses. In some cases legal requirements make it impossible to reclaim a site for certain uses. In such cases, possible added value is lost when the land is reclaimed for a less profitable use.

Further complicating the process of determining total costs is that each mine operator has a different method of compiling and reporting reclamation costs, and includes a slightly different set of parameters in figuring totals. None of the mine operators or reclamation personnel contacted during the conduct of recent programs could isolate all the reclamation cost factors for a given mine precisely enough to determine exact figures for reclamation separately from other processes. In most cases, however, an examination of the data made available by industry personnel, and published data gives considerable insight into the approximate range of costs associated with many reclamation practices.

Some of the factors through which reclamation costs are channeled are shown in Figure 1. Several options are usually available throughout the reclamation process and costs vary as these options are exercised. Costs also vary in relation to physical and cultural factors which may not be reflected in Figure 1. For any mining site, it is probable that several feasible post-reclamation land use options exist. Each land use scenario will require a different set of inputs during the reclamation program and will, therefore, have a different total cost. Total inputs required to reclaim a site for cattle grazing will be different than the total inputs required to reclaim the same site for residential development. This principle is generally true for all types of mining and for all regions.

EFFECTIVENESS OF RECLAMATION

The benefits directly related to a reclamation program are probably even more difficult to assess and quantify than are the costs. One method of measuring program effectiveness is to inventory the productivity and value of the land prior to mining and then compare the productivity and value of the reclaimed site to the previously existing conditions. This is a most popular method, and one that is sometimes espoused by environmental advocacy groups and used as a guideline in preparing state and federal reclamation laws. At least eleven states and the Federal Office of Surface Mining currently have "original contour" clauses in their reclamation laws, and seven require original, self-regenerative, or natural vegetation. Although this concept allows for a standard against which to measure productivity of the reclaimed land, it almost completely precludes the benefits that can be derived from reclamation planning and from reclamation designed to create a landscape that will fulfill a specific land-use

RECLAMATION COST FACTORS

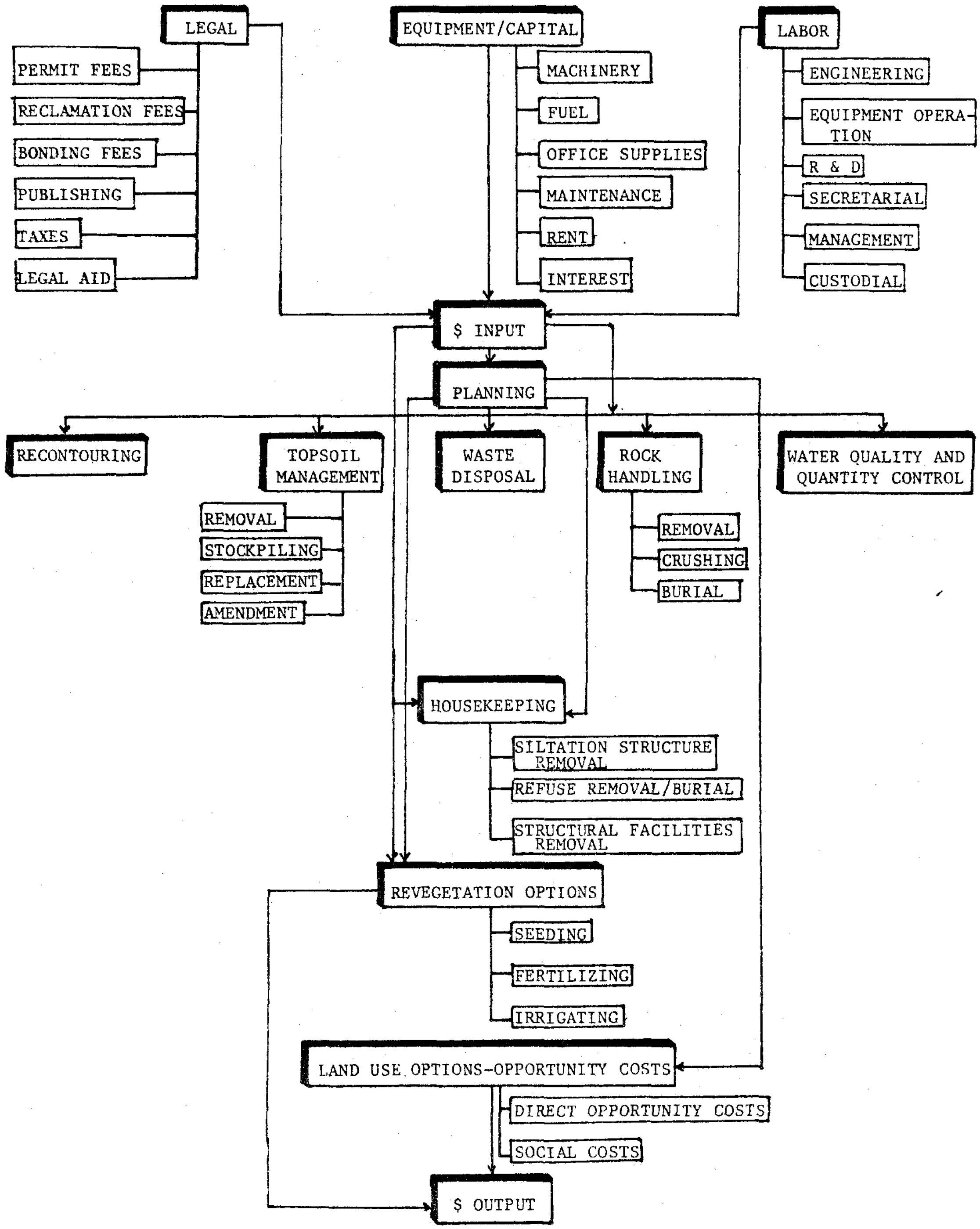

Figure 1.

need of the local community or state. It has been demonstrated elsewhere, for example, that land reclaimed for exotic uses (i.e., recreational housing sites in a forested area, or farm community) can be many times more valuable than unmined land in the same locale (LaFevers, 1974). It has not been demonstrated, on the other hand, that the conditions in which unmined land currently exists is the best of all possible conditions, and that it should, therefore, be returned to that state. In many cases, of course, the original (pre-mining) land use will be the most productive and the most feasible choice in a reclamation plan. However, the opportunity to make that decision, after consideration of alternatives, should not be denied.

As an alternative to these "original conditions" concepts, one might consider the reclaimed area relative to the conditions prevalent after mining but before reclamation, rather than prior to mining. After mining, the land might actually have a negative value, since a debt is owed on it that must be paid before a profit can be realized. The site occupies space, but in most cases the owner would be better off if he did not own it since the law will require him to expend capital in excess of that for which he could purchase adjacent similar land. An advantage exists, however, in that the owner (or operator) now has the opportunity and mandate to create an entirely new landscape designed specifically to suit the needs of a projected use.

Many of the benefits that accrue as a result of reclamation are almost intangible, and although it is sometimes possible to quantify many of them, it is beyond the scope of this paper to do so. These "social benefits," as they may be called, include beautification of the landscape, or aesthetic value, provision of non-commercial recreation areas, both public and private, pollution abatement, erosion prevention, preservation of wildlife resources, and maintenance of an acceptable self-image by the residents of the mined areas. It was demonstrated in a past study, however, that it is possible to quantify the relative attractiveness of adjacent reclaimed and unmined areas for some particular uses. Coal strip mine areas near a large population center in Indiana, for example, were shown to range up to almost ten times as attractive for recreational housing sites as adjacent unmined areas primarily because of the availability of lakes and the secluded setting afforded by the wooded ridge and valley topography (LaFevers, 1974).

CASE EXAMPLES - WESTERN STATES

Nevada

Open pit copper mining; Anaconda Copper Company. If one considers only direct costs, this is the only site reviewed by the author at which all the reclamation cost data were available. Since no reclamation procedures are planned for this site, reclamation costs are zero. After approximately thirty years of mining, the site will be abandoned, and the pit will partially fill with water.

Arizona, Tucson

Open pit copper mining. Although Arizona has no reclamation law, and the federal law (P.L. 95-87) does not apply to non-coal mining, most of the mining companies are experimenting with some type of reclamation procedures. The basic reclamation program consists of planting exotic or native shrubs or grasses on the outslopes of the tailing pond berms or other structures that are visible from the highway or nearby community. Costs average around two thousand dollars an acre, one-half of which is for the irrigation system (Thames, *et al.*, 1978). At present no general practice exists for revegetating the surfaces of tailing ponds, which are usually toxic to most plant life.

Arizona, Black Mesa

Peabody Coal Company area type coal mining. Because this operation is on the Navajo-Hopi joint use area, land value data are not used to help quantify benefits. Reclamation costs are exceeding $5,000 per acre for parts of this site, including grading to original contour, revegetating for grazing purposes, fencing to protect from overgrazing during initial years of revegetation, and monitoring. Peabody personnel report that the carrying capacity of reclaimed areas is higher than prior to mining, in part because the area was badly overgrazed.

North Dakota

Lignite mining. Four sites mined by four different companies. Under the reclamation law in effect until 1976, backfilling, grading, seeding, soil amendments, and the removal, stockpiling, and replacement up to eighteen inches of topsoil averaged about $2,400 per acre. When the state reclamation law was changed to require the replacement of up to five feet of topsoil, reclamation costs went up to as much as $6,600 per acre. At $2,400 per acre, reclamation costs were broken down as follows:

	$/Acre	% of Total
Grading	1,320	55
Topsoil Removal	480	20
Topsoil Replacement	192	8
Engineering and Administration	336	14
Seeding and Fertilizing	72	3
	2,400	

These costs include a maximum of two feet of topsoil removal and replacement and do not reflect a separate cost for backfilling. The topsoiling costs in this case average 21 cents per cubic yard. At $6,613 per acre, topsoiling costs averaged 50 cents per cubic yard, and five feet of topsoil was removed and replaced. At this rate, total costs break down as follows:

	$/Acre	% of Total
Grading	1,500	23
Topsoiling	4,033	61
Backfilling	1,000	15
Seeding and Fertilizing	80	1
	6,613	

In this case, topsoiling is the most expensive part of the operation, and it should be noted that if in the previous case, topsoiling costs were projected for five feet of material (8,067 cubic yards per acre), these costs would be $1,699 per acre. It can, therefore, be stated that topsoiling has become the most expensive part of the reclamation program (LaFevers, Johnson, and Dvorak, 1977).

These cost figures are somewhat substantiated by a recent U. S. Bureau of Mines report which states, "The average reclamation costs in the region ranged from $2,500 per acre where very little topsoil removal is required to $5,050 per acre where up to five feet is removed and replaced." (Persse, *et al.*, 1977). Land values in the area average from $175 to $300 per acre. Since no reclaimed land has been placed on the market, one can only assume that its value will be similar.

SUMMARY AND CONCLUSIONS

Research programs are needed that will identify and develop procedures for improving the cost-effectiveness of reclamation programs. The situation currently exists in which it is almost impossible for the direct benefits from reclamation to pay the direct costs. Land values and productivity, for example, are not usually increased enough by marginal inputs to cover the marginal costs. A primary consideration of all reclamation research programs should be economic implications.

It is most probable that even though subsurface conditions may not be completely reconstructed, under existing technology it is possible to recreate a landscape that will produce vegetation in quantities similar to that produced prior to mining. Whether this constitutes reclamation is a matter that will be determined by the people. It is also technologically feasible to create wildlife habitat and other land uses on mine sites. It can be said, therefore, that the surface value of the land can, in most cases, be restored to pre-mining levels or higher. Exceptions will occur in the case of special historic, archeologic, or other sites which have an indeterminate value (and which will probably be designated as "no mine" areas), and where an aquifer may be disrupted, thus reducing the value not only of the reclaimed area, but of surrounding land as well. In general, however, the technology exists to fill in practically any hole and revegetate any surface if cost is no object. The challenge is in developing technology that will allow improved environmental protection while keeping costs in line.

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THE ECONOMICS OF REVEGETATION AS OBSERVED BY

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Of the numerous ways to establish vegetation on a given project, it is my expressed opinion that our goal as educators, consultants, and contractors should be to obtain the desired results with the least expenditure of materials, equipment, and labor.

Years ago when I first became involved in the business of revegetation, it was considered a good seeding job when we planted 3 to 10, and in extreme cases up to 14, pounds per acre (3.3 to 16 kg/ha) of seed consisting of no more than two varieties. We would sometimes be paid as much as $30.00 per acre for disking and drilling. Today, a typical seeding job might consist of from 40 to 80 pounds (45 to 90 kg/ha) of seed costing as much as $200.00 per acre (I have seen some mixtures with woody plant seed which cost in excess of $1000.00 per acre), 300 to 500 pounds (334 to 557 kg/ha) of fertilizer and from 1 and 1/2 to 3 tons of vegetative mulch of one variety or another per acre. The cost to the owner will range anywhere from $250.00 to $10,000.00 per acre.

For many years I have observed overkill in specifications for revegetation projects, but as a contractor and a capitalist, I did not see reason for making an issue out of something which was supporting our business.

In the fall and winter of 1973 Vail Pass was begun. And in the following years during the execution of revegetation work on this project I became convinced of the importance of the economics of revegetation as an issue. In giving some background on Vail Pass, first let me say that I am not pointing a finger at anyone. I will be the first to state that the millions spent on Vail Pass for revegetation was necessary, not for successful revegetation, but to appease the many agencies and pressure groups who voiced concern over Vail Pass: the U.S. Forest Service, Colorado Game and Fish Trout Unlimited, The Sierra Club, and the adjacent cities of Frisco and Vail.

Research involving every consideration of surface revegetation was undertaken by the Colorado Department of Highways with the cooperation of the Forest Service. The result was a fool-proof plan which was expected to cover everyone's trail. Simply stated, the concept developed was to lay jute on every raw cut, fill, or otherwise disturbed area with additional instructions that no more than a specified area could be disturbed at a given time. It was not exactly fool-proof, but fortunately these agencies had the foresight to overkill on this project. Within the first construction season several contractors including ourselves were served with a million dollar lawsuit for contamination of the Eagle Valley's water system. Although the alleged contamination had happened every spring since the water system was built, we were the naughty contractors who caused it that year.

Specifications called for a seed mixture of from 40 to 80 pounds per acre of pure live seed and as many as 10 varieties. Fertilizer was fairly conventional at about 200 pounds (223 kg/ha) of phosphate and 50 pounds (56 kg/ha) of available nitrogen per acre. Hay was specified as a mulch at 1 and 1/2 tons per acre and, as previously stated, jute was laid over the entire area. The contract then called for watering. These are good specifications, or I should say excellent specifications for areas having severe erosion potential or severe cuts and fills. The fallacy was that these same specifications were also used on flat areas with little or no erosion potential. This process after mikes contouring and the topsoiling was complete cost the taxpayer approximately $10,000.00 per acre, before watering. If the Highway Department would have had less outside influence and could have substituted other methods for less critical areas, the saving on this one project would have approached one half million dollars. Vail is an extreme example of my subject matter. Too many times we as contractors are exposed to a set of plans and specifications for a specific reclamation project where the consultant has obviously given little or no thought to cost. In some extreme cases, he has given no thought to results either.

Probably the best example I can give is the requirement in a set of specifications which says, "The contractor will guarantee a stand of grass." This sounds good, but unless you have also specified maintenance the contractor has no choice but to "jack-up" his prices to protect himself for the few times when Mother Nature is not going to come through. An owner will pay a contractor from 25 to 150% more because of that clause. If the job is designed correctly, the grass will come up anyway. If specific watering and erosion control maintenance is specified, then a guarantee is in line and will cost little or nothing more.

Some other examples of poorly thought out specifications might be, "The contractor shall mulch and crimp all areas with 2 and 1/2 tons of hay per acre." These are good specifications unless it is on a 1 to 1 slope. Then, what do we do? The specification might say, "Contractor shall lay jute perpendicular to all slopes," etc. Which is fine, but what if the slopes are only 4 feet high and 800 feet long?

The type of treatment for any given area has bearing on both economics and results. Many times a combination effort of, for instance, hay on areas 3 to 1 or flatter, and wood fiber on slopes steeper than 3 to 1 might be a more economical and better alternative. Combinations of blankets on steep areas and vegetative mulch on flat areas would be another alternative. Sometimes it may be wise to consider just straight tillage and drilling, followed by drag chains or packer wheels, and no mulch if the area is flat and not subject to severe wind and water erosion.

Contractors are probably highly opinionated and old-fashioned, but you may be surprised at what we have to offer. Most of us are more than happy to discuss the feasibility of the execution of different concepts and approaches. We welcome the opportunity to give you approximate costs for budget purposes.

In closing, I would like to express one observation; we as a contracting company work in several states for several state and federal agencies, and for many different mines and private developers. One thing I cannot help noting is that almost every consultant has been living in his own little world, inventing his own wheel. Thanks to seminars like this one, the International Erosion Control of California, and ALCA's (American Landscape Contractors Association) Erosion Control and Reclamation seminars, and to people such as Burgess Kay and William Berg, and many others from universities and from the private sector, this era is ending with their input into successful revegetation.

The following are some approximate sales prices on today's market for the various items of revegetation. For this purpose I have based everything on 100 acres of ground and less than 3 to 1 slopes.

Straight tillage and drilling:	$20.00 to $30.00 per acre plus the cost of seed.
Fertilizing:	.15 cents to .50 cents per pound depending on whether it's inorganic, organic and or slow released.
Straw mulch:	$90.00 to $110.00 per ton applied and crimped.
Hay mulch:	$120.00 to $150.00 per ton applied and crimped.
Wood fiber:	$300.00 to $400.00 per ton applied.
Jute netting:	90 cents to $1.00 per square yard installed.
Excelsior neeting:	65 cents to 75 cents per square yard.
Economy netting:	30 cents to 40 cents per square yard.
Hold grow:	85 cents to $1.00 per square yard installed.
Sod:	$1.00 to $1.10 per square yard installed.
Watering:	$3.00 to $10.00 per M (thousand) gallons (Depending on source, quantity and method of application--a pipe system is cheaper).
P.V.A.	Approximately $7.00 per gallon installed. (Also other comparable chemicals).
Asphalt emulsion:	50 to 60 cents per gallon installed.

DISCUSSION

COMMENT: I would like to point out that the cost of Vail Pass does not appear high when compared to the cost of going back to a poorly done project. In the late sixties a highway on Straight Creek (not far from Vail Pass) was built not using good revegetation techniques. Now the Colorado Highway Department is going to repair the poor revegetation effort at a cost of 3 to 4 million dollars. The seed species and the seeding rate were recommended on the basis of U. S. Forest Service research.

RANDALL: I am convinced that a large quantity of seed is necessary for a fast cover and a good revegetation program to prevent erosion.

BOWMAN: The Vail Pass project is almost a front yard landscaping program. Spending $10,000 per acre for coal mine reclamation may not be possible.

RANDALL: Vail is an extreme example, especially on the flat areas. I think we can get good results without going as far as the Vail project went.

SWANSON: There was some straight drilling and mulching on some gentle slopes.

RANDALL: Yes, some work was done without jute netting in the last season. It is too early to tell, but it looks like the results will be as good as areas with jute. The results may even be better because some evidence indicates that the jute is detrimental to the seeds-timothy did not germinate through the jute.

MARR: The fact that Vail Pass was like a lawn landscaping program points out the special fearures of the Vail Pass highway. There were special aesthetic considerations so that the highway could blend with the landscape. It is more comparable to a metropolitan boulevard in in terms of people use and desired aesthetics. This unique feature should be remembered when comparing Vail Pass to other projects.

RANDALL: Vail Pass was a demonstration project. It is pleasing to the eye. We as contractors are proud to have had something to do with the project.

SCHWENDINGER: Strict specifications work well for the engineer, but they may be a detriment to reclamation work and also very expensive. For example, a highway project specified watering to insure revegetation. That summer we received a lot of rainfall, but we were still required to water in the rain.

RANDALL: Water is a difficult area to specify. All climatic conditions are hard to predict and this affects the contractor's price. Specifications are starting to be put together for water maintenance in a way that is good for both the owner and the contractor.

THE USE OF THE PLANT INFORMATION NETWORK (PIN) IN HIGH ALTITUDE REVEGETATION

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The Plant Information Network (PIN) is a computer-based data bank for rapidly retrieving and organizing information on the native and naturalized vascular plants in the states of Colorado, Montana, and Wyoming.

PIN is not a new concept or a new development in information systems. It is a new adaptation or modification of previous systems. The previous programs were called (1) TAXIR and (2) RAPIR. TAXIR is a program started at the University of Colorado as a means of recording, cataloging and updating herbarium information. In this system TAXIR catalogued the individual specimens collected, vouchered, and recorded in the herbarium. RAPIR, the Rapid Access Plant Information Center, using the RAPIR program in addition to cataloging herbarium information, was also expanded to include other taxonomic, geographic, and some biological and economic information.

The Colorado State University Experiment Station funded the RAPIR program for 5 to 6 years and spent about $60,000 on its development and operation. During this time, the principles involved in the project were Dr. William Klein and Dr. Robert P. Adams of the Botany and Plant Pathology Department.

In 1974, The Office of Biological Services, of the Fish and Wildlife Service, was established. Within the Office of Biological Services, four national teams were established, of which the Western Energy and Land Use Team in Fort Collins, Colorado is one. The Western Energy and Land Use Team began its initial staffing in 1975. As the Team began to plan and develop its projects the applicability of RAPIR was quickly recognized as a potential tool for land use managers and people making decisions and needing information about plant species and vegetation.

A new project was initiated which included the basic concepts of the RAPIR system and greatly expanded its geographical coverage and its informational base. At this time the name of the system was changed to the Plant Information Network or PIN. The concept behind this system was to develop a tool that could provide information about plant species and vegetation to land use planners and resource managers. Much of the information these people need is often unavailable to them because of a lack of library facilities, or a lack of time to obtain the appropriate information. The PIN system is designed to provide that information in a short time to the users.

Sources of information included in PIN are: (1) herbarium specimen labels from major herbaria in each of three states; (2) extensive searches through scientific, professional, and popular publications pertaining to the taxonomy, geography, biology, ecology, and economics of the plants found in the three states; and (3) the unpublished judgment and experience of long-time experts and field researchers on the attributes and utility of plants in the areas of wildlife-plant relations, livestock-plant relations, soil-plant relations, and man-plant relations.

Three major uses of PIN were anticipated and are now resulting from the system. These include (1) vegetation inventories--lists of species found in any county of the three states can be queried from the system, (2) environmental assessment and impact analysis--economic and ecologic value of species are recorded in the system and can be queried and used for anticipating the effects of disturbances or land use changes, (3) reclamation planning--queries can be constructed to obtain lists of plants adapted to site conditions and having desirable characteristics to fulfill reclamation objectives.

INFORMATION AVAILABLE

The basic information entry in the system is by species. The species included are the ones for which there are vouchered specimens collected and on file in four herbaria. These herbaria are the Colorado State University Herbarium, the University of Colorado Museum Herbarium, the Rocky Mountain Herbarium at the University of Wyoming and the Montana State University Herbarium in Montana. Currently there are approximately 4,000 plant species entered in the system.

The characteristics for these species are grouped into five categories. These categories include taxonomic, geographical, biological, economic, and ecological information. The information in these categories is divided into units called descriptors. At the present time there are 239 descriptors for each plant species in the system. These descriptors include 96 general bits of information in the 5 categories, plus the 143 counties of the three states.

Within each descriptor, there are classes or ranks of information called descriptor states. The descriptors and descriptor state definitions are listed in the appendix (Voires, and Sims, 1977).

Care must be exercised in interpreting the results of a PIN query. Where possible, definitions were used that are commonly accepted in the plant ecology, range science, and revegetation fields of expertise. However, because the descriptor states must be mutually exclusive this was not always possible. In these cases, working definitions as noted in the appendix were used.

A brief list and description of some of these descriptors follow. this description includes descriptors that will be of most interest or those which may cause some confusion or misinterpretation.

Taxonomic

The taxonomic descriptors include the division, family, genus, species, infraspecific names and common names for each one of the species in the system. Most of this taxonomic information came from local floras and botanical literature. The infraspecific names may be varieties or subspecies. The common name descriptor information came from a ranked order of references. The first reference used was Plummer (1976), the Intermountain Range Plant Symbols. If Plummer did not have a common name for the species in PIN, then Kelsey and Dayton (1942), Standardized Plant Names was used. If neither of these two sources had a common name then Beetle's (1970) Recommended Plant Names was used.

Geographic

The geographic category of descriptors in PIN include origin, counties, and minimum and maximum elevations at which the vouchered collections of that species has been found in each of the three states. The county locational information is of two levels of reliability. A county "present" record means that the species has a vouchered specimen collected and stored in one of the four herbaria listed above. A county "reported" record means that a reliable source has reported the species' occurrence in that county, but no specimen was collected.

Biological

The biological category of descriptors includes anthesis, carbon dioxide fixation, habit, life cycle, reproduction and trophic status. Anthesis is the mode month in which a plant flowers or pollinates. Habit is the growth form or outward appearance of the plants, such as grasslike, trees, or shrubs.

Life Cycle

The life cycle descriptor includes the descriptor states of perennial, biennial, annual and combinations of these for plants that are not distinctly one or the other of the three.

Reproduction

The reproduction descriptor includes the sexual or asexual process by which a plant generates others of the same kind. The descriptor states for reproduction include sexual, vegetative, apomictic, and combinations of these three.

Ecological and Economic

The above descriptors and descriptor states have been completed for the 4000 species, if the information was available in documented sources. Because of the immensity of the task to develop the information base of ecological and economic descriptors and descriptor states for this many species, a subset of approximately 400 "important" species was chosen.

This 400 "important" species was chosen because of high economic, ecologic, or biological values such as importance to grazing resources; importance to wildlife populations; importance as rare, threatened or endangered plants; reclamation value, or predominance in the three state area. For this 400 species the ecological and economic descriptor information was completed and added to PIN as described below.

The ecological categories of plant descriptors includes structural relationships or the proportional influence of a particular species in 20 vegetation types. These vegetation types are taken from Kuchler (1964) and are the vegetation types he mapped in the three states included in PIN. Each species is ranked as dominant, codominant, subdominant or a component for each of these 20 vegetation types.

Also included in the ecological descriptors are disturbance indicators; edaphic indicator; growth relationships of the species on textural classes of soils; habitat or ecological conditions under which a plant grows; the optimum slope on which the plant is normally found; the optimum soil depth on which the plant normally obtains the best growth; vegetation indicators; major dispersal agent for seed dispersal; mycorrhizal relationships; nodule forming information; nitrogen fixing information; potential biomass production; and population dynamics, including endemic species, rareness in the three states, species stability or the relative vulnerability of the species to extinction including endangered, threatened, or vulnerable species by states.

The economic category of descriptors include allergenic; edible; culture; erosion control potential; establishment requirements; revegetation potential; weediness; cover for various classes of wildlife; food value for cattle, sheep, horses, and various classes of wildlife; forage value for cattle, sheep, horses, and various classes of wildlife; and poisonous to livestock.

The establishment requirements include descriptor states of high, medium, and low and describe the relative extent of cultural practices which must be employed to insure successful planning of the species.

The revegetation potential descriptor has descriptor states of high, medium and low. This is the ability of a plant to become established and persist on sites to which it is adapted.

The culture descriptor is a text descriptor, Text descriptors are included in PIN in a narrative format and are retrieved in narrative form. All other descriptors are recorded as bits of information of one to three words usually. These descriptors and descriptor states must be mutually exclusive and that is the reason that the descriptors, the descriptor definitions, and the descriptor states and their definitions must be strictly adhered to in querying or asking the system questions and interrupting the results. This mutual exclusiveness is one of the reasons that system is so efficient in using and keeping costs of use of PIN down.

EXAMPLE USE OF PIN

Below is a series of examples of how PIN can be used in developing and helping to plan a revegetation project in Northwestern Colorado. Northwestern Colorado was chosen because it was anticipated that many workshop participants would be interested and familiar with this area because of the interest and research that has been going on related to revegetation and exploration in the oil shale projects of the past few years.

The first step used in this example was to query PIN for those species found in mountain mahogony-oak scrub, sagebrush steppe, juniper-pinyon woodland, or pine-Douglas fir vegetation types in Routt, Moffatt, and Rio Blanco counties. These species also had to be found between 5900 and 9100 feet (1,790 - 2,780 m) elevations, have revegetation potential of high or medium, and have establishment requirements of low or medium.

An example of the print command and partial listing of the query response is shown in Table 1.

This particular query resulted in a list of 216 species. The list could be further restricted by fewer vegetation types and/or fewer counties being included. More restrictive elevations or revegetation potentials, or establishment requirements could also have been used. Sometimes queries are constructed that are so restrictive that no species in PIN satisfies those restrictions.

Similar queries to that shown in Table 1 were also run limiting the species to grasslike; forb; or tree or shrub species. A portion of the print-out showing the print statement and species listed for forbs is shown in Table 2.

The Plant Information Network is now available for public use. Charges for the use of the system are minimal and can be obtained by contacting the PIN staff. Either call or write the PIN staff to explain your information needs and they will give you an estimate of costs. The PIN address is:

Plant Information Network
Department of Botany and Plant Pathology
Colorado State University
Fort Collins, CO 80523
Telephone: 491-5026.

LITERATURE CITED

Beetle, Alan A. 1970. Recommended plant names. Agric. Exp. Stn. Res. J. 31. Univ. Wyo., Laramie. 124 p.

Kelsey, Harlan P. and William A. Dayton. 1942. Standardized plant names (2nd ed.) J. Horace McFarland Co., Harrisburg, Pa. 675 p.

Table 1. Partial Listing of Plants that May Be used for Revegetation in Northwest Colorado. The Total PIN Response Included 216 Species.

PRINT, GENUS, SPECIES, INFRASPECIFIC, REVEGETATION POTENTIAL, EROSION CONTROL POTENTIAL, ESTABLISHMENT REQUIREMENTS, MOUNTAIN MAHOGANY-OAK SCRUB, SAGEBRUSH STEPPE, JUNIPER-PINYON WOODLAND, PINE-DOUGLAS FIR FOREST FOR WITH (ROUTT-CO, PRESENT OR MOFFAT-CO, PRESENT OR RIO BLANCO-CO, PRESENT) AND (NOT MOUNTAIN MAHOGANY-OAK SCRUB, UNKNOWN OR NOT SAGEBRUSH STEPPE, UNKNOWN AND NOT JUNIPER-PINYON WOODLAND, UNKNOWN OR NOT PINE-DOUGLAS FIR FOREST, UNKNOWN) AND MINIMUM ELEVATION-CO, LESS THAN 9100 AND MAXIMUM ELEVATION-CO, GREATER THAN 5900 AND REVEGETATION POTENTIAL, HIGH OR MEDIUM AND ESTABLISHMENT REQUIREMENTS, LOW OR MEDIUM*

Genus	Species	Infraspecific	Revegetation Potential	Erosion Control Potential	Establishment Requirements	Relative Dominance in Mountain Mahogany-Oak Scrub	Relative Dominance in Sagebrush Steppe	Relative Dominance in Juniper Pinyon Woodland	Relative Dominance in Pine-Douglas Fir Forest
Abies	lastocarpa	none	medium	high	medium				component
Acer	glarrum	glarrum	medium	high	medium	component		component	component
Acer	negundo	none	high	medium	low	component	component	component	component
Achillea	millefolium	langulosa	medium	medium	low	component	component	component	component
Agoseris	glauca	glauca	medium	medium	low	component	component	component	component
Agropyron	caninum	caninum	medium	medium	low	component	component	component	component
Agropyron	caninum	majus	high	high	medium	component	component		component
Agropyron	cristatum	none	high	high	low	component	component	component	component
Agropyron	dasystachyum	dasystachyum	medium	medium	medium	component	component	component	component
Agropyron	elongatum	none	high	high	low	component	component	component	
Agropyron	repens	none	medium	high	low	component	component	component	component
Agropyron	smithii	none	high	high	medium	component	component	component	component
Agropyron	spicatum	inerme	medium	high	medium	component	component	component	component

Table 2. Partial Listing of Forb Species that May Be Used for Revegetation in Northwest Colorado. The Total PIN Response Included 39 Species.

PRINT, GENUS, SPECIES, INFRASPECIFIC, REVEGETATION POTENTIAL, EROSION CONTROL POTENTIAL, ESTABLISHMENT REQUIREMENTS FOR ALL PLANTS WITH (ROUTT-CO, PRESENT OR RIO BLANCO-CO, PRESENT) AND NOT MOUNTAIN MAHOGANY-OAK SCRUB, UNKNOWN AND NOT JUNIPER-PINYON WOODLAND, UNKNOWN AND MINIMUM ELEVATION-CO, LESS THAN OR EQUAL TO 9000 AND MAXIMUM ELEVATION-CO, GREATER THAN OR EQUAL TO 6000 AND REVEGETATION POTENTIAL, HIGH OR MEDIUM AND EROSION CONTROL POTENTIAL, HIGH OR MEDIUM AND ESTABLISHMENT REQUIREMENTS, LOW OR MEDIUM AND HABIT, FORB.

Genus	Species	Infraspecific	Potential	Erosion Control Potential	Requirement
Achillea	millefolium	lanulosa	medium	medium	low
Agoseris	glauca	glauca	medium	medium	low
Artemisia	frigida	none	high	medium	low
Artemesia	ludoviciana	none	medium	high	low
Aster	chilensis	adscendens	high	high	low
Aster	ericoides	pansus	medium	medium	low
Aster	hesperius	none	high	high	low
Atriplex	hortensis	none	medium	medium	low
Atriplex	nuttallii	none	medium	medium	medium
Bassia	hyssopifolia	none	medium	medium	low
Castilleja	linariaefolia	none	medium	medium	medium
Castilleja	sulphurea	none	medium	medium	medium
Epilobium	angustifolium	none	medium	medium	low
Erigeron	eatonii	none	medium	medium	medium

Kuchler, A. W. 1964. Potential natural vegetation of the coterminous United States. (maps and manual). American Geographical Society Special Publication 36. 39 p. and map.

Plummer, A. Perry, Stephen B. Mouson, and Richard Stevens. 1976. Draft revision intermountain range plant symbols. Intermountain Forest and Range Exp. Sta. 124 p. (in press).

Vories, K. C. and P. L. Sims. 1977. The Plant Information Network: Volume I, A User's Guide. Western Energy and Land Use Team, Off. of Bio. Serv., USDI Fish and Wildlife Serv., Fort Collins, Co. pp. 1-56.

DISCUSSION

QUESTION: Will there be any on-line access to PIN?

DITTBERNER: We have planned for the use of interactive terminals. In the near future, the U.S. Geological Service Area Oil Shale Office in Grand Junction will have an interactive terminal. I understand the terminal should be available for other agencies' use. Further interactive terminals are planned for and will be set up as necessary.

QUESTION: Can a user locate only native species? Are the listed plants identified as introduced or native?

DITTBERNER: There are no descriptors for introduced or native species. Included in the 4000 species listed are vascular native or naturalized species. Naturalized means self-regenerating in natural conditions. No horticultural species are included as such, although several native or naturalized species are sometimes used for landscaping purposes.

APPENDIX

Taxonomic

The classification of plants into the following appropriate categories.

1. DIVISION--a non-scientific category of the major vascular plant groups.

   a. conifer--(Gymnospermae) a member of a group of predominantly evergreen and cone-bearing trees.
   b. dicot--(Dicotyledoneae) one of the two major divisions of angiosperms, characterized by a pair of embryonic seed leaves.
   c. monocot--(Monocotyledoneae) one of the two major divisions of angiosperms, characterized by a single seed leaf.
   d. fern allies--vascular plants not producing seeds or true flowers, reproducing by spores (Lycopodiophyta, Equisetophyta, Polypodiophyta).

2. FAMILY--a name category ranking below an order and above a genus This category has the ending "-aceae."

3. GENUS--a name category ranking below a family and above a species. The use of the genus followed by a Latin adjective or epithet forms the scientific name of a plant.

4. SPECIES--the lowest, most commonly used category of taxonomic classification, ranking below a genus.

5. INFRASPECIFIC--a morphologically recognizable category of classification ranking below a species. Usually a variety or subspecies.

6. COMMON NAME--the colloquial epithet in general usage and language of the inhabitants of a geographic region.

Geographic

The attributes of a plant which pertain to a specific region.

7. ORIGIN--the geographic area to which a plant is indigenous.

   a. Africa
   b. Asia
   c. Europe
   d. North America
   e. South America

f. Eurasia
g. native--any plant known to be indigenous to Colorado, Montana, or Wyoming. The descriptor state, "native," takes precedence over the descriptor state, "North America."

8. COUNTIES--each county name is a descriptor state and must be asked for specifically. Each county name ends with "-CO, -MT, or -WY" to designate the appropriate state it is in, Colorado, Montana or Wyoming, respectively. Includes all counties for Colorado (63) Montana (56) and Wyoming (24).

   a. present--a specimen of the plant has been deposited and verified in one of the following herbaria: Colorado State University; University of Colorado; U.S. Forest Service Herbaria, Fort Collins; Montana State University; Rocky Mountain Herbarium, Laramie, Wyoming.
   b. reported--the plant is known to occur in that county but there is no herbarium record of it.

9. MAXIMUM ELEVATION-CO--the highest elevation at which a plant has been observed in Colorado. Recorded in 100 foot intervals from 3,000 to 15,000 feet.

10. MAXIMUM ELEVATION-MT--the highest elevation at which a plant has been observed in Montana. Recorded in 100 foot intervals from 1,500 to 13,000 feet.

11. MAXIMUM ELEVATION-WY--the highest elevation at which a plant has been observed in Wyoming. Recorded in 100 foot intervals from 3,000 to 15,000 feet.

12. MINIMUM ELEVATION-CO--the lowest elevation at which a plant has been observed in Colorado. Recorded in 100 foot intervals from 3,000 to 15,000 feet

13. MINIMUM ELEVATION-MT--the lowest elevation at which a plant has been observed in Montana. Recorded in 100 foot intervals from 1,500 to 13,000 feet.

14. MINIMUM ELEVATION-WY--the lowest elevation at which a plant has been observed in Wyoming. Recorded in 100 foot intervals from 3,000 to 15,000 feet.

Biologic

The attributes of a plant which pertain to its own life processes.

15. ANTHESIS--for angiosperms, this is the time of flowering of a plant; for gymnosperms, this is the time of pollination of a plant. Anthesis time is recorded by month, or by the mode month if it occurs in more than one month. Grasses, sedges, and rushes are excluded from this descriptor.

The plant flowers or pollinates during the month of:

a. January	d. April	g. July	j. October
b. Feburary	e. May	h. August	k. November
c. March	f. June	i. September	l. December

16. CARBON DIOXIDE FIXATION--the biochemical and physiological mechanism associated with the incorporation of CO_2 and its ultimate conversion into carbohydrates.

   a. C_4--the plant uses a pathway where the first step in CO_2 fixation involves the formation of four-carbon compounds, the stomata are open and CO_2 is fixed in the daylight.
   b. C_3--the plant uses a pathway where the first step in CO_2 fixation involves the formation of three-carbon compounds, the stomata are open and CO_2 is fixed in the daylight.
   c. crassulaceous--the plant uses a pathway where the first step in CO_2 fixation involves the formation of four-carbon compounds. The stomata are open and CO_2 is fixed in the dark.
   d. other--the plant uses another type of pathway.
   e. none--the plant does not fix carbon dioxide.

17. HABIT -- the growth form, or outward appearance of a plant.

   a. tree--a woody plant that usually produces one main trunk or bole and a more or less distinct and elevated head.
   b. shrub-tree-- a plant whose growth form is intermediate between that of a shrub and tree.
   c. shrub--a woody plant that remains low and produces shoots or trunks from the base.
   d. vine--any woody plant whose stem requires support, and which climbs by tendrils or other means.
   e. forb--a non-woody plant dying down each year that is not grass-like.
   f. grasslike--herbaceous plants with narrow leaves usually belonging to the grass, sedge, and rush families.

18. LIFE CYCLE--the series of stages in form and mode of life which an organism exhibits between successive recurrences of a certain primary stage.

    a. perennial--the plant grows for three or more years duration.
    b. biennial--the plant grows for two years duration from seed to maturity to death.
    c. annual--the plant grows for one year's duration from seed to maturity to death.
    d. perennial-biennial--the plant has the potential for growth as either a perennial or a biennial.
    e. biennial-annual--the plant has the potential for growth as either a biennial or an annual.
    f. perennial-annual--the plant has the potential for growth as either a perennial or an annual.

19. REPRODUCTION--the sexual or asexual process by which a plant generates others of the same kind.

    a. sexual--the plant reproduces by pollination and fertilization.
    b. vegetative--all cases where structures such as bulbils, tubers, stolons, rhizomes, etc., which are normally accessory means of reproduction, take over the whole reproductive process of a plant.
    c. apomictic--the plant has a type of reproduction which results in the formation of seeds and embryos by a non-sexual process.
    d. vegetative-sexual--the plant reproduces sexually and vegetatively.
    e. sexual-apomictic--the plant reproduces sexually and apomicticly.
    f. vegetative-sexual-apomictic--the plant reproduces by all three methods.

20. TROPHIC STATUS--a plant's method of nutrient procurement.

    a. autotrophic--the plant is capable of self-nutrition; can use carbon, nitrogen, and sulfur in inorganic combinations and obtain energy from the sunlight.
    b. parasitic--the plant lives on and/or in other living organisms and obtains some or all of its nutrients from the host.
    c. saprophytic--the plant lives on and/or in dead organic material and obtains nutrients from it.
    d. symbiotic--the plant lives in close association with another plant and the symbionts derive nutritional requirements from each other.

Ecologic

The attributes of a plant which pertain to its relationship to community structure and function, environment and population dynamics.

Structural Relationships

Relative Dominance--the proportional influence of a plant within each of the vegetation zones listed below. Each zone is a descriptor and must be asked for separately. Vegetation zones as defined by Kuchler (1964). Descriptors 21-40 use the following states:

a. dominant--a plant, which by means of its number, coverage, or size has major influence upon the environmental conditions within the vegetation type.
b. codominant --a plant, which by means of its number, coverage, or size, has in association with other plants a major influence upon the environmental conditions within the vegetation type.
c. subdominant--a plant, which by means of its number, coverage, or size, has a moderate influence upon the environmental conditions within the vegetation type.
d. component--a plant species existing in the vegetation type exclusive of dominant, codominant, and subdominant.

21. ALPINE MEADOWS/BARREN
22. WESTERN SPRUCE-FIR FOREST
23. SW SPRUCE-FIR FOREST (SW=Southwestern)
24. DOUGLAS FIR FOREST
25. PINE-DOUGLAS FIR FOREST
26. BLACK HILLS PINE FOREST
27. WESTERN PONDEROSA FOREST
28. EASTERN PONDEROSA FOREST
29. NORTHERN FLOODPLAIN FOREST
30. JUNIPER-PINYON WOODLAND
31. MOUNTAIN MAHOGANY-OAK SCRUB
32. GREAT BASIN SAGEBRUSH
33. SALTBUSH-GREASEWOOD
34. SAGEBRUSH STEPPE
35. WHEATGRASS-NEEDLEGRASS SHRUBSTEEPE
36. FOOTHILLS PRAIRIE
37. SANDSAGE-BLUESTEM PRAIRIE

38. WHEATGRASS-NEEDLEGRASS

39. GRAMA-WHEATGRASS-NEEDLEGRASS

40. GRAMA-BUFFALOGRASS.

41. DISTURBED AREA—the relative dominance of a plant on areas of environmental disruption.

   a. dominant--the plant becomes a dominant on disturbed areas during one or more of the early stages in natural revegetation through processes of secondary succession.
   b. codominant--the plant becomes a codominant on disturbed areas during one or more of the early stages in natural revegetation through processes of secondary succession.
   c. subdominant--the plant becomes a subdominant on disturbed areas during one or more of the early stages in natural revegetation through processes of secondary succession.
   d. component--the plant becomes a component on disturbed areas during one or more of the early stages in natural revegetation through processes of secondary succession.
   e. no--the plant does not normally occur on disturbed areas.

Environmental Relationships

42. DISTURBANCE INDICATOR--a plant whose growth and distribution commonly indicates one of the following types of disturbance. (Indicators are only scored once in the order of precedence shown.)

   a. erosion—the general process of the wearing away of rocks soils at the earth's surface by natural agencies.
   b. mechanical--the physical disturbance of the soil and vegetation by trampling of man or animals or machinery used in road building or agriculture.
   c. overgrazing--excessive feeding by domestic or wild animals.
   d. fire--disturbance by burning.
   e. other--indicates a disturbance not listed.
   f. no--the presence of the plant does not indicate a disturbance, nor will it grow in a disturbed area.

43. EDAPHIC INDICATOR--a plant whose growth and distribution commonly indicates the presence of one of the following unusual soil characteristics.

   a. boron--soils which contain boron-containing minerals such as borax, sassolite, ulexite, colemanite, boracite, tourmaline.
   b. gypsum--soils contain hydrous calcium sulfate.
   c. selenium--soils which contain selenium or selenikds such as clausthalite.
   d. serpentine--soils which contain hydrous magnesium silicate, indication of a magnesium-calcium imbalance.

e. very acidic--soil pH less than 5.
f. saline--soils with a conductance of saturation extract exceeding 4 mmho/cm but with Na comprising less than 15% of the absorbed cations.
g. very alkaline--soils pH greater than 8.5.
h. saline-alkaline--plants are indicators of either or both saline or alkaline soils.
i. other--other unusual soil characteristics may be indicated. User should consult expert.
j. none--plant does not indicate any unusual edaphic characteristic.

Texture and Growth Relationships--the relative ability of a plant to show full development of all phases of its growth potential on a particular soil texture where the plant normally occurs. Descriptors 44-48 use the following states:

a. good--the plant is highly adapted to growth on a particular soil texture.
b. fair--the plant is moderately adapted to growth on a particular soil texture.
c. poor--the plant shows little adaptability to growth on a particular soil texture.

44. GROWTH ON SAND--a soil in which the sand separates (0.05 mm and larger) make up 70% or more of the material by weight.

45. GROWTH ON SANDY LOAM--a loamy soil which is intermediate in texture between sand and loam.

46. GROWTH ON LOAM--a soil which is considered to have an ideal texture for gardening. It should contain about equal amounts of silt (0.05-0.002 mm) and sand, and less than 25% clay.

47. GROWTH ON CLAY LOAM--a loamy soil which is intermediate in texture between clay and loam.

48. GROWTH ON CLAY--a soil must have at least 35% clay separates (less than 0.002 mm) by weight.

49. HABITAT--the type of locality or set of ecological conditions under which a plant grows.

a. submerged aquatic--the plant grows in a fresh water environment with its vegetative parts not rising above the water surface.
b. emergent aquatic--the plant grows in a fresh water environment with its vegetative parts rising above the water surface.
c. wet--the plant grows in soil that is saturated with water.
d. moist--the plant grows in soil that is characterized by conditions of medium soil moisture.

e. dry--the plant grows in soil that is characterized by conditions of extended periods of soil drought.
f. epiphytic--a plant which germinates on other plants and grows without obtaining nutriment at the cost of the substance of the host.
g. phreatophyte--a plant which derives its water supply from the water table and is more or less independent of rainfall.

50. OPTIMUM SLOPE--the slope condition on which the plant is normally found.

a. level-sloping--0-8% slope.
b. rolling-hilly--9-30% slope.
c. steep-very steep 31% and greater slope.

51. OPTIMUM SOIL DEPTH--depth of soil to parent material on which the plant normally obtains best growth. Measured in inches.

a. 0-6
b. 7-12
c. 13-24
d. 25-36
e. 37-60
f. 61-120.

52. VEGETATION INDICATOR--the plant's presence must indicate exclusively one of the following vegetation zones. Zones defined by Kuchler (1964).

a. Alpine Meadows/Barren
b. Western Spruce-Fir Forest
c. SW Spruce-Fir Forest (SW = Southwestern)
d. Douglas Fir Forest
e. Pine-Douglas Fir Forest
f. Black Hills Pine Forest
g. Western Ponderosa Forest
h. Eastern Ponderosa Forest
i. Northern Floodplain Forest
j. Juniper-Pinyon Woodland
k. Mountain Mahogany-Oak Scrub
l. Great Basin Sagebrush
m. Saltbush-Greasewood
n. Sagebrush Steppe
o. Wheatgrass-Needlegrass
p. Foothills Prairie
q. Sandsage-Bluestem Prairie
r. Wheatgrass-Needlegrass
s. Grama-Wheatgrass-Needlegrass
t. Grama-Buffalograss

Functional Relationships

53. MAJOR DISPERSAL AGENT--the primary agent of seed dispersal (descriptor states self-explanatory).

a. birds
b. mammals
c. insects
d. gravity
e. water
f. wind
g. other

54. MYCORRHIZAL RELATIONSHIP--the nature of the relationship of a plant to a mycorrhizal association.

a. endomycorrhizal--mycorrhizal assocation having a loose network of fungal hyphae enclosing the root and intracellular hyphae penetrating the cortical cells of the root.
b. ectomycorrhizal--mycorrhizal association having a dense fungal sheath enclosing the root and intercellular hyphae penetrating the root cortex.
c. ectendomycorrhizal--mycorrhizal association having a dense fungal sheath enclosing the root and both inter- and intracellular hyphae penetrating the root cortex.
d. endo/ecto--refers to plants reported as being both endomycorrhizal and ectomycorrhizal.
e. ecto/ectendo--refers to plants reported as being both ectomycorrhizal and ectendomycorrhizal.
f. nonmycorrhizal--refers to either plants that have been examined for mycorrhiza with none found, or plants that occur in families considered to be classically nonmycorrhizal (Aizoaceae, Amaranthaceae, Brassicaceae, Caryophyllaceae, Chenopodiaceae, Commelinaceae, Cyperaceae, Fumariaceae, Juncarceae, Nyctaginaceae, Polygonaceae, and Urticaceae).

55. NODULE FORMING--occurrence of root nodules on a plant's roots.

a. reported--reported as nodule forming by observation or in the literature.
b. possible--reported as possible nodule forming in the literature.
c. no--plant is known not to fix nitrogen.

*

57. POTENTIAL BIOMASS PRODUCTION--the relative ability of a plant to produce plant material by weight on an annual basis as a major component of an established stand, within a comparable lifeform.

a. high--plant possesses ability to produce a yield of dry plant material comparable to moist forests or tall grass prairies.
b. medium--plant possesses ability to produce a yield of dry plant material comparable to mountain forests or mid grass prairies.
c. low--plant possesses ability to produce a yield of dry plant material comparable to semi-arid woodland, shrublands, or short grass prairies.
d. very low--plant possesses ability to produce a yield of dry plant material comparable to slow growing plants from arid climates.

Population Dynamics

58. ENDEMIC--confined to a certain area or region, having a comparatively restricted distribution.

*56. errata on last page of this article.

a. Colorado--plant population is confined to the state of Colorado.
b. Montana--plant population is confined to the state of Montana.
c. Wyoming--plant population is confined to the state of Wyoming.
d. local--plant population is confined to more than one of the above states.
e. no--not endemic in any of the above states.

59. RARE-CO--a plant which has a small population in its range in Colorado. It may be found in a restricted geographic region, or it may occur sparsely over a wider area.

a. yes--the plant is rare in Colorado.
b. no--the plant is not rare in Colorado.

60. RARE-MT--a plant which has a small population in its range in Montana. It may be found in a restricted geographic region, or it may occur sparsely over a wider area.

a. yes--the plant is rare in Montana.
b. no--the plant is not rare in Montana.

61. RARE-WY--a plant which has a small population in its range in Wyoming. It may be found in a restricted geographic region, or it may occur sparsely over a wider area.

a. yes--the plant is rare in Wyoming.
b. no--the plant is not rare in Wyoming.

62. SPECIES STABILITY-CO--the relative vulnerability of a plant to extinction in Colorado. Descriptors 62-64 use the following states.

a. endangered--any plant which is in danger of extinction throughout all or a significant portion of its range, due to change in habitat, disease, predation, exploitation, etc.
b. threatened--any plant which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. This includes species categorized as rare, very rare, or depleted.
c. vulnerable--a plant which sould be monitored for possible decreases in range and/or number and is not yet considered endangered or threatened.
d. good--a plant whose population is stable or increasing.

63. SPECIES STABILITY-MT--the relative vulnerability of a plant to extinction in Montana.

64. SPECIES STABILITY-WY--the relative vulnerability of a plant to extinction in Montana.

Economic

The attributes of a plant which have either positive or negative monetary value.

Human Health and Nutrition

65. ALLERGENIC--inducing an allergic response in humans.

   a. yes--the plant is reported in the literature as allergenic.
   b. maybe--the plant is reported to possibly cause allergic response; thought to be allergenic but not yet proven so.
   c. no--the plant is known to be definitely not allergenic in any circumstances and reported so in the literature.

66. EDIBLE--a plant which can be eaten as food by humans.

   a. yes--the plant is edible.
   b. yes-qualified--it is edible only after a specific preparation or in certain seasons. User should consult an expert.
   c. no--the plant is not edible but not poisonous.
   d. poisonous--the plant contains toxic substances or potential toxic substances that would prove harmful if ingested.

Revegetation Planting

67. CULTURE--a text descriptor on the planting requirements of a species.

68. EROSION CONTROL POTENTIAL--a plant which commonly exhibits growth habit, plant structure, and/or biomass that potentially reduces soil erosion.

   a. high--plant has aggressive growth habits, persistent plant structure, high potential biomass, and good soil binding root or root-rhizome-runner systems in established stands.
   b. medium--plant has moderately aggressive growth, moderately persistent plant structure, good potential biomass, and good soil-binding characteristics in established stands.
   c. low--plant has growth, persistence, biomass, or soil-binding characteristics which make it generally inadequate for erosion control.

69. ESTABLISHMENT REQUIREMENTS--the relative extent of cultural practices which must be employed to insure a successful planting of the species on sites to which it is adapted.

   a. high--requires elaborate, energy intensive cultural practices.
   b. medium--requires special cultural practices of short duration and/or moderate resource inputs.

c. low--only minimal cultural practices are required.

70. REVEGETATION POTENTIAL--the ability of a plant to become established and persist on sites to which it is adapted.

a. high--plant demonstrates good growth, cover, reproduction, and stand maintenance characteristics.
b. medium--plant demonstrates fair growth, cover, reproduction, and stand maintenance characteristics.
c. low--plant demonstrates poor growth, cover, reproduction, and stand maintenance characteristics.

71. WEEDINESS--a plant considered undesirable, unattractive, or troublesome; especially one that is growing where it is not wanted.

a. noxious--plants which are listed on official noxious weed seed lists of Colorado, Montana, and Wyoming. User should consult authorities for individual state lists. Has priority over economic.
b. economic--plants whose growth and reproduction cause economic loss.
c. colonizing--a plant which has attributes enabling it to become easily established in suitable habitats.
d. non-weedy--not a weed.

Wildlife and Livestock

Cover Value--the degree to which the plant provides environmental protection for an animal. Descriptors 72-77 use the following states:

a. good--readily utilized for cover when available.
b. fair--moderately utilized for cover when available.
c. poor--rarely utilized for cover when available.

72. ELK COVER VALUE

73. MULE DEER COVER VALUE

74. ANTELOPE COVER VALUE

75. GAME BIRD COVER VALUE

76. SMALL NON-GAME BIRD COVER VALUE

77. SMALL MAMMAL COVER VALUE.

Food Value--the relish and degree of use that an animal shows for a particular plant, or plant part as well as its availability. Descriptors 78-86 use the following states.

a. good--readily available in the plant's range and consumed to a high degree.
b. fair--readily to moderately available in the plant's range but consumed only to a moderate degree,
c. poor--may or may not be available but the plant is consumed very little by the animal.

78. CATTLE FOOD VALUE

79. SHEEP FOOD VALUE

80. HORSE FOOD VALUE

81. ELK FOOD VALUE

82. MULE DEER FOOD VALUE

83. ANTELOPE FOOD VALUE

84. GAME BIRD FOOD VALUE

85. SMALL NON-GAME BIRD FOOD VALUE

86. SMALL MAMMAL FOOD VALUE

Forage Value--the relish and degree of use (i.e. palatability) that an animal shows for a particular plant or plant part. Descriptors 87-95 use the following states.

a. good--highly relished and consumed to a high degree.
b. fair--moderately relished and consumed to a moderate degree.
c. poor--not relished and normally consumed to only a small degree.

87. CATTLE FORAGE VALUE

88. SHEEP FORAGE VALUE

89. HORSE FORAGE VALUE

90. ELK FORAGE VALUE

91. MULE DEER FORAGE VALUE

92. ANTELOPE FORAGE VALUE

93. GAME BIRD FORAGE VALUE

94. SMALL NON-GAME BIRD FORAGE VALUE

95. SMALL MAMMAL FORAGE VALUE

96. POISONOUS-LIVESTOCK--a plant which contains or produces, under normal conditions, physiologically active or toxic substances in sufficient amounts to cause harmful effects in animals.

a. acute--animal shows immediate symptoms after ingestion of a small amount of the plant. Ingestion of the plant may cause rapid death.

b. cumulative--animals usually require repeated ingestion of poisonous plants and concentrations in their system to show symptoms.
c. geographically variable--the plant is posionous in certain parts of its range. User should check with expert.
d. seasonally variable--the plant is posionous during certain phases of its growth cycle or as a response to abnormal weather conditions. User should consult with expert.

*56. NITROGEN FIXING--a plant that can assimilate and fix the free nitrogen of the atmosphere with the aid of microorganisms.

a. Yes--plant fixes nitrogen, as reported in the literature.
b. Maybe--the plant may fix nitrogen, but has not been reported as such in the literature.
c. No--plant is known not to fix nitrogen.

UPPER COLORADO ENVIRONMENTAL PLANT CENTER STATUS REPORT

S. Stranathan
Manager
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The Upper Colorado Environmental Plant Center (EPC) is taking the work off the revegetation drawing boards and putting it on the ground. The Center, like its older relatives the SCS Plant Materials Centers (PMC's), hopes to function actively in the selection of superior ecotypes for the Upper Colorado Region.

SCS Plant Materials Centers have selected Colorado ecotypes for evaluation at locations in New Mexico, Montana, Idaho and Kansas. Two of the most famous Colorado selections have been 'Arriba' western wheatgrass, *Agropyron smithii*, and 'Paloma' Indian ricegrass, *Oryzopsis hymenoides*. Many species have been tested on the farms and ranches of Colorado. 'Luna' pubescent wheatgrass was introduced at the Los Lunas PMC from Eastern European collections, proved its superiority in New Mexico and Colorado field tests, and was formally released cooperatively with the New Mexico and Colorado Crop Improvement and varietal release organizations.

Grasses have dominated the plant materials program of the region and they continue to receive emphasis relative to new problems. PMC's have evaluated forbs and shrubs, but very few of the selections released have had or will have much influence on the Colorado region's high country vegetation.

THE MEEKER CENTER

The Meeker Plant Center grew out of that void and has been enthusiastically supported by private industry and federal and state agencies. The Center is located five and one half miles southeast of Meeker, Colorado on a mesa overlooking the White River . It receives 15 to 16 inches (38 to 41 cm) of annual precipitation on the average and has a 75 to 90 day growing season at its 6,500 foot (1,980 meter) elevation. It is located in the heart of the energy development area. The Center is open for you to visit and a brochure about the Center is available.

Mr. Glenn Carnahan discussed the physical development of the Center at the Second High Altitude Revegetation Workshop (Carnahan, 1976). Two Colorado Soil Conservation Districts own the Center and administer its operation. The Center budget is funded in part by annual federal grants handled through the USDA-Soil Conservation Service and in part by support from industry.

Eighty percent of the planned building construction is completed. A heavy equipment modification and installation load still exists. We will be processing seed raised on the Center by fall, 1978. The bulk of our activities are in the field producing and evaluating hundreds of ecotypes of native shrubs, forbs, legumes and grasses.

One of the special aspects of this Center is its Advisory Committee. This committee has a great amount of expertise in the field of the Center's endeavor with representatives of cooperating agencies and contributors. This body meets twice a year to formulate recommended actions for incorporation into the Administrative Board's Center program.

PROGRAMS AT THE CENTER

A major progress accomplishment has been the development and publication of a working Long Range Program for the Center. The Advisory Committee developed the program around eight major priority areas of vegetative needs: vegetation for big game; mining (oil shale and coal); highways; other land disturbing activities (alpine and subalpine to desert); low rainfall range; and turf grasses for heavy uses.

Twenty-one projects have been initiated during 1976 and 1977; eight new ones are proposed for 1978. Table 1 identifies the active projects. I would like to illustrate four areas of activity carried out by Center staff.

Initial Evaluation

One phase is described as initial evaluation. Project 1-76 is an initial screening of 260 accession of shrubs, forbs, legumes and vines. Species selected were thought to have potential for at least four of the priorities described in the Long Range Plan. The data begins on each accession with the original collector recorded site conditions. Many of the accessions in this project came from high altitude sites.

Table 1. Active Environmental Plant Center Projects--January 1, 1978.

INITIAL EVALUATIONS: The evaluation of the characteristics and comparative performance of an assembly of plants under controlled conditions so that promising plants can be selected for further evaluation.

PROJECT

1-76 -- A look at 260 native accessions of forbs and woody plants
4-76 -- Direct seeding of 480 accessions of grasses (Dryland)
5-76 -- Direct seeding of 66 accessions of forbs and legumes (Dryland)
6-76 -- Direct seeding of 1776 accessions of grasses (4 acres, Irrigated)
9-76 -- Direct seeding for germination and seedling vigor of 171 native accessions of forbs and shrubs (Mulched, Dryland)
17-77 -- Direct seeding of 105 accessions of irrigated grasses and sedges
18-77 -- Direct seeding of 240 accessions of irrigated forbs and legumes
19-77 -- Potted material planting of 107 accessions of irrigated forbs and legumes
20-77 -- 8 acre orchard of woody species under evaluation and seed production
21-77 -- A block of outstanding grasses propagated from collection site to Center by root stock.

ADVANCED EVALUATIONS: The more intensive testing of plants which have been seleced as being superior in one or more attributes in the initial evaluation.

2-76 -- Planting of potted and bare root material from Los Lunas Plant Materials Center, 50 accessions
3-76 -- Planting of potted materials from Cheyenne Horticultural Station, 30 accessions
8-76 -- Direct seeding of 40 accessions of grasses and legumes proven superior at other Centers
10-77 -- Intercenter shrub planting of bare root and potted plants. Tublings from USFS, Coeur d'Alene Nursery, bareroot and potted materials from Los Lunas PMC, SCS

FIELD EVALUATION PLANTINGS: Plot or row plantings of one or more species or accessions established at locations selected to represent soil, climate, or other conditions not represented on the Environmental Plant Center.

7-76 -- Colony-Parachute Creek-Oil Shale Area--initiated by Los Lunas PMC in 1971. 64 accessions of grasses, forbs and shrubs. Interplanted by EPC in 1976
11-77 -- Climax/AMAX Mine - High altitude disturbed land--planted 15 accessions of potted woody plants and 48 accessions of grasses and sedges
12-77 -- TOSCO-Uintah Co., Utah-Low rainfall site in mineral development area. Planted 35 accessions of potted woody plants and 48 accessions of grasses and sedges
13-77 -- ColoWyo-Coal mining area--planted 84 accessions of shrubs
14-77 -- Energy Fuels-Reclaimed coal mined area--planted 68 accessions of shrubs

FIELD SCALE INCREASES: The reproduction of plant materials for use in field plantings and by cooperating agencies for further testing to finalize the feasibility of a variety release, and to maintain a supply of genetically pure, high quality seed.

15-77 -- Luna pubescent wheatgrass, *Agropyron trichophorum* (4 acres)
16-77 -- Redondo Arizona fescue, *Festuca arizonica* (4 acres)

Seed and materials for Center projects have come from three major sources. Plant Material Centers have shared seed of their best performers. A second source was the staff of the environmental Plant Center. A third source has been the SCS state level plant sciences staff along with field office employees, and range and soil scientists located throughout the Upper Colorado region of Colorado, Utah, and Wyoming. Once the seed enters a project, records are kept on each accession as it responds to the various techniques employed to encourage germination.

Table 2 is a sample of data recorded for Project 1-76. In addition to germination, we have evaluated each accession for seedling vigor, winter hardiness, growth, leafiness and seed production. In addition, over the last two years, we have had a chance to measure deer browse selectivity and their degree of utilization on this project. Fall migrating deer herds foraged randomly for 30 nights each fall. We think their selectivity denotes a definite accessional preference.

Table 3 lists the top twenty-one plants as they relate to four priority areas of the Long Range Program on the basis of the first two years' results which are far from conclusive. These twenty-one are selected out of 260 accessions representing 56 genera and 78 species. The Center has on hand 3,000 different accessions or ecotypes. Most are in a Center project.

Field Evaluations at Reclamation Sites

In a second phase of evaluation, cooperating mining companies have, in some cases, gone to great expense to provide a fenced site near major reclamation areas suitable for evaluation of plant materials. We have five evaluation plantings at such sites.

One high altitude planting is in cooperation with the Climax Moylbdenum Company, AMAX, at 11,000 feet (3,350 meters). At the other elevation extreme, an evaluation plot is located in Uintah County, Utah at 5,000 feet (1,525 meters) in cooperation with TOSCO. ColoWyo, or W.R. Grace, has assisted us with a site near their coal mine at 7,400 feet (2,255 meters). Energy Fuels, south of Hayden, Colorado, has selected a plot site on reclaimed spoils in cooperation with the Bureau of Land Management and the Center. One of the oldest field evaluation plantings in the area is located near Colony's Parachute Creek operation at 8,500 feet (2,590 meters). These projects permit the evaluation of superior accessions under several different conditions and comparison of their growth characteristics at the Center.

Table 2. Sample Data Recorded for Project 1-76.

Scientific Name & Accession Number	Origin	Year	Germ. in Strat.	Germ.		SPRING		FALL							Comments
										Annual Ht./ Spread (cm.)[1]	Production		Deer Browse		
				A	B	Surv.	Vig.	Surv.	Vig.		Seed	Leaf	Selectivity	Utilization	
Amelanchier alnifolia 409	Grand Co., CO	1976	4	4	ND			3/3	ND				1	3	Serviceberry
		1977				2/3	4	2/3	4	10	N	3	1	1	
511	Rich Co., UT	1976	2	2	ND			4/8	ND				N		
	6000 ft.	1977				4/8	3	4/8	3	5	N	3	4	5	
Amorpha fruticosa 617	Morgan Co., CO	1976	5	3	ND			3/4	ND				N		Indigobush
		1977				3/4	5	3/4	2	80	N	3	N		
Artemisia arbuscula nova 296	Gunnison Co., CO	1976	ND	ND	2			7/7	ND				N		Black sagebrush
	8240 ft.	1977				7/7	2	7/7	3	30	3	2	N		
332	Maita, ID	1976	ND	ND	2			9/11	ND				N		
		1977				9/11	2	9/11	3	30	4	3	N		
571	Crouse Canyon,	1976	ND	ND	2			9/10	ND				N		
	UT 5400 ft.	1977				9/10	1	9/10	2	50	2	2	N		
Artemisia frigida 432	Fairplay, CO	1976	ND	ND	3			6/6	ND				5	5	Fringed sagewort
	9600 ft.	1977				6/6	1	6/6	1	70	1	1	N		
589	La Veta Pass, CO	1976	ND	ND	3			8/8	ND				4	5	
	9000 ft.	1977				8/8	1	8/8	1	90	1	1	N		
Artemisia spp. 397	Driggs, ID	1976	ND	ND	2			3/4	ND				1	5	sagebrush
	6000 ft.	1977				3/4	1	3/4	3	40	3	3	N		Spreads

STANDARD VALUES LEGEND: 1 = excellent; 2 = good; 3 = fair; 4 = poor; 5 = very poor; N = none; ND = no data or not tested

DEER BROWSE LEGEND: 1 = 81 - 100%; 2 = 61 - 80%; 3 = 41 - 60%; 4 = 21 - 40%; 5 = 1 - 20%; N = none; ND = no data or not tested

[1] 1 in. = 2.54 cm.

Table 3. Top Plants in Initial Evaluation Relative to Four Major Priorities* Project Number 1-76. (Upper Colorado Environmental Plant Center)

		Revegetation of Disturbed Lands	Roadside Stabilization and Beautification	Plants for Restoration of Processed Oil Shale	Wildlife Habitat Improvement for Big Game
Artemisia frigida	589	8	1	1	
Potentilla fruticosa	300	5	4	2	7
Prunus virginiana	222	9		9	10
Aster sp.	423		5	10	
Ribes sp.	337	4	10		1
Rhus trilobata	566	3	9		5
Oenothera hookerii	477		2		2
Amelanchier alnifolia	393	1			3
Cercocarpus montanus	192	2			4
Atriplex canescens	317	6		3	
Peraphyllum ramosissimum	461	10			6
Symphoricarpos oreophylus	216				8
Penstemon barbatus	368		3		
Purshia tridentata	146	7		5	9
Eurotia lanata	585			4	
Ephedra sp.	68			6	
Fallugia paradoxa	580		7		
Astragalus sp.	612			8	
Epilobium sp.	416		6		
Lupinus argenteus	628			7	
Eriogonum sp.	313		8		

*Based on two years recorded data and observations throughout evaluation period. Numerical ratings 1 through 10 with 1 as the best.

Cultural Evaluations

A third phase carried out at the Center is classed as cultural evaluations. Project 10-77 compares the use of bare root, tar paper pots, or tubling materials as best methods for transplant. Project 9-76 measures the response of 171 top shrubs to direct seeding.

Seed Supply

A fourth phase deals with the actual production of seed supplies for superior plants. The increase plantings consist of clean fields producing high quality seed capable of qualifying as Foundation Seed.

The Center is not in the business of selling plants or seeds. It will develop outstanding ecotypes that will be released to commercial producers who will produce and sell Certified Seed or planting stock. The EPC will be responsible in many cases for maintaining the genetic purity and available seed supply of the released ecotype. Materials dispersed for further testing or commercial production are coordinated through the SCS Plant Materials Specialist.

SUMMARY

This presentation does not cover all projects and data developed by the EPC program. It demonstrates that a facility exists, operating harmoniously with government and private interests, which can help locate and provide vegetation useful in reducing the impact of development upon the environment of the Upper Colorado region. The EPC needs your constructive help. No one has the time to waste trying to prove again and again what is already known.

The development of just one superior plant will require a minimum of five years; getting it into commercial production will require an additional three to five years. We cannot afford to waste time on a "less than superior" accession.

Some may wonder about the full value of superior accessions. We think they spell long term success. According to a recent public news release today's revegetation tests in the Upper Colorado region lose 50 to 70 percent of the tested plants as soon as supplemental water is stopped. Superior accessions should improve not only our chances for successful revegetation, but should also harmoniously improve the quality of the environment.

LITERATURE CITED

Carnahan, G.F. 1976. Report on the current status of the Upper Colorado Environmental Plant Center. p. 29-32. In R. H. Zuck and L. F. Brown (eds.) Proceedings: High Altitude Revegetation Workshop No. 2, Environmental Resources Center Information Series No. 21, Colorado State University, Fort Collins, Colorado.

REGIONAL PLANT MATERIALS CENTERS

Environmental Plant Center
Box 488
Meeker, Colorado 80217

Aberdeen Plant Materials Center
Box AA
Aberdeen, Idaho 83210

Manhattan Plant Materials Center
Rt. 2, Box 314
Manhattan, Kansas 66502

Los Lunas Plant Materials Center
1036 Miller Street S.W.
Los Lunas, New Mexico 87031

Bridger Plant Materials Center
Rt. 1, Box 81
Bridger, Montana 59014

A NOTE ON THE VARIETAL RELEASE PROCESS

W. G. Hassell
SCS Plant Materials Specialist
Colorado and New Mexico

Plant materials developed by public agencies generally go through a formal release procedure: 1) The data supporting outstanding qualities of the new variety are assembled. 2) This information is presented to the state varietal release committee of the respective states. They either accept, reject, or request more supportive data. 3) If it is accepted, information about identifying characteristics are assembled and the plant variety is presented to the respective state crop improvement association as the quality control agency for commercial seed production. 4) The material is released and made available to the public (release notice) for commercial production. 5) If more supportive data is needed we have to continue testing.

Where there is not a "standard" variety to compare or where we are working with native plants and variation is a desirable characteristic, agencies and varietal release committees are recognizing the use of different standards and methods than generally applied to the agronomic crops where statistical differences in stands or yields is needed to support the release.

The State Crop Improvement Associations are developing different levels of certification to deal with woody plants. For example, the following two classes were developed by the New Mexico Crop Improvement Association:

1) Source Identified is a class of tree seed defined as seed from either natural stands with known geographic source and elevation, or a plantation of known geographic location.

2) Selected seed is a class of tree seed which shall be the progeny of rigidly selected trees or stands of untested parentage that have promise but not proof of genetic superiority, and further for which geographic source and elevation shall be stated on the certification label.

Other states are developing similar standards. As federal agencies, I feel we can use these classifications and procedures to meet the objectives of releasing plants for public use and to maintain a quality product. These procedures should help make plants available (released) to the public in a shorter period of time.

It is important to release plants for public availability. However, we do need to know we are releasing a plant that will do a job in the field and this requires a period of testing.

GRASS AND LEGUME IMPROVEMENT FOR HIGH ALTITUDE REGIONS

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Department of Agronomy
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The Committee on High Altitude Revegetation which has sponsored the High Altitude Revegetation Workshops held in 1974, 1976, and 1978, and Summer Field Tours each year since 1974, has also sponsored some research in high altitude plant materials development. This is an informational progress report about our activities which comprise species and strain testing, breeding, and selecting and improving native species. The latter program is our newest area of research.

BREEDING OF SMOOTH BROME

As a result of the good performance of 'Manchar' smooth bromegrass (*Bromus inermis* Leyss.), at Climax and other high altitude plantings in 1969, Drs. William Berg and Robin Cuany, started a breeding project in 1970 whose early years are reported in Cuany 1974. Briefly, there were 480 seedlings of each of four cultivars, 'Manchar,' 'Sac,' 'Saratoga,' and 'Polar,' established as spaced plants on disturbed soil at 11,200 feet (3,410 m) at Climax. After two winters selections were made in June, 1972, and pieces of 79 plants were transplanted to Fort Collins for seed production in 1973 and subsequent summers. The first progeny test was planted in disturbed soil at 11,200 feet in June, 1974, and scored for growth and vigor in the summers of 1975, 1976, and 1977. In the 79-plant nursery, observation of greater rhizomatous spreading tendency led to the choice of nine clones which were separated into an isolated recombination block in 1973, parents 102-157 represent CSU-1, and harvested for polycross seed in 1973 and subsequently. The choice of five other spreading clones in 1974 lead to another recombination block, CSU-2, whose components 218-267 were harvested in 1974 and 1975.

In order to test the polycross progeny of the CSU-1 and CSU-2 series, all 14 polycrosses were included in the 1976 species and strain tests (following section) and were seeded on molybdenum ore tailings at the Climax mine. (Climax, Colorado at about 11,300 feet (3,450 m) is the site of one of the Climax Molybdenum Company, AMAX, mines.) The tailings plot, located below the west end of the

Robinson Tailings Pond, was limed with 4 tons of lime per acre (8.96 metric tons/ha) and mulched with 2 tons per acre (4.48 metric tons/ha) barley straw. Fertilizers incorporated were 200 lb per acre (224 kg/ha P_2O_5 as (0-46-0) and 200 lb per acre K_2O as (0-0-50). Ammonium nitrate was top dressed after seedling emergence to give 60 lb N per acre (67 kg/ha). The polycross progeny were hand seeded into three rows each with three replications (nine rows per entry). Although spreading tendency as observed in the Fort Collins clay loam soil was the basis for selection of the 14 clones, it may be valuable in the Climax tailings situation.

The results of the two sets of seeded row tests of 1974 and 1976 are summarized, for the parents involved in polycrosses in CSU-1 and CSU-2, in Table 1. There are discrepancies in their performance at one site compared to another; in the case of the 1974 plantings, there is an interaction with the years of observation (1975, 1976, and 1977) so that the results from any one year may be unrepresentative. Nevertheless, polycrosses 139, 145, 249, 252, and 267 have not shown sufficient value to be kept, but the other nine have been saved. Certainly some of these progenies are better than the check, 'Manchar.' More years of observation are needed for proper evaluation.

From the remainder of the original 79 parents, three years of progeny test results led to the retention of 13 additional clones. Repeated annual observation of the original 1,920 spaced plants growing at Climax revealed, by 1976, some that looked as good as, or better than, the 79 selected in 1972. Therefore, a further 56 plants were removed to our Fort Collins nursery in 1976. Fifty-five of these were put with the 22 retained from the 1972 set into a new duplicate seed production nursery. In this set, 35 plants were from 'Manchar;' 24 from 'Polar' 12 from 'Sac;' and 6 from 'Saratoga.' The progenies of these 77 plants, with appropriate varietal checks, are scheduled for test seedings in 1978 or 1979. In these critical environments, hasty choices are unwise.

SPECIES AND STRAIN TESTS

In 1974 and 1976 species and strain tests were established at several subalpine locations in northcentral and central Colorado (Table 2). Our testing program has consisted of seeded row plantings of numerous species and different named varieties of some. At the time of planting 100 lb per acre (112 kg/ha) of P_2O_5 was incorporated into the soil and 50 lb N per acre (56 kg/ha) was added as a top dressing. The rows were hand seeded and planted to contain about 20 pure live seed per foot of row. Two replications of each entry were

Table 1. Smooth brome progenies seeded in the subalpine.

Parent: Origin	Parent: PC no.	1974 Seeded Rows: Climax 1977	1974 Seeded Rows: Climax 3 yr. average	1976 Seeded Rows: Climax tailings	1976 Seeded Rows: Average of 5 locations
Manchar	102	6	5.6	4.0	5.5
	104	8	5.6	6.7	6.0
	107	8	5.2	6.7	5.5
	124	5	3.0	6.0	6.0
	139	6	4.6	4.0	4.8
Sac	141	5	4.0	6.7	5.0
	142	6	6.0	5.3	4.3
	145	4	3.6	4.7	4.0
Polar	157	5	5.2	5.3	5.3
Manchar	218	8	4.5	6.7	5.2
	229	5	4.3	6.0	4.8
Sac	249	5	4.0	5.3	4.5
Polar	252	3	3.7	5.3	4.3
	267	4	2.5	5.3	4.7
Average of 79		5.0	4.1	--	--
Manchar		--	--	5.3	5.8

Vigor ratings from 0-9.

Table 2. High altitude test plot plantings.

Location	Year	Elevation (ft)	m
Steamboat Springs	1976	9,700	2,950
Winter Park	1974	10,600	3,330
	1976	9,500	2,890
		10,500	3,300
Urad	1974	10,600	3,330
Eisenhower Tunnel	1976	11,200	3,410
Vail	1974	9,000	2,740
Breckenridge	1974	10,700	3,260
Climax	1974	11,200	3,410
	1976	11,400	3,470
Leadville	1974	10,000	3,040
Snowmass	1976	9,500	2,890
		10,500	3,300

planted in each plot. The average performance evaluations (Tables 3 and 4) generally reflect vigor and persistance. In Table 4, numerical ratings are given for average establishment amounts in the row.

The 1974 Plots

The plot at Breckenridge was established on July 10 on a recently cleared ski slope. Some of the rows were damaged by heat from a slash burn bonfire in 1974. No evaluation was made in 1975. During the 1976 evaluation, many of the rows could not be distinguished because of seed washed or blow in from the ski slope seeding.

The Climax plot was graded by a front-end loader prior to planting on July 9. A few entries were added on July 31 to this severely disturbed soil site.

Two plots were established at the Colorado Mountain College, Leadville. One was planted in October 1974 and the other in Spring 1975. The latter plot was replicated four times. Both plots were hand cleared and not fertilized at the time of planting. In 1977, nitrogen fertilizer was broadcast over the plot.

Two adjacent plots were planted at a site below Urad Lake. Both plots were prepared by a front-end loader on July 8. Some entries were added on July 23 and the adjacent plot was planted on October 21. No evaluation was made in 1975, but all rows were extensively hand weeded.

A plot was established on a recently cleared ski slope at Vail on July 10. This plot was completely overgrown by seed washed or blow into the plot from the ski slope seeding by 1976. Other plots were established by Vail Associates at a higher elevation, but these plots were overgrown by tansy mustard probably brought in with the mulch used. (Only these plots were mulched.)

The Winter Park site was also established on a recently cleared ski slope on July 10. This plot too was invaded by seed from the ski slope seeding, but replication 1 was carefully hand weeded in 1975 and 1977. A complete evaluation was not possible in 1976.

The 1976 Plots

Two adjacent plots were established on disturbed glacial till at Climax. One plot was planted on June 30 and the other on October 2.

Table 3. Evaluation of the 1974 plantings.

Specific name	Common name	Named Variety	Breckenridge 10,700 ft.	Climax 11,200 ft.			Leadville Fall 1974 10,000 ft.			Leadville Spring 1975 10,000 ft.			Urad July 1974 10,600 ft.		Urad October 1974 10,600 ft.		Winter Park 10,600 ft.		
			76	75	76	77	75	76	77	75	76	77	76	77	76	77	75	76	77
LARGE GRASSES																			
Agropyron dasytachyum	Thickspike wheatgrass		++	+	+	++	++	.	.	.	+	++*	+	++	.	..	.		0
A. desertorum	Crested wheatgrass	Ruff	-	-	-	-	.	0	0	.	0	0	-	-	+.	+.	-	-	-
A. riparium	Streambank wheatgrass	--		+.	+	++	-	-	-	-	-	-	+.	++.	-	-	+	+.	.
A. smithii	Western wheatgrass	Arriba		+	+	+	++	0	0	.	.	+.	..	.	-	-	.	+	+
		Rosana	++	+	+.	+	-	-	-	-	-	-	++	+	-	-	.	+	.
A. trachycaulum	Slender wheatgrass	Primar	+++	+	+	+.	-	-	-	-	-	-	++	++.	-	-	+	..	++
Alopecurus arundinaceus	Creeping foxtail	Garrison		.	+	+	.	+	++*	.	0	0	+	+.	+.	+	0		0
A. pratensis	Meadow foxtail	--		+	+	++.	-	-	-	-	-	-	+.	++.	-	-	++		++.
Bromus inermis	Smooth brome	CSU-1		+	++	++.	-	-	-	-	-	-	++	+.	-	-	++	++	++
		Lincoln	-	.	+	+.	+	+	0	+.	0	0	+	+.	+	..	-	-	-
		Manchar	++	+.	+.	++	++	0	0	+.	.	0	++.	++.	+.	+.	++	++	++.
		Polar		.	.	+	-	-	-	-	-	-	..	..	-	-	+	+	++
B. marginatus	Mountain brome	Bromar	+	+	+	+	-	-	-	-	-	-	+	..	-	-	+		.
Dactylis glomerata	Orchardgrass	Nordstern	-	-	-	-	++	+	+*	..	0	0	-	-	++.	++	-	-	-
		OSG-7		+	+	+	-	-	-	-	-	-	++	++	-	-	+	++	0
		--		++	++	++.	-	-	-	-	-	-	++.	++.	-	-	+	++	0
Festuca arundinacea	Tall fescue	Fawn		+	+	++	-	-	-	-	-	-	+	+.	-	-	.		0
Phalaris arundinacea	Reed canarygrass	--	-	.	.	+.	.	0	0	.	.	+.*	+	+	+.	++	-	-	-
Phleum pratense	Timothy	--	+	+.	++	++.	+	+	++*	.	+	-	+++	++.	++	++	+++	+++	++.
Stipa viridula	Green needlegrass	Source 1		0	0	0	.	0	0	.	0	0	0	0	.	.	+		0
		Source 2	-	0	0	0	+	.	++*	.	.	-	.	.	.	.	-	-	-
SMALL GRASSES																			
Agrostis alba	Redtop	--		.	.	.	-	-	-	-	-	-	..	.	-	-	.		0
A. palustris	Creeping bent	Seaside	++*	..	+	..	.	.	.	.	0	0	+	+	.	..	.		0
Deschampsia caespitosa	Tufted hairgrass	--	-	-	-	-	.	.	++.*	.	0	0	-	-	.	+	-	-	-
Festuca arizonica	Arizona fescue	Redondo	++	.	+	+	-	-	-	-	-	-	.	+.	-	-	0		0
F. ovina var *duriuscula*	Hard fescue	C-26	++	+	++.	+++	+.	+	+++	.	+	++	++	++.	++.	++.	+		++.
		Durar	++	..	+.	++	-	-	-	-	-	-	++	++	-	-	++		++

Table 3 (continued)

Specific name	Common name	Named Variety	Breckenridge 10,700 ft	Climax 11,200 ft.			Leadville Fall 1974 10,000 ft.			Leadville Spring 1975 10,000 ft.			Urad July 1974 10,600 ft.		Urad Oct. 1974 10,600 ft.		Winter Park 10,600 ft.		
			76	75	76	77	75	76	77	75	76	77	76	77	76	77	75	76	77
Small grasses (cont')	Red fescue (cont')																		
F. rubra		Dawson	++	+	++	++	+	.	+.*	.	+	0	++.	++	++.	++	++		++
		Illahee	++	+	++.	+.	+	++	+++	.	.	0	++	++	+.	+.	+		+.
		Pennlawn	++	..	++	+.	..	+	++*	.	+	+*	++	++.	++	+.	+		+.
		Wintergreen	++	..	+.	++	++	..	+*	..	+.	+*	++.	++.	++.	++	++		++
		--	++	+	+++	+.	-	-	-	-	-	-	++.	++	-	-	++		++
F. rubra var. *commutata*	Chewing's fescue	--	-	.	+.	++.	++	+	++.*	+	++.	++.	+++	++.	+++	++.	-	-	-
Poa compressa	Canada bluegrass	--	-	-	-	-	.	0	0	.	0	0	-	-	+	+	-	-	-
P. pratensis	Kentucky blue-grass	Nugget	-	.	+	++	.	0	0	.	0	0	+	+	+.	+.	-	-	-
		Park	++	.	+	+.	-	-	-	-	-	-	++	+++	-	-	+		+++
P. compressa x *P. pratensis*		NJE-167		.	+	+.	.	0	0	.	0	0	++*	+.	++*	+.	.		+
FORBS AND LEGUMES																			
Astragalus cicer	Cicer milkvetch	Lutana	+*	..	+*	++*	-	-	-	-	-	-	++*	+*	-	-	0		0
		Oxley	++*	.	+*	+.*	-	-	-	-	-	-	++*	++.*	-	-	0		0
		Size 12	+	.	.*	++*	-	-	-	-	-	-	+*	++*	-	-	0		0
Atriplex canescens	Fourwing salt-bush	--	-	0	0	0	0	0	0	..	0	0	0	0	-	-	-	-	-
Medicago sativa	Alfalfa	Ladak			+.	+++	+.	-	-	-	-	-	++.	++.	-	-	.		0
		Nomad	-	-	++	++.	.	.	+*	++	.	+*	++	++	..	+*	-	-	-
		Apredor	-	-	-	-	-	0	0	++	.	+.*	-	-	+.	+	-	-	-
Melilotus officinalis	Yellow sweet-clover	Madrid	-	+	++*	0	.	0	0	.	.	0	++*	0	0	0	-	-	-
Sanguisorba minor	Small burnet	--	-		0	0	0	0	0	+++	0	0	0	0	++*	0	-	-	-
Trifolium ambiguum	Kura clover	--		.	.*	+.*	..	-	-	-	-	-	++*	++*	-	-	..		++*
T. hybridum	Alsike clover	--	-	+	0	0	0	0	0	.	0	0	++*	++.*	+.*	++*	-	-	-
T. medium	Zigzag clover	--	+*	.	.*	+*	.	-	-	-	-	-	+*	+.*	-	-	.		+*
T. repens	White clover	--			+.	++	+.	0	0	+	0	0	+++	++	.	+	+++		++

LEGEND

0 = None present
. = Poor growth
+ = Fair growth
++ = Good growth
+++ = Excellent growth

* = Only a few plants present
.. = Poor to fair
+. = Fair to good
++. = Good to excellent
\- = Not planted

Table 4. One year of evaluation of the 1976 plantings.

Specific name	Common name	Named Variety	Climax June 1976 11,400 ft.		Climax Oct. 1976 11,400 ft.		Eisenhower Tunnel 11,200 ft.	Mary Jane 9,500 ft.	Steamboat 9,700 ft.		Snowmass 9,500 ft.	Snowmass 10,500 ft.
LARGE GRASSES												
Agropyron dasystachyum	Thickspike wheat-grass	--	++	.3	+.	.3	+.	+.	++.	.8	-	-
A. desertorum	Crested wheatgrass	Ruff	++	.2	++.	.4	++	++	++.	.7	-	-
A. smithii	Western wheatgrass	Arriba	.	.01	++	.4	+	+	+	.3	-	-
		Rosana	+.	.04	+	.1	..	+.	+.	.7	-	-
	Collected at Tincup,	CO	-		+++	.4	-	-	-		-	-
A. riparium	Streambank wheat-grass	Sodar	++	.2	..	.2	++	++.	+.	.5	-	-
Alopercurus arundinaceus	Creeping foxtail	Garrison	++	.1	+	.1	++	++.	+	.1	-	-
A. pratensis	Meadow foxtail	--	+++	.2	++	.2	++.	+++	++.	.5	-	-
Bromus inermis	Smooth brome	Lincoln	+.	.2	+	.2	++	++	+	.6	-	-
		Manchar	++.	.3	-		+	++	++	.8	-	-
Dactylis glomerata	Orchardgrass	Latar	++	.02	++.	.3	+	+++	++.	.5	-	-
Festuca arundinacea	Tall fescue	Fawn	+.	.1	+++	.4	+.	++.	+.	.4	-	-
Phalaris arundinacea	Reed canarygrass	--	++	.1	+	.2	++	++.	+.	.3	-	-
Phleum pratense	Timothy	Climax	++	.5	..	.01	+++	++.	++.	.3	-	-
Stipa viridula	Green needlegrass	--	0		.	.01	.	+.	+.	.5	-	-
SMALL GRASSES												
Agrostis palutris	Creeping bent	Seaside	++	.01	0		++	++	+	.01	-	-
Festuca arizonica	Arizona fescue	Redondo	++	.2	+	.01	+	++.	+.	.1	-	-
F. ovina var *duriuscula*	Hard fescue	C-26	++.	.3	.	.03	++.	++.	++.	.6	-	-
		Durar	+	.3	.	.06	++	++	++.	.4	-	-
F. rubra	Red fescue	Dawson	+	.1	++.	.2	++	++.	++	.2	-	-
		Illahee	++	.1	.	.1	++.	+++	+.	.3	-	-
		Pennlawn	++.	.1	++	.2	++	+++	++	.6	-	-
F. rubra var *commutata*	Chewing's fescue	--	++	.1	+	.2	+++	+++	++.	.5	-	-
Panicum clandestinum	Deertongue grass	--	++	.1	+	.01	++	+.	+.	.1	-	-
Poa compressa	Canada bluegrass	--	+.	.1	0		+++	+++	++.	.5	-	-
Poa pratensis	Kentucky bluegrass	Nugget	+.	.06	0	-	+.	++	+.	.3	-	-
		Park	+.	.1	.	.01	+	+.	++	.3	-	-
		Troy	+.	.01	0		+	++	+.	.08	-	-
P. pratensis x *P. compressa*		NJE-167	+.	.1	+	.1	+	++	+.	.09	-	-

Table 4. (Continued)

Specific name	Common name	Named Variety	Climax June 1976 11,400 ft.		Climax Oct. 1976 11,400 ft.		Eisenhower Tunnel 11,200 ft.		Mary Jane 9,500 ft.		Steamboat 9,700 ft.		Snowmass 9,500 ft.	Snowmass 10,500 ft.
FORBS AND LEGUMES														
Astragalus cicer	Cicer milkvetch	Lutana	++	.2	++.	.4	++.	.2	+	.5	++	.6	++	.
Coronilla varia	Crownvetch	Chemung	-		++	.4	-		-		-		-	-
		Emerald	-		++.	.2	-		-		-		-	-
		Penngift	+.	.3	++	.5	++.	.3	++.	.6	+.	.5	++	+++
Hedysarum boreale	Sweetvetch	--	++	.01	++.	.1	+.	.01	+	.3	..	.01	+.	+
Lotus corniculatus	Birdsfoot trefoil	Empire	+	.01	+	.06	+.	.03	++.	.8	+.	.01	++	++
Lupinus argenteus	Lupine	--	..	.01	++	.7	+.	.03	..	.3	.	.1	..	+.
Medicago sativa	Alfalfa	Creeper	++	.2	++.	.1	++	.1	++	.6	+.	.01	++.	+.
		Ladak	++.	.4	+.	.06	++	.2	++	.6	++	.5	++.	..
		Nomad	+++	.2	+.	.2	+.	.2	+.	.5	+.	.3	+++	+.
Melilotus officinalis	Yellow sweetclover	Madrid	++	.01	++.	.2	+.	.07	++	.5	++	.01	++	+
Penstemon strictus	Rocky Mtn. penstemon	Bandera	+.	.01	++	.01	++	.01	++	.2	+.	.01	+	+++
Sanguisorba minor	Small burnet	--	+.	.01	-		0		+++	.8	+.	.01	++.	0
Trifolium hybridum	Alsike clover	--	+.	.01	++	.01	+.	.03	+++	.8	++	.1	++	+.
T. medium	Zigzag clover	--	+.	.01	-		+.	.04	++	.5	+.	.01	..	+.
T. repens	White clover	—	++	.03	++	.2	++	.06	++.	.7	++.	.5	++	++

Numerical ratings indicate average establishment in the plot 1 = 100%.

0 = None present
. = Poor growth
+ = Fair growth
++ = Good growth
+++ = Excellent growth

* = Only a few plants present
.. = Poor to fair
+. = Fair to good
++. = Good to excellent
- = Not planted

Two plots of legume entries and one plot of smooth brome polycross progenies (CSU-2) were established at Snowmass-at-Aspen. The legume plot at 9,500 feet (2,890 m) is in a clearing in an aspen forest with relatively undisturbed soil. The other legume plot and the smooth brome plot were established on a disturbed steep ski slope at 10,500 feet (3,300 m). These plots have the advantage of continuously-monitored weather data. Both plots were planted on July 1.

One plot was established on a recently graded slope near the West Portal of the Eisenhower Tunnel on July 15.

Two plots were established in the Winter Park area. One was planted on a previously graded slope in a spruce/fir forest at the Mary Jane ski area at 9,500 feet (2,890 m) on July 16. The other plot was established at 10,500 feet (3,300 m) on October 1 and has not been fully evaluated.

The final plot was established on a ski slope at Steamboat Springs on July 20. One replication was on graded subsoil, and the other on a 3 inch (7.6 cm) layer of top soil which had been spread over the graded slope. The bromegrass polycross progenies represented by CSU-1 and CSU-2 were planted in these six test plot locations.

Observations

The results at Leadville (Table 3), the unfertilized plot, demonstrate the need for supplemental fertilizer when planting on these nutrient poor disturbed soils. The fescues seem to be better adapted to these nutrient poor conditions than the large grasses.

The plot at Steamboat Springs demonstrated the benefits of topsoil. The plants on the topsoil had a higher percentage of establishment, persistence and vigor--the topsoil plants were 3-6 inches (7.6-15 cm) larger than those on subsoil. The reason for this is probably due to the higher nutrient and water holding capacity of topsoil.

With respect to planting time, for the grasses there appears to be no difference, but for legumes there is a difference. The legumes appear to benefit from a fall planting since they germinate early enough the following season to produce enough growth for over-wintering root reserves.

Table 5 summarizes the best all-around performing species and strains according to category. A close look at Tables 3 and 4 shows that no one species performs well at all locations. The data from

Table 5. The best all-around performing species.

Common name	Number tested	Variety	Remarks
LARGE GRASSES			
Thickspike wheatgrass	1		
Crested wheatgrass	1	Ruff	May produce seed.
Meadow foxtail	1		May produce seed; persistant.
Smooth brome	3	Manchar	May become sod bound; persistant.
Orchardgrass	4	Latar	Best on protected sites; may produce seed.
Reed canarygrass	1		Best on moist sites.
Timothy	2	Climax	Small seeded
SMALL GRASSES			
Hard fescue	2	C-26	Bunch type; persistant; may produce seed.
Red fescue	5	Pennlawn	Bunch type; persistant.
Chewing's fescue	1		Larger bunch type; persistant.
Canada bluegrass	1		Spreads.
Kentucky bluegrass	3	Park	Spreads.
LEGUMES			
Crownvetch	1	Penngift	New entry; not grazed.
Alfalfa	4	Nomad	Extensively grazed.
Yellow sweet clover	1	Madrid	Biennial, lower elevations reseeds.
White clover	1		Moist sites especially favorable.

Table 3 is more reliable since it shows three years of observations at most locations.

Potential seed was harvested in 1977 from the 1976 test plots at Steamboat and Winter Park. The Steamboat plot has a south exposure while the Winter Park plot has a north to east exposure in an open wooded area. The hard fescues, Canada bluegrass, and meadow foxtail produced seed at both locations. 'Ruff' crested wheatgrass, 'Latar' orchardgrass, and 'Garrison' creeping foxtail all produced some seed at Steamboat. The other species tested did not produce seed. These species, then, could reseed to a limited extent in some locations in some years. (The 1977 growing season was longer and warmer than usual.)

Some of the species listed in Table 5 have particular adaptive characters: reed canarygrass does best in moist sites; orchardgrass in protected sites which are snow covered in winter; the Kentucky bluegrass and the smooth brome both show spread out of the rows. The fescues stay green later into the season than the other grasses with no apparent affect on their over-winter survival. Timothy has the advantage of being small seeded and hence can get into cracks readily.

The legumes are all difficult to establish. Better establishment and survival may be obtained in fall seedings. Crownvetch is a new entry which looks good from the aspect of being ungrazed by the small mammals and occasional deer and elk feeding in our plots. Alfalfa is the most grazed species. The biennial yellow sweet clover does best at lower elevations where it can reseed itself

We will continue to monitor these plots for survival of the tested species. The plots at Breckenridge and Vail have been unweeded to allow for observation of persistence of the planted species in conjunction with competition from invading species.

Plans for the future call for new test plantings with new accessions and some natives compared to proven performers to be planted in 1978. Continued testing is important to screen newly released varieties and other untested materials in the high elevation locations; continued observations are necessary to obtain reliable information on the usefulness of the tested strains. Because revegetation plantings are expected to last for many years, evaluations must be made for many years.

THE ALPINE ZONE AND NATIVES

Discussions with the Climax Molybdenum Company, AMAX, held in the fall of 1977 brought out the need for more work on the revegetation problems and possibilities in the true alpine (about 11,500 feet (3,500 m) or higher in Colorado), whether it be tundra or talus. Some rock waste from mining may have to be treated as talus; other disturbances can be modified with soil materials to provide a place for seeding to alpine species which are native to the Rocky Mountains. The search for native plant materials will begin this summer with the guidance of Dr. Beatrice Willard.

Information provided by Brown *et al.* (1976, 1978) at the High Altitude Revegetation Workshops has demonstrated the feasibility of reseeding with native species in the alpine zone. The availability of seed by gathering or by seed production of selected sources is a critical factor. Seeds or plants could be transferred from the alpine to a slightly less hostile climate at 9,000 to 10,000 feet (2,740-3,040 m) to enable "controlled" seed production.

We have drawn up a "shopping list" of species to be collected. The number of experimental seedings will be determined by the quantities of seed collected, their content of pure live seed, and the number of species which are actually available this year. Among the grasses we intend to represent in test plots, because of their adaptation to one part or another of the alpine environment, are one or more species of *Agropyron, Calamagrostis, Deschampsia, Festuca, Phleum, Poa* and *Trisetum*. We would like to be able to plant sedges such as *Carex* spp. and *Kobresia* spp.

There are numerous forbs on our "shopping list." The Rosaceae, for example, are represented by the genera *Dryas, Geum, Potentilla, Rubus, Sibbaldai,* and *Rosa*. There are at least five genera of Compositae and of Leguminosae, some with several species such as *Trifolium parryi*, *T. dasyphyllum*, and *T. nanum* in the Leguminosae.

In our studies we shall hope to pay attention to moist or dry areas and to predict which reconstructed places in the reclamation of the Climax mine will have snow patches. It is well known that certain genera and species thrive in show patches. It will probably be necessary to make up three or four native seed mixtures after we have tested the adaptation to seed propagation (or vegetative sprigging) or the component species. Testing of the native alpine species and strains of them, along with one or two introduced species already found to do well at 11,000 feet (3,350 m) will begin in the fall of 1978.

NATIVE PLANT IMPROVEMENT

Native plants are receiving increasing emphasis in revegetation plantings. The usefulness of native plants depends upon the availability of constant seed supplies. In developing a seed source, it is our belief as plant geneticists and breeders that improvements can be made on native plant populations similar to those made in agricultural plants. Our intent is not to drastically change the plants with respect to their important adaptive characters; but characteristics which might be improved include seedling vigor, persistence, spread, vigor, and other desirable traits for rangeland uses. In revegetation the primary concerns are plant establishment and survival with minimum maintenance input.

How do we decide which natives should receive emphasis? Where do we find "good" plants? How long does selection and establishment of a seed source take? We hope to answer these questions in this section using, as an example, research work begun on lupine (*Lupinus argenteus*).

The best place to find suitable native plants is a disturbed habitat. These environments are most like those encountered in revegetation projects. The plants growing on disturbed sites should already be "pre-adapted" to be able to survive and grow under nutrient poor conditions. Lupines are found in disturbed habitats throughout western and central Colorado. Our seed populations come from about 7,500 to 11,000 feet (2,285-3,350 m).

Lupinus argenteus is a highly variable species with a wide range of morphological and habitat variability. Flower color ranges from white to blue to purple; pubescence from none to high; leaf shape narrow to wide; plant type stemmy to bushy; habitat from forest understory, road banks, sagebrush communities to sand dunes. The presence of this visible variability should indicate other "invisible" variation, for example in biochemical processes. In plant breeding and selection, variation is a must; without it we can make no improvements.

Nitrogen is usually the most limiting plant nutrient and especially so on disturbed soils. Legumes, lupines for example, have the potential to fix nitrogen. Not all legumes fix nitrogen, but preliminary studies indicate that lupines do. Nodules have been observed in the field; greenhouse tests have shown variability for nodulation among populations. We hope to be able to capitalize on this variability in improving lupine populations.

An important aspect of lupines with respect to their potential poisonous hazard is their alkaloid content. Although we have not sampled our populations for alkaloid levels we intend to do so and expect to find variability in amounts. Keeler (1973) has shown that alkaloid content and level can vary significantly between populations.

Cuany (1974) presents a discussion on general breeding methodology and release of selected materials. Our selection of source populations of lupines will be based on those with greatest nitrogen fixation potential. Within these populations we will select for lower alkaloid content and other desirable characteristics such as seedling vigor. Testing the selected populations in seeded row adaptation tests is necessary to indicate the ecological amplitude of the various populations. Based on these results we will be able to decide upon the best adapted source populations for special purpose releases.

Any testing program requires either many years at one location or less number of years at several locations. To speed up the time required for testing and consequently the years required, we will use the latter approach. Before we can release a seed source we must be sure of its performance. Early work with the lupines indicates that ten years will be required before adequately tested seed sources can be released.

ACKNOWLEDGEMENTS

We acknowledge the contributions to carry out this work made to the High Altitude Revegetation Committee. Many companies have contributed; the Climax Molybdenum Company, AMAX, Winter Park Recreational Association, and LTV-RDI, 'Steamboat' have made the larger financial contributions. We thank also the agencies who have cooperated with us in planting our test plots through the donation of land and in many cases manpower to prepare plots and to plant them.

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DISCUSSION

HARRIS: In your plans for the future, you mentioned that you would be planting test plots in the true alpine. How high will these plots be? Will you use just natives:

CUANY: These plots will be at 12,000 to 12,300 feet (3,650 to 3,750 m) at Climax, Colorado. The intent is to just use natives, but a few non-native checks will be planted for comparison.

HARRIS: Will you plant test plots at areas other than Climax?

CUANY: It is important to test at more than one location, but these other tests may need to be planted in 1979 or later depending on harvests of native seed.

QUESTION: Is there any plan to study the longevity of the introduced species?

CUANY: Yes, we will continue monitoring our test plots for persistence and succession.

CROFTS: There is a tremendous interest in the use of native plants. A portion of your research effort is directed towards the use of lupines in revegetation. Moore pointed out that post-mining management is a most important aspect of reclamation and revegetation. How can you justify the use of a known posionous plant (since before 1900, lupines have been reported to be highly poisonous to livestock) in revegetation plantings?

KENNY: Lupines, as do many other plants, contain alkaloids which can be poisonous to animals when ingested in large amounts. Work at the USDA Poisonous Plant Research Lab in Logan, Utah has shown that some species of lupines cause crooked calf disease due to the presence of the alkaloid anagyrine. (Journal of Range Management, March 1977, Volume 30 p. 97-102.) The incidence of this birth defect can be reduced by management techniques such as the timing of grazing. Levels of total alkaloids and anagyrine have been shown to vary between lupine species and populations within a species. By screening potential source populations for alkaloid content followed by selection for low alkaloids we hope to reduce the alkaloid content to an acceptable level. Although low alkaloid plants will not eliminate the potential hazards, combined with good range management techniques they could significantly reduce hazards to livestock.

DEVELOPMENT OF PLANT MATERIALS FOR REVEGETATION IN ALASKA

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INTRODUCTION

Plant materials for Alaska must deal with a complex of forested and tundra regions that span almost 20° in latitude (Mitchell 1973a). Tundra develops not only above timberline in alpine regions but also at sea level from the lowest to the highest latitudes in the state (Figure 1). Permanently frozen substrates confer a stunted aspect on large forested tracts in the interior region, in contrast to the healthy stands also occurring there on unfrozen or deeply thawed substrates. Uplands and bogs provide a diversity of habitats immediately adjacent to each other. The arctic tundra is underlain with continuous permafrost often interlaced with ice wedges. These offer particular concerns in erosion control.

The boreal region of Alaska bears certain similarities with the subalpine regions of the mid-latitude Rocky Mountains. Many species are common to the two regions. White spruce (*Picea glauca*), a major dominant of the Alaskan boreal forest, is a close relative of the Engelmann spruce (*P. engelmannii*), a subalpine dominant of the Rocky Mountains. The two hybridize where they meet in Montana and Canada (Fowler and Roche, 1977). Groves of aspen (*Populus tremuloides*) are prominent in both regions. Unlike the high altitude stations in the Rockies, however, where weedy annuals have not succeeded (Eaman, 1974), a number are well established at boreal locations in Alaska. These include lambsquarters (*Chenopodium album*), shepherdspurse (*Capsella bursa-pastoris*), chickweed (*Stellaria media*), pineappleweed (*Matricaria matricarioides*), and others. A longer growing season at the low altitude boreal stations than at the subalpine Rocky Mountain stations probably permits this.

As may be expected, some of the same kinds of plants are in use in the two regions. Many of the writers in the previous workshops have mentioned 'Manchar' bromegrass, timothy, and meadow foxtail as constituents of high-altitude revegetation mixes (Berg, 1974; Cuany, 1974; Welin, 1974; Brown and Farmer, 1976; Gregg, 1976; Hendzel, 1976). These three grasses are important forage grasses and are also used in revegetation mixes in Alaska.

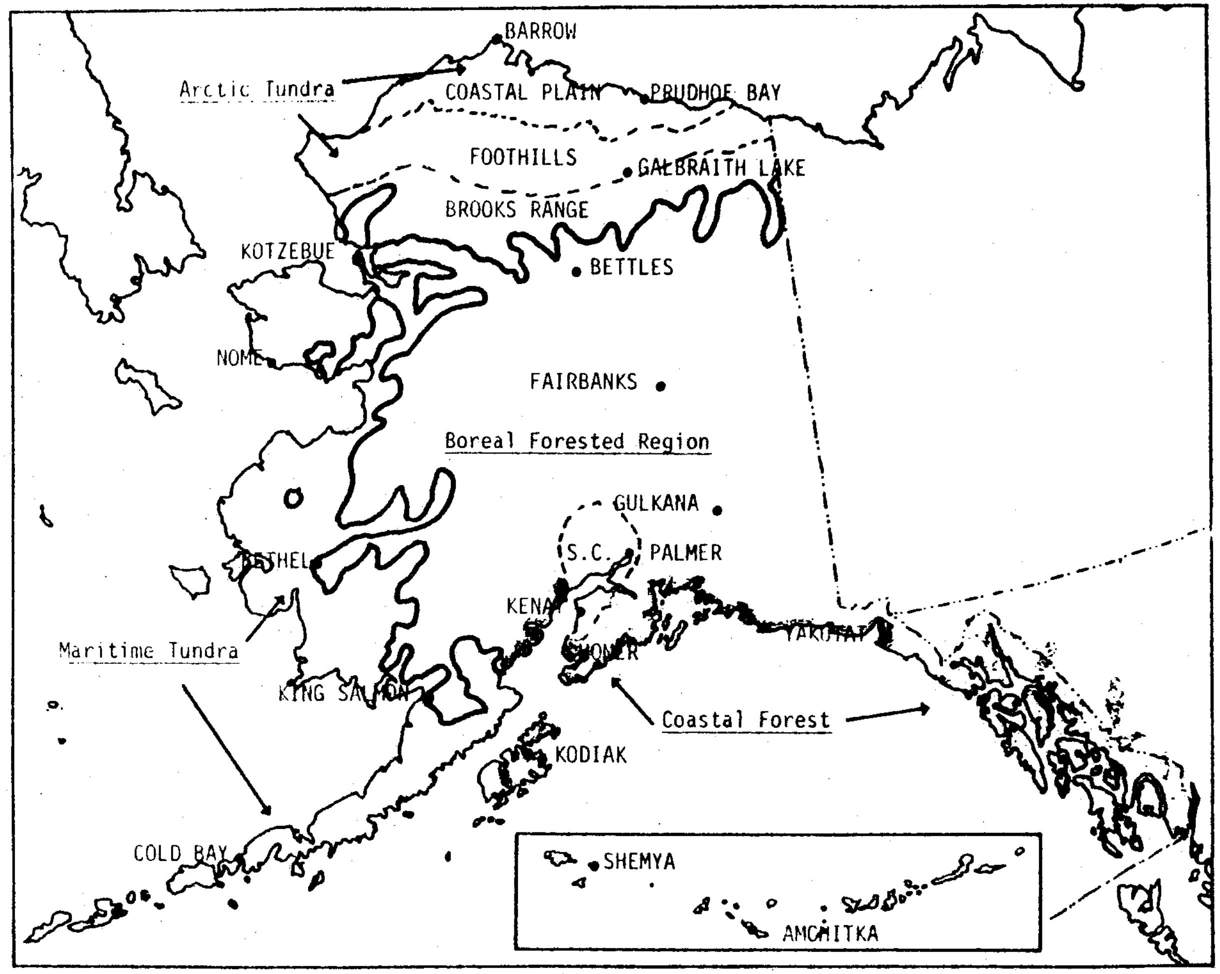

Figure 1. Major physiographic regions of Alaska. S. C. refers to the southcentral region transitional in nature between the continental interior and coastal (shaded) regions.

Some indications of behavioral similarities between elements of the Colorado and Alaska flora have been gained in transplant garden studies conducted in the two states. In a study at Palmer (near sea level, southcentral Alaska), entries of alpine foxtail (*Alopecurus alpinus*) from southcentral Alaska resembled entries from a high altitude station in Colorado more than those from northern locations in Alaska (Mitchell and McKendrick, 1975). Furthermore, a low, subalpine meadow entry of hairgrass from southcentral Alaska and two Colorado entries were similarly unhardy in both the Palmer and arctic (Prudhoe Bay) gardens.

Grasses from Alaska grown in Colorado transplant gardens on an altitudinal transect were highly variable in performance, some virtually failing while others grew vigorously (Bonde and Foreman, 1973). The evidence suggests that northern or high altitude origins for plant materials do not necessarily confer adaptability for similar habitats at other latitudes.

SOME FACTORS LIMITING SUCCESS OF INTRODUCTIONS

The use of plant materials at high latitudes places a premium on adaptability for winter hardiness. While introduced plants often encounter shorter growing seasons than those under which they developed, the longer day lengths are a compensating factor. Long days under low evaporative stress can produce a lush growth, but the long day regime also may affect winterhardiness. Some informative work on alfalfa conducted at Palmer (ca. 62° N) demonstrated the role of day length in the winter hardening process (Hodgson, 1964). The cold tolerance of 'Ranger' alfalfa was increased significantly by artificially shortening the photoperiod commencing in mid August. Similar results were obtained with some grasses in a later trial (Klebesadel, 1971). Plants with their origin in a regime with a lengthy autumn following the equinox may be found deficient at higher latitudes. In the boreal and arctic regions, days are relatively long until the equinox, with little or no time after the equinox before the onset of winter. Winter generally arrives before the equinox in the Arctic and at some alpine stations. Maritime tundra locations in the southwestern regions of Alaska experience longer fall periods than the alpine and arctic tundra sites.

Unusually cold soils which may be underlain by permafrost are a factor in plant establishment. Establishment is difficult in the colder tundra regions where proper temperatures and moisture conditions must coincide for a sufficient period for germination and establishment to occur. During moist periods in the Arctic temperatures may be too cold for germination to occur, and on well drained sites, conditions may become too dry during the warmer periods. In plantings at Prudhoe Bay near the north coast, perennials generally grow only 4 to 8 cm (1.5 to 3 in.) tall in the first year, thus must endure the first winter in a poorly developed state.

A number of introductions are potentially useful in the boreal region, but severe winters can decimate the less hardy. Introduced materials often are low in heading ability in Alaska; they may, however, be otherwise useful.

PLANT MATERIALS NOW IN USE

Plants used for revegetation purposes in Alaska are mostly those that have been used for forage or turf purposes. These include the following:

Common Name	Latin Name	Recommended Cultivar
Smooth bromegrass	*Bromus inermis*	Polar, Manchar, Carlton
Meadow foxtail	*Alopecurus pratensis*	Common
Creeping foxtail	*Alopecurus arundinaceus*	Garrison
Timothy	*Phleum pratense*	Engmo, Climax
Red fescue	*Festuca rubra*	Arctared, Boreal, Pennlawn
Kentucky bluegrass	*Poa partensis*	Nugget, Merion, Park, Sydsport
Hard sheep fescue	*Festuca ovina* var. *duriuscula*	Durar
White clover	*Trifolium repens*	Common
Alsike clover	*Trifolium hybridum*	Aurora

Highway roadbank seedings generally consist of a mixture of red fescue and Kentucky bluegrass, sometimes with white or alsike clover added. 'Arctared' fescue and 'Nugget' bluegrass are the preferred varieties. Common often is used, however, because of price considerations or shortages of seed supplies of the recommended varieties. Consequently, such plantings may sustain considerable winterkill during the more severe winters. Bromegrass and meadow foxtail may be included in some mixtures. The other grasses also have been and can be used in various situations. Other grasses that have shown potential for use on dry sites in interior Alaska are 'Sodar' wheatgrass (*Agropyron riparium*) and 'Summit' crested wheatgrass (*A. cristatum*).

Those of the above grasses selected under Alaska conditions include Polar bromegrass, Arctared fescue, and Nugget bluegrass. Polar involves hybrid material between the introduced *B. inermis* and the native *B. pumpellianus* and selected backcrosses with *B. inermis* (Wilton, et al., 1966). Arctared fescue is based on a collection made near Palmer in the Matanuska Valley (Anonymous, 1965a). Because of the circumstances of the collection, provenance of the variety cannot be known, but the variety behaves like indigenous material. Nugget bluegrass is based on a collection made at a gold mining camp in southcentral Alaska and almost certainly was an introduction into the camp that persisted and experienced some natural selection (Anonymous, 1965b). It is an excellent turf grass for Alaska where snow mold is not a severe problem.

Arctared fescue has been the most important of the Alaska-derived materials for revegetation purposes. It has proved to be more adaptable and hardier than the other two grasses in the Arctic and in some alpine regions where a critical need has developed for revegetation materials. Nugget bluegrass has been marginally successful in the Arctic, while none of the introduced varieties from other states or regions have proved satisfactory there.

Scandinavian materials, though from latitudes on a par with Alaska, often have been insufficiently winterhardy for use in Alaska. 'Engmo' timothy developed for northern Norway is used in Alaska but may sustain injury in some winters. Some turf grasses from Scandinavia are coming into use.

NEW RELEASES AND EXPERIMENTAL MATERIALS

A number of native Alaskan materials have shown potential for revegetation use and probably represent the best source for winterhardiness. Because a material is native, however, does not necessarily mean it will be hardy when taken out of habitat and applied in a different situation. Many native materials tested at Palmer have not been sufficiently hardy. Palmer, though not in an area of severe winter temperatures, is subject to occasional, strong winds in the winter that remove the protecting snow cover from the open fields. At times, the wind-chill factor can be severe. Thus, it has constituted a good field laboratory to test winter hardiness.

Previously named plant species, and in some cases even varieties have been reminiscent of those in use or under consideration for the Rocky Mountain high altitude regions. But in discussing native Alaskan materials under consideration, some new names, plus some other familiar names, will come into play. The following species are under experimentation:

Arctagrostis latifolia	- Polargrass (or arcticgrass)
Agropyron macrourum	-
Agropyron spicatum	- Bluebunch wheatgrass
Agropyron trachycaulum	- Slender wheatgrass
Agropyron violaceum	- Violet wheatgrass
Bromus pumpellianus	- Pumpelly bromegrass
Calamagrostis canadensis	- Bluejoint reedgrass
Deschampsia beringensis	- Bering hairgrass
Deschampsia caespitosa	- Tufted hairgrass
Elymus sibiricus	- Siberian wildrye
Elymus mollis	- Dune wildrye
Festuca ovina	- Sheep fescue (naturalized sources)
Festuca rubra	- Red fescue
Poa glauca	- Glaucous bluegrass (or Greenland bluegrass)
Poa Pratensis	- Kentucky bluegrass (native and naturalized sources)
Puccinellia borealis	- Boreal alkaligrass
Puccinellia grandis	- Alkaligrass

A number of others have been named as having potential (Klebesadel, 1973). Not all are receiving an equal amount of attention, and determining which to stress, of course, is an important decision that must be made and reviewed as one proceeds.

The discovery of oil at Prudhoe Bay centered attention on revegetation problems in the oil field and along the pipeline route, and provided funds for research. The Arctic has been the area of most concern with regard to finding appropriate plant materials. A number of collections have been made of arctic materials of Pumpelly bromegrass, polargrass, reedgrasses, wheatgrasses, wildrye (*Elymus innovatus*), red fescue, tufted hairgrass, and glaucous bluegrass. Working with arctic materials at boreal latitudes has presented particular problems, and the efforts have been largely unsuccessful. The arctic materials may become subject to diseases to which they have not been exposed in their native habitats. Many, rather than growing more luxuriously in a warmer climate, assume a more prostrate growth habit and produce their flowering culms low or flush to the ground. The bulk of them are very poor seed producers in their native habitat, and bringing them to a more southern, warmer climate has not improved on that ability. Some may grow well vegetatively but not reproductively.

Glaucous Bluegrass

The most signal success with the arctic materials tested to date has been made with some collections of *Poa glauca*. The original collections were made in 1969 as a member of an ecological survey team along the trans Alaska pipeline route (Mitchell, 1970). A spaced planting of the material at Palmer was highly variable, with individuals demonstrating an extremely prostrate to a somewhat upright growth habit, and many showing signs of stress early in the growing season. Fortunately, some individuals with the more upright growth habit also were the more durable and were good seed producers. They have bred true to form, either being highly self fertile or apomictic, probably the former.

The cultivar 'Tundra' bluegrass has been released (Mitchell, 1976a) based on selections of the more upright type and is now a patented variety. Though most of the native perennials require two years' growth to produce a seed crop, under proper conditions Tundra bluegrass can produce a crop in the seedling year. It is subject to winter injury or winterkill where ponding and glaciering occur in a field. Without injury, it can produce a heavy seed crop in the second year, but generally declines in subsequent years. It is susceptible to powdery mildew (*Erysiphe graminis*) infestations. Germination percentages generally have exceeded 90% in laboratory trials. Tundra has performed very well in arctic trials, where it will provide a valuable addition to revegetation mixes. It is best adapted to mesic to dry sites.

Polargrass and Bluejoint Reedgrass

Two other cultivars of native origin have been developed and released for use. *Arctagrostis latifolia* occurs throughout mainland Alaska, generally in mesic to wet sites. It can produce a tall, lush plant with relatively broad leaves, which spreads conservatively by thick rhizomes. Tests of a number of collections have indicated their adaptability to a range of sites from lowland to alpine to arctic locations with preference for the more moist situations. The variety 'Alyeska' polargrass is a composite based on 27 collections made through interior and western Alaska (Mitchell, 1976b). Collection sites include coastal tundra, boreal forest, and alpine tundra locations. No arctic materials were found satisfactory for use. Seed yields of 100 to 200 lb/acre appear readily obtainable in field plantings. Higher yields may be possible. Germination rates generally have ranged from 70 to 90%. The grass also has shown potential as a forage grass (Klebesadel, 1969a).

Calamagrostis canadensis is the most abundant grass in Alaska. It occurs in dense, tallgrass stands in various locations through southcentral and southwestern Alaska and is frequent throughout most of mainland Alaska south of the Arctic. The variety 'Sourdough' bluejoint reedgrass was released for revegetation use based on 36 collections made in a variety of locations through interior and southcentral Alaska (Mitchell, 1976c). Sourdough is adapted to forested, alpine, and arctic sites, similar to Alyeska, but is better able to withstand the physical stress of the more exposed sites. Seed yields of Sourdough are expected to be low, however, partly because of large losses due to shattering as it approaches maturity and to the death of lowering culms from insect or fungal damage (a condition known as white top). Germination qualities are similar to Alyeska. Bluejoint reedgrass is an important hay meadow grass in Alaska (Mitchell, 1974).

The expense of seed supplies of these cultivars will likely require that they be used in mixes with other seeds. Some of the advantages of their use include adaptability to cooler, shorter growing season sites, superior winterhardiness, tolerance to acid soils, and immunity to some diseases. Both bluejoint and polargrass can be found on extremely acidic soils, as low as pH 3.5, and can be used without the need for liming, which is very expensive in Alaska. Snow mold (*Sclerotinia borealis* and possibly others) is a severe problem in some areas. In tests at a moist alpine site, snow mold seriously depelted or ravaged some bluegrasses, red fescues, and timothy. Meadow foxtail was badly injured, but recovered fairly well. Polargrass and bluejoint, however, evinced complete immunity to the disease. Some entries of hairgrass were highly susceptible while others appeared resistant, demonstrating the possibility of selection for immunity within this complex. Bromegrass cultivars generally are not well adapted to alpine or acidic sites. Thus, there is a scarcity of suitable materials for such situations.

Hairgrass

The hairgrasses--*Deschampsia caespitosa*, interior form, and *D. beringensis*, coastal form--offer good potential for use in Alaska. However, they are an example of a group in which it is necessary to identify the capabilities of individual collections or populations. Ecotypical differences appear to be large with populations varying a great deal in hardiness, disease responses, and amount of growth.

Bering hairgrass was used in a revegetation seeding on Amchitka Island in the Aleutians following the completion of the nuclear testing program (Mitchell, 1973b; 1976d). Though hairgrass is native to the island, the seed did not originate there. The Amchitka populations are extremely poor in seed production, and seed increase at Palmer was unlikely because of insufficient hardiness in the island material. Seed for the planting was collected by hand from a coastal population in southcentral Alaska, having been proved satisfactory in tests conducted on the island.

Another interesting development with the same hairgrass is its possible use in Iceland. A plant exchange program with Icelandic workers has led to some promising results with the grass in Icelandic trials. Plans are underway for larger plantings of the material in a reclamation program by the Icelandic SCS with seed being produced in Alaska. Consequently, a varietal description and release are in progress to preserve the integrity of the material and afford certification of the seed to be transported to Iceland. This variety can be used in various tundra regions of Alaska, as well.

Other hairgrasses are being tested that may have application in the interior region. The taxon is under research for forage as well as revegetation uses.

Red Fescue

Festuca rubra may be one of our most widely adapted species, occurring from Mexico to the arctic coast of Alaska. Over the length of that range it inhabits both tideland flats at sea level and mountain meadows. In Alaska it is a component of tideland communities, alpine and coastal tundra, the boreal forest, and arctic riparian communities. Rarely abundant, nevertheless it often can be found in some habitat of a given region.

I have spent considerable effort in assessing collections of red fescue. To date, the release of a variety in addition to Arctared does not appear justified. Nothing sufficiently superior to Arctared has been identified for use through the interior forested region of Alaska. Some apline and arctic materials have been isolated that may be superior for the tundra locations. However, certain problems have prevented final action. Susceptibility to diseases is a deterrent with some of the arctic collections. Also, a very annoying lack of consistent performance has prevented selecting individuals for seed yielding ability. High producers in one year may be extremely poor producers in the ensuing year. Work is continuing, however, to derive a red fescue that is sufficiently winter hardy and that is more snow mold resistant than current varieties for possible revegetation, turf, and grazing use.

Other Materials

Selections of *Festuca ovina* are being attempted as a possibility for dry sites, but only a limited amount of material is available for trial. A number of wheatgrasses have been tested at various revegetation sites, but little work has been carried on with them. Possibly they have been neglected too much. The wildrye *Elymus sibiricus* has received some attention in forage work (Klebesadel, 1969b), is a prolific seed producer, but appears to be relatively short lived.

The wheatgrasses and wildryes tested seem to do best in sparse plantings.

The wildrye *Elymus mollis* has a possible special purpose application. It occurs along the sea coast of Alaska in the upper high tide zone and on dune sites and some bluffs out of the tidal zone. It performs abominably in seed production, but spreads vigorously by thick rhizomes. It has been used successfully as vegetative transplants in oil spill trials at Palmer (unpublished data). If the need arises, the abundant native populations stand ready as sources of material for oil spill rehabilitation on the sea coast or for dune stabilization by sprigging.

An alkaligrass, *Puccinellia grandis*, has provided a source of material for some small plantings of waterfowl habitat on tideland flats of southcentral Alaska. The possibility of future needs is prompting expanded work with this grass.

Thus major efforts have been concentrated on a few grasses, but a number of others have been kept in the lineup for possible use in special situations or a shift in emphasis of needs. Major coal field developments could bring such a shift.

SOME CONCEPTS BEHIND SELECTION PROGRAM

The principal objectives behind the development of the three varieties were as follows:

(1) To meet a critical need for more and better materials for use in the Arctic. Tundra was developed specifically for this purpose and is the first material of arctic orgin that has been released for use. The cultivars Alyeska nad Sourdough also can be used in the Arctic, thus improving further on the mix.

(2) In addition to the above to provide some broad-based material that would have a wide application in the state, particularly in situations where currently available materials grow with difficulty. This includes the tundra regions in general and often the lowland muskeg sites that may be acidic and prone to disease problems. Alyeska and Sourdough help to meet this problem on mainland Alaska.

(3) To make available indigenous seed for inclusion in mixes where it is desired to promote the return of native materials or where stipulations require their use. In some park and refuge plantings it is being stipulated that only native seeds be used.

It appeared best at this stage to make available some varieties with broad adaptability. Both polargrass and bluejoint reedgrass, as species, evince this plasticity with their frequent occurrence throughout the bulk of Alaska from lowland to alpine situations. By synthesizing varieties from collections made in a number of locations, a broad base was given the cultivars. Refinements may be necessary in the future, however, as more results of their applications are obtained.

Some progress has been made in identifying likely sources of material for research. For instance, grasses obtained from alpine tundra and western coastal tundra regions are likely to be better seed producers than those obtained from the arctic tundra. But grasses derived from maritime tundra in the Aleutian Islands, at some of the southernmost latitudes in Alaska, have been poor seed producers. While tundra locations are climatically severe, materials obtained from such sites may not be sufficiently winter hardy for general use. This probably reflects the adaptation of local demes to habitats with a heavy, protective snow cover, so habitat preferences must be considered.

An interesting problem revolves around the fact that some species are a complex of chromosome races. *Calamagrostis canadensis* in Alaska consists of three races--namely, tetraploids ($2\underline{n} = 28$), hexaploids, and octoploids (Mitchell, 1968). All three races are represented in the variety Sourdough. Whether one race has an advantage over another has not been determined. However, in some regions the tetraploid race appears to have been the most competitive, with the hexaploid and octoploid races being restricted to relic stands. The Alaska populations are the first reported tetraploids on the North American continent. The evidence suggests that they are relatively recent migrants across the Bering Straits and may be in the process of expanding their range.

Other grasses under study, such as polargrass, the hairgrasses, and red fescue, also are known to consist of different chromosome races. Interbreeding populations of mixed races could limit recombination opportunities and possibly reduce reproductive capacities. The merits of combining or isolating different races in deriving cultivars need to be determined.

SUMMARY

The primary emphasis on the development of plant materials for revegetation use in Alaska has been on materials for arctic tundra regions. Of the commercially available cultivars, only Arctared

fescue demonstrated any degree of reliability in the early trials conducted in the Prudhoe Bay region. Nugget bluegrass was marginal in performance. All other available cultivars failed. Both Arctared and Nugget had been selected from collections made in Alaska.

Three varieties of native origin have been developed that can be applied on the Arctic. Tundra glaucous bluegrass (*Poa glauca*), based on arctic material, has been a superior performer in arctic trials. It is recommended that its use be confined to the Arctic. Alyeska polargrass (*Arctagrostis latifolia*) and Sourdough bluejoint reedgrass (*Calamagrostis canadensis*) are based on collections made in numerous locations through mainland Alaska south of the Arctic. Both cultivars can be applied throughout most of Alaska but most particularly in the more difficult tundra regions and on boggy and strongly acidic sites.

An ecotype of Bering hairgrass (*Deschapmsia beringensis*) has been used in revegetation seedings on Amchitka Island, a maritime tundra location, and shows promise for reclamation use in Iceland. Assignment to varietal status is now in process.

Alkaligrass (*Puccinellia grandis*) has been used in some waterfowl habitat plantings on tideland flats. Work is continuing on the grass to serve such specialized purposes.

Less attention has been given the revegetation needs of the forested region of Alaska because grasses currently available can be applied there. Alyeska polargrass and Sourdough reedgrass can supplement these in the more moist problem areas. Nevertheless, an improved seed mix for use in the forested region is desirable. Work is underway on the development of hardy, close growing, low maintenance types for roadside plantings. Some refinement of Polar bromegrass is in progress, particularly with respect to raising its seed producing qualities.

Native species have demonstrated a high degree of variability in hardiness, disease resistance, and seed producing characteristics. Selection efforts have been necessary to identify individuals or populations that possess appropriate adaptations and agronomic traits for commercial growth and revegetation plantings over wide areas.

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DISCUSSION

WILLARD: Have you done any work with *Carex*?

MITCHELL: *Carex* is difficult to work with. It generally requires a cold treatment to enable germination. One could make vegetative transplants, however, we have not had much success at Palmer.

CUANY: How many plants are in your initial nurseries; how many in the released synthetic varieties?

MITCHELL: *Poa glauca*, 'Tundra' bluegrass - 500 plants initially; 29 in the variety; *Arctagrostis latifolia*, 'Alyeska' arcticgrass - 1,000 to 2,000; 28 in the variety; *Calamagrostis canadensis*, 'Sourdough' bluejoint reedgrass - 1,000 - 2,000; 36 in the variety.

REHABILITATION OF A HIGH ELEVATION MINE DISTURBANCE

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INTRODUCTION

Of the approximately 3 million ha (7.5 million acres) of alpine tundra in the western U.S., nearly 12 percent (344,000 ha, or 850,000 acres) has been disturbed and is in need of rehabilitation. A recent survey shows that the major causes of disturbance in the alpine zone are due to such activities as 1) grazing, 2) recreation, 3) mining, 4) roads, and 5) other sources (Brown *et al.* 1978). This survey also documents that the rate of disturbances is accelerating, and that this trend is expected to continue into the next century. Unfortunately, the most alarming disclosure of this survey is the apparent lack of regard by some land managers for the vital watershed and recreational values of high elevation lands. It is essential that these values be managed with the same degree of concern given other resources, such as timber.

In order to restore surface stability, esthetic compatibility, and perhaps productivity to high elevation disturbances, reliable rehabilitation techniques are needed. In most cases the establishment of a plant cover is viewed as the primary means of achieving rehabilitation. The general principles of revegetation probably apply in any ecosystem, but the subtle aspects of timing, selection of adapted plants, and considerations of harsh micro-environmental factors are of magnified importance in environments that approach the limits of adaptability for vascular plants. Unfortunately, the development and implementation of suitable revegetation techniques continues to lag behind other aspects of natural resource management. Nowhere is this more evident than in extreme environments such as the upper subalpine and alpine life zones.

In the development of revegetation techniques, an attempt is made to mesh together the requirements for plant growth with the various features of the physical environment. This implies a basic knowledge of the physiological requirements of the plants to be used together with the identification of their limiting factors. The unique physiological features of alpine plants (Billings 1974) together with the impacts caused by disturbance, coupled with the severe environment of high elevations, dictates that specific techniques for revegetation be developed.

Since Harrington's (1946) early efforts on Trail Ridge in Colorado, very little research has been devoted to the development of high elevation revegetation methods. Our research was initiated to develop rehabilitation methods for high-elevation disturbances on the Beartooth Plateau in 1972. Studies included several different aspects of rehabilitation such as consideration of 1) plant succession, 2) species adaptability, 3) characterization of microenvironmental factors, including soils and hydrologic phenomena (Johnston *et al.* 1975), 4) revegetation trials by seeding and transplanting (Brown and Johnston 1976, Brown *et al.* 1976), and 5) laboratory bioassays.

During the 1976 growing season we applied the combined results of these various studies to a larger scale rehabilitation demonstration effort on the McLaren Mine in the Beartooth Mountains of Montana. The objective of this effort was to develop a rehabilitation plan which would lead to the establishment of a stable plant cover on relatively sterile acid-producing spoils in a high elevation environment. Also, we intended to demonstrate that the results from small revegetation plots and other studies could be applied to large scale rehabilitation efforts.

REHABILITATION METHODS

The study area is located on the McLaren Mine at an elevation of about 3,000 m (9,800 ft) in a subalpine-alpine transition zone. With the exception of some recent mineral exploration, this mine has been abandoned since the early 1950's. Prior to this, the McLaren Mine was a shallow open-pit copper-gold-silver mine that occupies a disturbed are of about 13.5 ha (33 acres). The mine is situated on a west-facing slope in the headwater drainage of the Stillwater River. Considerable off-site damage to adjacent plant communities and the aquatic habitat has resulted from the drainage of highly acidic water containing toxic concentrations of heavy metals from the mine (Johnston *et al.* 1975).

A site of approximately 1.0 ha (2.4 acres) in area with a west aspect and a 15 percent slope was selected on the north edge of the mine. The spoil materials and topography of the site were characteristic of the entire disturbance, and was selected so as not to interfere with future mineral exploration or other rehabilitation activities. Numerous spoil piles, trenches, deep depressions, and debris which are commonly associated with abandoned mines characterized the site.

The rehabilitation plan for the study area included: 1) shaping and contouring the spoil material, 2) revegetation (seeding, transplanting, and associated treatments), followed by 3) monitoring evaluation, and supplemental maintenance as required.

Shaping and Contouring

The site was shaped and contoured with a crawler-mounted D9 dozer equipped with a soil pushing blade. Approximately 16 hours of operation time was required to complete this phase in early August, 1976. The spoil materials with the lowest pH and containing the highest concentrations of toxic substances were used to fill depressions, and were covered with the best growing medium available. The entire site was rough-graded and contoured to conform to the natural topography of the area using only the materials available on the site.

Revegetation

The revegetation phase of the study was completed in the fall (September) of 1976. As a result, two requirements of the study were met: 1) the spoil material on the contoured site was allowed to settle, and 2) fall seeding and planting were accomplished, which has been shown to be most advantageous in high elevation regions (Brown *et al.* 1976). Late fall planting avoids pre-winter seed germination and the breaking of dormancy of transplants which could result in frost damage to young tissues. Also, some native species have cold-induced dormancy requirements for germination and growth and fall planting ensures that plants will initiate growth during optimum periods in the spring. In addition, high elevation areas are generally inaccessible until late spring or early summer because of late melting snow drifts. By then the short-growing season may have already begun, and growing conditions may no longer be favorable.

Soil amendments. Results from plot studies and laboratory bioassays have shown that several soil amendments are essential for plant growth on this site (Brown and Johnston 1976). In addition, analyses of soil samples from the site were used to determine nutrient deficiencies, cation exchange capacity, pH, water-holding capacity, and levels of heavy metal concentrations. Amendments were applied to ameliorate the limiting edaphic factors where feasible.

Based on these analyses and trials, lime was applied at the rate of 2,200 kg per ha (2000 lbs per acre) to increase the spoil pH to about 5.0, and provide increased nutrient availability to plants in acid soils. In addition, a granular fertilizer with an N-P-K ratio of 18-46-5 with 0.8 percent zinc was applied at the rate of 672 kg per ha (600 lbs per acre). Dried steer manure was then applied to the surface at a rate of 2,200 kg per ha (2,000 lbs per acre). The lime, fertilizer, and manure were applied separately and as uniformly as possible with a fertilizer spreader pulled by a small crawler mounted dozer. Then these three amendments were incorporated into the surface 15 cm (6 in) of soil with a spring-tooth harrow pulled by the dozer. Care was taken to work the spoil material on the contour to avoid creating drainage paths down the slope.

Seeding and planting. Previous revegetation plot studies (Brown and Johnston 1976) have shown that most commercially available introduced species are not suitable for seeding on the McLaren Mine. Therefore, only a mixture of native species was used, the seeds of which were collected by hand from surrounding undisturbed areas earlier in the summer. The seed was dried, cleaned, weighed, and tested for germinability in the laboratory prior to seeding. The species selected for use were determined from plant succession studies and observations of native plant colonization on other areas of the mine (Brown *et al.* 1976). However, the actual seeding rate of each species was determined more by the amount of seed that could be collected than by any other factor. Seed availability at high elevations may be severely limited in any given year because of poor growing conditions. The species used and their seeding rates are listed in Table 1. The seed was applied uniformly over the surface with a seeder-packer pulled by the dozer at a bulk rate of 83 kg per ha (74 lbs per acre). The seeder-packer ensures intimate contact between the seed and soil particles and firms the seedbed. About 0.7 ha (1.7 acres) of the study area was seeded in this manner.

Grass transplant plugs, grown from seed collected the previous year, were planted on the remaining 0.3 ha (0.7 acre) area of the study site. Both native and introduced species were used in this phase of the study. The adaptability of introduced species used as transplants had not been tested previously on this site. These plants were grown from seed in plastic tubes (Cone-tainers pine cells[1]) by the U.S. Forest Service, Coeur d'Alene Nursery, in northern Idaho. The plants were allowed to harden-off on the site for about 3 weeks prior to planting in September 1976. The species and number of each used are listed in Table 2. Approximately 5,300 grass plugs were planted in rows contouring the slope on a grid pattern of 0.6 m (2 ft) between rows and plants.

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[1]Ray Leach Cone-Tainer Nursery, Canby, Oregon. Trade names are provided for the convenience of the reader and do not imply endorsement by the USDA Forest Service.

Surface mulch. A surface mulch consisting of 2,500 kg per ha (2,200 lbs per acre) of straw, tacked down with water soluble asphalt emulsion, was blown onto the site with a power mulcher. The entire seeded area was covered with the mulch, but only one-half of the transplant area was mulched. An effort was made to avoid thick accumulations of straw on the site that might act as an excessive heat trap and barrier to seedling emergence. A total of 9 barrels (about 1,875 l or 495 gal) of asphalt emulsion was applied simultaneously with the straw in order to bond the individual interlocking fibers together on the surface. This prevents redistribution of the straw by wind prior to plant emergence.

Post-Treatment Maintenance

As a precautionary measure, the entire area was fenced and posted to control access to grazing animals and recreational traffic, which is quite heavy in this area. The following year, soil samples were collected and analyzed for pH and major plant nutrients. This practice will be continued routinely in future years to follow the development of the spoil as a growing medium. Then the area was fertilized with a granular mix of 27-0-0, at the rate of 112 kg per ha (100 lbs per acre). This early refertilization is intended to provide the plants with a readily accessible supply of nitrogen for more rapid growth during the first growing season.

Near the end of the 1977 growing season, 54 quadrats, each 0.1 m^2, were used to estimate total plant cover, species density, species frequency, litter cover, and total plant production. Production was determined by clipping all above-ground plant parts, oven drying at 85°C and weighing. The quadrats were randomly distributed over the entire seeded area. On the transplanted area, percent survival of each species was recorded, and measurements for basal diameter, plant height, observations of flower production, and samples for plant production were collected. These monitoring procedures will be continued for several years to determine long-term species adaptability.

RESULTS AND DISCUSSION

The first-year results from the seeded portion of the study site are summarized in Table 1. The average total dry weight production of plants on the seeded area was 113 kg per ha (1,01 lbs per acre) with an average plant density of 399 plants per m^2 (about 11 ft^2). Also, the average vegetation cover after the first growing season was 21.7 percent and the average litter cover, including straw mulch, was 49.3 percent. It should be noted that during the first growing

Table 1. Summary of first-year results of seeded demonstration area on McLauren Mine, Beartooth Plateau, Montana.

Species	1976 Seeding rate kg/ha[a]	1977 No. plants per m^2[a]	1977 Plant Frequency
Agropyron scribneri	1.6	0	0
A. trachycaulum	8.6	26	0.83
Carex drummondii	7.8	0	0
Deschampsia caespitosa	45.2	279	1.00
Phleum alpinum	5.2	14	0.43
Poa alpina	12.7	72	0.85
Trisetum spicatum	1.9	0	0
Triticum aestivum	0	4	0.19
Weeds	0	4	0.39
Total	83.0	399	
Average production	113 kg/ha		
Total cover	71.0 percent		
Average plant cover	21.7 percent		
Average litter cover	49.3 percent		

[a] 1 kg/ha ≅ .897 lb/acre

$1\ m^2 \cong 11\ ft^2$

season some invasion by forbs (weeds) occurred, and that some plants of *Triticum aestivum* became established from seed that apparently came in the straw mulch. It is anticipated that the plants of *T. aestivum* will continue to decline in future years because the growing season is too cool and short to promote seed production of this species. However, continued invasion by native plants is expected from the surrounding undisturbed communities, as was documented for other portions of the McLaren Mine by Howard (1978).

Four native species provided virtually all of the first year cover and production on the site (*Deschampsia caespitosa, Poa alpina, Agropyron trachycaulum,* and *Phleum alpinum*). These are the same species that Brown and Johnston (1976) earlier noted as being most successful on revegetation plots on the McLaren Mine. Also, these same species have been commonly observed as active native colonizers on disturbed sites throughout the Beartooth Plateau (Brown *et al.* 1976). However, it is reasonable to expect that some of the other species planted may have experienced delayed germination, and may contribute to total cover and production in future years. Their value as revegetation species may not be apparent for several years since some of them have well documented narrow germination requirements (Amen 1966). This is particularly true for *Carex* spp. (Johnson *et al.* 1965). *Deschampsia caespitosa* was the most abundant species on the site and was the only one encountered in all of the quadrats studied.

We would like to emphasize that these are only first-year results and that caution must be exercised in projecting their potential impact on site rehabilitation. However, comparisons of these results with first year results of previous revegetation plots on the McLaren Mine are encouraging. For example, Brown and Johnston (1976) used essentially the same species but treatments that did not include lime, organic matter, or a surface mulch, and found that cover were virtually impossible to estimate because of poor plant development during the first growing season. They found that average plant cover was only about 2 percent after one growing season, whereas in the present study, using these additional treatments, plant cover was about ten times as great. Also, on these earlier study plots, Brown and Johnston (1976) noted plant densities ranging from two to three times as great as those reported here. Despite the higher plant densities, low cover and production estimates indicate that poor site protection was provided during the first growing season. Also, a seeding rate of 83 kg per ha (74 lbs per acre) was used in the present study compared to 56 kg per ha (50 lbs per acre) in the earlier study. Some explanations for discrepancy in seedling densities on the two different study areas include the possibility of lower seed germinability of plants used on the demonstration area and less favorable seed germination conditions in 1977 than in 1975. Climatic data collected during these growing seasons indicate that 1977 was much cooler and wetter than the 1975 season. The greater production in the present study may be attributed to the more intensive soil treatments applied, together with the higher availability of soil water during the 1977 growing season.

The percent survival and production of the transplants during the first year are summarized in Table 2. The average survival of all species was 65 percent, but there is a substantial difference between native and introduced species. The natives had an average first year survival of 75 percent, whereas the introduced species had only 39 percent. Also, the data show that, on the average, the native species had a slightly higher production per plant than did the introduced species.

Although the native transplant *Agropyron scribneri* had 100 percent survival, too few plants were available for conclusive evaluation for its adaptability to these conditions. However, the results with the other native species, exclusive of *Agropyron scribneri*, are similar to those obtained in other years (Brown and Johnston, 1976) and probably can be accepted with somewhat greater reliability. Also, since this was only the first time that introduced species were tested as transplants on this mine, the encouraging results of *Alopecurus pratensis* and *Poa compressa*, and the discouraging results of the other introduced species, should be viewed with caution.

The results of transplant growth and development are summarized in Table 3. The apparent depressant effect of the straw mulch on transplant growth and development was unexpected. These data show that the mulch has a negative effect on basal diameter and height growth for all species, and a depressing effect on flower development for nearly all species. Growth of the native species was affected less than that for the introduced species by the mulch. Although survival data were not presented for the mulch effect, our field data reveal that 80 percent of all mortality of the transplants occurred in the mulched portion of the study area.

Although quantitative data are not available to explain the depressant effect of the straw mulch on plant survival, growth, and development, some justification for speculation exists. In normal years the growing season is relatively dry and warm, and a surface mulch could be expected to retard evaporation, ameliorate high surface temperatures, and retard severe frost action (Brink *et al.* 1967, Johnston *et al.* 1975). However, the 1977 field season was considerably cooler and wetter than the normal years since 1972. It is possible that the mulch may have maintained suboptimum temperatures for growth near the soil surface. On several occasions it was noted that mid-summer snow fall accumulations lingered on the mulch surface, whereas it melted more quickly on the untreated spoil piles. The effect of straw mulch on transplant growth and survival may be quite different during dry years. Needle-ice formation was not noted in the mulched area, but was observed frequently in the surrounding unmulched areas (Howard 1978).

Table 2. Summary of first-year results of transplant survival and production on the McLaren Mine.

Species	Percent Survival	Ave. dry wt. per plant gm[a]	No. Planted 1976	No. Live 1977
NATIVES				
Agropyron scribneri	100	2.0	8	8
A. trachycaulum	83	1.4	124	103
Deschampsia caespitosa	72	2.4	993	711
Phleum alpinum	73	3.5	1016	739
Poa alpina	80	3.7	1682	1351
Trisetum spicatum	24	0.9	86	21
Total/Average	75	2.3	3909	2933
INTRODUCED				
Alopecurus pratensis	72	0.9	349	253
Bromus inermis	29	1.3	272	78
Dactylis glomerata	7	1.1	270	20
Festuca arundinacea	24	0.5	245	59
Phleum pratense	40	1.1	248	100
Poa compressa	91	6.5	70	64
Total/Average	39	1.9	1454	574
Total/Average All Species	65	2.1	5363	3507

[a]1 gm = .035 oz.

Table 3. Summary of first-year results of transplant growth and development on the McLaren Mine. The average basal diameter for all species at the time of planting was 2 cm.[a]

Species	Mulch			No Mulch		
	Basal diam. cm	Plant ht. cm.	Flower %	Basal diam. cm.	Plant ht. cm.	Flower %
NATIVES						
Agropyron scribneri	--	--	--NO DATA COLLECTED		--	--
A. trachycaulum	1.5	12.0	0	2.1	19.3	37
Deschampsia caespitosa	2.7	8.9	0	4.4	9.4	0
Phleum alpinum	3.9	14.6	9	4.6	26.2	76
Poa alpina	4.0	7.6	0	4.8	14.7	40
Trisetum spicatum	1.5	6.0	0	4.0	6.5	0
Average	2.7	9.8	2	3.9	17.4	31
INTRODUCED						
Alopecurus pratensis	2.3	18.8	25	2.8	19.9	43
Bromus inermis	1.1	12.4	0	1.9	22.0	60
Dactylis glomerata	0.6	8.5	0	1.2	11.7	0
Festuca arundinacea	0.5	9.0	0	1.9	22.6	40
Phleum pratense	1.2	14.6	20	2.2	19.5	30
Poa compressa	5.2	33.0	100	6.0	34.0	100
Average	1.8	16.1	24	2.7	21.6	46
Average All Species	2.2	13.2	14	3.3	18.7	39

[a] 1 in = 2.54 cm.

Three introduced species, *Bromus inermis*, *Dactylis glomerata*, and *Festuca arundinacea*, showed clear indications of poor adaptability to conditions on the McLaren Mine. Their percent survival and average dry weight (Table 2), and their average basal diameter (Table 3) were substantially lower than the other species. This suggests that these species should probably not be included in a rehabilitation plan for such areas. However, the other three introduced species, *Alopecurus pratensis*, *Phleum pratense*, and *Poa compressa* showed encouraging results, and may have some potential for rehabilitation. In particular, *Poa compressa* should receive intensive study since it its rhizomatous habit could prove to be most advantageous. The other two introduced species have been widely used for high elevation rehabilitation (Cuany 1975, Brown 1976), and appear to be well adapted for at least short-term applications.

Among the native species transplants, only *Agropyron trachycaulum* showed marginal basal diameter growth during the first growing season. Although *Trisetum spicatum* had the lowest percent survival of the native species, its growth under the no-mulch conditions was very substantial. The lack of flower production in both *Trisetum spicatum* and *Deschampsia caespitosa* was not unexpected, since we have noted this phenomenon during the first growing season under nursery conditions. Although growth and development data for *Agropyron scribneri* were not collected (too few plants were planted to provide a fair appraisal), all 8 plants had flowered and had assumed the prostrate stature characteristic of this species. The severe nature of the environment under which this species naturally grows suggests that *A. scribneri* should be studied in greater detail to determine its adaptability for revegetation purposes. Laboratory and field studies (Table 1) indicate a low seed viability for this species, but vegetative propagation has been successful.

CONCLUSIONS

The results of this study suggest several conclusions, even though the data presented are only first year results and must be viewed with caution. It appears that the methods and techniques proposed here provide an ameliorative effect on the acid spoils of the McLaren Mine. It has been shown, for the native species used, that certain treatments are essential to alter conditions of the spoils sufficiently to support plant growth and development. These treatments include lime, organic matter, fertilizer, and a surface mulch. Native subalpine and alpine grasses can be successfully used to establish a plant cover on high elevation severe disturbances, and these species can produce substantial growth and development during the first growing season.

One of the major objectives of this study was to demonstrate that the results of small plot studies and greenhouse bioassays can be applied to larger areas. It appears that this was achieved, and that at least within the limits of the present study, results from small plots are applicable to large rehabilitation programs. Data from small plot and greenhouse studies are often criticized as being unrelated to a large area requiring rehabilitation. The results here demonstrate that when applied with care, such studies can contribute substantially to rehabilitation efforts.

Based on the early results of this study, it seems apparent that the proposed techniques can be applied to other similar disturbances in the Rocky Mountain area. One major point of concern, however, is the relative inaccessibility of many of these disturbances, and yet the need for heavy equipment to prepare them for planting. In particular, shaping and contouring appear to be vital steps in the program, requiring the use of a dozer or similar earth-moving equipment. The shaping and contouring eliminates wind-swept ridges that tend to scour during the winter and become parched barrens during the summer. Also, it removes depressions and other irregularities that become pockets of deep snow accumulation and ponds of acid water that frequently wash out and spill onto the natural plant communities downslope. We noticed that snow distribution on the study site was very homogeneous early in the spring, which appeared to promote uniform infiltration of snow-melt water, a more regulated rate of runoff, and evenly distributed plant emergence and development.

The spoil amendments of lime, fertilizer, organic matter, and a surface mulch appeared to promote excellent plant growth uniformly over the entire seeded area. However, a surface mulch may not be desirable on transplants, as evidenced by its depressant effect on plant survival and growth. Transplant survival and growth on the unmulched portion of the plot appeared to be satisfactory, especially for the native species. This will require additional research since this effect may have been tempered by climatic conditions.

Perhaps the most expensive part of rehabilitating high elevation disturbances is the collection of native seed. The rehabilitation plan for these harsh environments should include the development of nurseries or other facilities for raising seed and plants of native species under controlled conditions. Many alpine species can be successfully grown and encouraged to produce abundant viable seed crops in nurseries, and a cooperative effort for this purpose is presently being formulated between the U. S. Forest Service and the Soil Conservation Service.

The "key" native grasses that appear to have the greatest potential for the rehabilitation of high elevation disturbances include:

Agropyron scribneri
A. trachycaulum
Deschampsia caespitosa
Phleum alpinum
Poa alpina

Other natives such as various *Carex* species and *Trisetum spicatum* may be important, but certain physiological limitations need to be studied in greater detail before their inclusion can be justified. Among the commercially available introduced species, *Alopecurus pratensis* appears to have the broadest adaptability. Other introduced species, such as *Poa compressa*, which are not generally commercially available, may also be well adapted. Further study of *Poa compressa* is needed to determine if its rhizomatous habit is adapted to high elevation harsh environment.

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DISCUSSION

WILLARD: The problem with *Carex drummondii* is that it is killed by snow cover. Will you try anymore with *Carex?*

BROWN: Yes, on a vegetative basis. We have been very successful using *Carex* transplants, but not in seedings because of low seed germinability.

WILLARD: Is there a possibility of using topsoil on some of these sites?

BROWN: Topsoil in alpine regions is in limited supply. It is not feasible to plan to have enough topsoil around in alpine regions, particularly for use on abandoned mines. I think that there are alternatives which can be used to ameliorate adverse conditions, such as fertilizer, lime, and organic matter such as manure.

QUESTION: Explain your use of manure applications.

BROWN: These mine spoils have a low nutrient capital and nutrient holding capacity. The manure was applied to supply some nutrients, but also because it has a higher exchange capacity for nutrients than the spoil material. The manure provides some nutrient holding capabilities.

MITCHELL: What is the growing season?

BROWN: The plots are free of snow about the end of July. The growing season starts about the first of August. By the end of

August, or in about 30 days, the plants have set seed and are going dormant. Sometimes of course, the season lasts 60 days.

HENDZEL: You applied lime to the very acidic spoils. How much did you apply and what changes did you find? Will you have to apply lime again to maintain the stands?

BROWN: It has been our experience that lime is not very mobile in the soil. We applied lime at about 1 ton per acre which brought the pH to about 5 to 5.5. The site was very heterogeneous. A year later the pH of the spoil was still about 5. I do not know if leaching will occur or if we will have to lime again.

JOHNSTON: We set up the lime treatment on the basis of bioassay on greenhouse material. We attempted to find the best recommendation for the entire 30 acre site. One could perform an extensive soil survey on the site to determine the most acidic sites. Mine planning and stock piling soil of less acidic material would help. We could bury the highly acidic material with a few feet of either topsoil or a less acidic material.

USE OF MYCORRHIZAL FUNGI IN REVEGETATION OF MOLYBDENUM TAILINGS

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INTRODUCTION

Mycorrhizas are structures formed by plant roots and fungi, and are common in most species of plants. Many forest trees (e.g. Pinaceae, Betulaceae, Fagaceae) which form ectomycorrhizas are often dependent on the mycorrhizal association for normal growth under natural conditions. It has been observed that introduction of trees into areas devoid of mycorrhizal fungi is often unsuccessful unless a concurrent introduction of essential mycorrhizal fungi is made (Mikola, 1973). This has been demonstrated for areas in Australia, Puerto Rico, the high Andes of Peru, subalpine areas of Austria, the great plains of the U. S. and mine spoil areas in the eastern United States.

The benefits of the association between the mycorrhizal fungi and plant host, has been extensively reviewed by many authors (c.f. Harley 1969, Marks and Kowlowski, 1973). In general, the benefits to the host include the increased uptake of nutrients, increased tolerance to varying soil temperatures and pH extremes, increased resistance to drought, and protection of the host root against pathogens. The increase in nutrient absorption, is primarily the result of increased surface area provided by the mycorrhizal structure and its associated mycelium (Bowen 1973).

One of the first studies to indicate the importance of mycorrhizal plants on mining waste material was the study by Schramm (1966). He observed that the only successful plant colonizers on anthracite mining wastes in Pennsylvania were those that were either mycorrhizal or nitrogen-fixers. More recent work by Marx (1975), Daft and Hackaylo (1977) has indicated that mycorrhizal plants can have significant advantages in growth and survival on such diverse sites as acid coal spoils, kaolin spoils and copper mining spoils.

The purpose of this present report is to outline the procedures in establishing containerized ectomycorrhizal seedlings and to present preliminary findings on field performance of such seedlings on high-altitude spoil material. In 1976, mycorrhizae were established on three conifer species grown in containers under greenhouse conditions. In 1977, these mycorrhizal seedlings were then planted at a high-altitude molybdenum tailing site to evaluate their field performance.

METHODS

Mycorrhizae Establishment

In January, 1976, three mycorrhizal fungi, *Pisolithus tinctorius*, *Suillus granulatus*, and *Cenococcum graniforme* were grown as fungal inoculum according to the procedures of Marx and Bryan (1975). The mycorrhizal fungi were grown in sterilized Petri dishes containing nutrient agar media for a period of six weeks. These fungi were then transferred to flasks containing 35 ml (1 U.S. fl oz) nutrient media, and allowed to grow for a period of 8 to 10 weeks.

To prepare the inoculum to be actually used in seedling containers, a sterile mixture of vermiculite, peat and nutrient media contained in 1.9 liter (2 quart) jars was inoculated with pure fungal material from the liquid flask cultures and allowed to grow for 2 to 3 months. At the time of soil preparation and planting of seed, the vermiculite-peat inoculum was removed from the jars, rinsed thoroughly with tap water to remove excess nutrients, and mixed with sterilized potting mix (1 part peat, 2.5 parts vermiculite) at a ratio of 15% by volume. Seeds of lodgepole pine (*Pinus contorta*), limber pine (*P. flexilis*) and Engelmann spruce (*Picea engelmannii*) were planted in the potting mix in styrofoam cavities (460 cm^3, 28 in^3 volume). A total of 1,500 seedlings were grown. Each tree species was grown in combination with each fungal species and without fungal inoculation (3 species x 4 mycorrhizal treatments). Seedlings were grown in a Colorado State Forest Service greenhouse under the environmental conditions of enriched CO_2 (1,500-2,000 ppm), extended light period (10 watts/ft^2 over 6% of dark period), 50-70% relative humidity and a 72°F (22°C) day, 75°F (24°C) night. We conducted our own watering and fertilization schedules to ensure proper levels of nitrogen and phosphorous for optimum mycorrhizal formation. During the growing period, periodic measurements of height and diameter growth were conducted. After the growing period, seedlings were allowed to reach a dormant winter-hardened condition. Representative seedlings from each tree species-fungal combination were examined for mycorrhizal formation, shoot and root weights, shoot and root lengths and water content.

Field Performance of Mycorrhizal Trees

Planting of the greenhouse grown "tailored" mycorrhizal conifers was begun in early June of 1977 on an upper tailing pond site of the Urad mine (elev. 10,500 ft, 3,200 m) situated 9 miles (14.5 km) west of Empire, Colorado. The mine tailing material was previously covered by fragmented rock. Characteristics of the rock material included basic pH, low P, no organic matter, moderate salts, high lime, high K, moderate N and adequate levels of Zn, Ca, Fe, Mg for plant growth. The mean air temperature during the growing season (June-Sept) for this area in 1977 was 53°F (12°C). Total precipitation for 1977 was 25.1 inches (63.8 cm) with 8.6 inches (21.8 cm) occurring between June and September.

The field study consisted of three 30 x 40 meter (98 x 131 ft) blocks each consisting of the 3 tree species, 4 mycorrhizal treatments and 4 fertilizer treatments in a $4^2 x 3^2$ factorial design (Figure 1). Within each block, four fertilization treatments were established: (1) no fertilization, (2) 80 lbs/acre (89 kg/ha) of P, (3) 80 lbs/acre of P and 60 lbs/acre (67 kg/ha) of N, and (4) sewage sludge and woodchips at 20 tons/acre (45 metric tons/ha). After fertilization application, the surface material of each block was thoroughly mixed by a D-9 Caterpillar tractor and plowing bar. Within each fertilization strip, each tree species and mycorrhizae treatment was randomly placed.

After planting of the containerized seedlings, some protection from wind and high radiation was afforded by placing cedar shingles on the southwest side of each seedling. Height and diameter growth, bud activity, and mortality were monitored periodically for each treatment from time of planting until 2 November. Because of the differences in size of each tree species resulting from the mycorrhizal treatments, the initial characteristics of individual seedlings were noted at time of planting.

RESULTS

Mycorrhizal Establishment

The effect of mycorrhizal inoculation on each tree species is presented in Table 1. As can be noted, the "control" treatments became inoculated, presumably with wind disseminated spores from indigenous fungi (perhaps *Thelephora terrestris*). Mycorrhizal development was relatively good for all mycorrhizal treatments with both *Pinus contorta* and *P. flexilis*, but was very low with *Picea engelmannii*. Although the percentage of short roots which became mycorrhizal was very similar for all mycorrhizal treatments within a tree

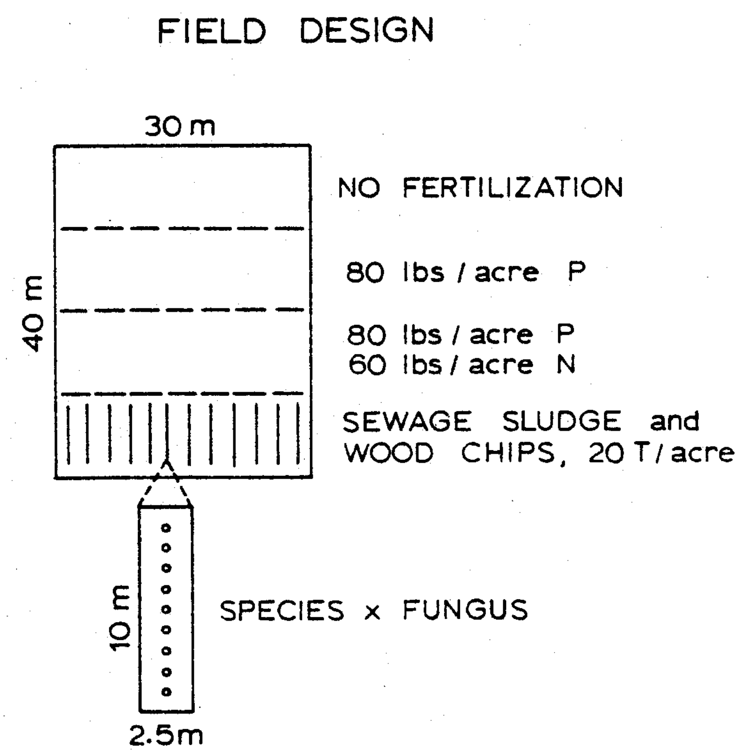

Figure 1. Diagram of field design used for examining the effect of tree species, fungus, and fertilization treatments on field performance (1m = 3.28 ft).

Table 1. Growth Responses of Containerized Conifer Seedlings with Various Mycorrhizal Fungi Inoculation.

Pinus contorta

Mycorrhizal Species	Root Length cm[1]	Top Length cm	Total Length cm	Root Dry Wt. g	Shoot Dry Wt. g	Total Dry Wt. g	% MYC*	Stem Diameter mm	R/S (D.W.)**	$gH_2O/gD.W.$
P.t.	34.82	7.51	42.63	.2565	.3239	.5804	78.1	1.45	.8335	3.30
S.g.	33.04	11.22	44.27	.5207	.9053	1.425	78.7	2.18	.5854	3.00
C.g.	29.85	7.79	37.64	.280	.441	.6209	64.4	1.85	.6480	2.87
Control	31.45	10.33	41.78	.535	.810	1.340	77.2	2.1	.6908	2.59

Pinus flexilis

Mycorrhizal Species	Root Length cm[1]	Top Length cm	Total Length cm	Root Dry Wt. g	Shoot Dry Wt. g	Total Dry Wt. g	% MYC*	Stem Diameter mm	R/S (D.W.)**	$gH_2O/gD.W.$
P.t.	29.48	5.88	35.36	.323	.419	.742	55.3	1.95	.8783	3.27
S.g.	25.91	7.14	33.06	.589	.982	1.571	55.0	2.5	.6506	2.62
C.g.	28.09	5.81	33.86	.328	.450	.778	55.3	1.8	.7405	3.09
Control	28.81	7.29	36.12	.477	1.173	1.65	55.0	2.3	.4269	2.43

Picea engelmannii

Mycorrhizal Species	Root Length cm[1]	Top Length cm	Total Length cm	Root Dry Wt. g	Shoot Dry Wt. g	Total Dry Wt. g	% MYC*	Stem Diameter mm	R/S (D.W.)**	$gH_2O/gD.W.$
P.t.	21.35	6.08	27.43	.0936	.1533	.2469	1.5	1.1	.5881	2.16
S.g.	24.96	10.39	35.35	.2642	.4844	.7486	7.8	2.1	.5712	2.45
C.g.	22.76	6.74	29.5	.0795	.1547	.2342	5.5	1.35	.4921	2.94
Control	26.7	11.09	35.59	.4138	.6183	1.1007	1.5	2.3	.5998	2.13

* % MYC represents the percentage of short roots which were mycorrhizal.

** R/S is root/shoot ratio based on dry weight.

P.t. = *Pisolithus tinctorius*; S.g. = *Suillus granulatus*; C.g. = *Cenococcum graniforme*; Control = inoculation by unknown fungus.

[1] 2.54 cm = 1 inch

species, there were marked differences in growth response. For example, *Pinus contorta* and *P. flexilis* both showed greater root and shoot weight production with *Suillus granulatus* and the "wild" fungus than with either *Pisolithus tinctorius* or *Cenococcum graniforme*. *Picea engelmannii* showed a similar response even though the percentage of mycorrhizae was relatively low. The better root response to *S. granulatus* and the "wild" fungus might be attributed to local occurrence of these fungi and their possible adaptation to local species and conditions. *S. granulatus* was isolated from fruiting bodies collected in the Colorado Front Range. Even though the isolates of *Pisolithus tinctorius* and *Cenococcum graniforme* have been shown to form mycorrhizae with these three tree species, both are isolates obtained from the southeastern United States.

Field Performance of Mycorrhizal Trees

It may be too early to adequately evaluate the performance of the various mycorrhizal and fertilization treatments after one growing season in the field. This is especially true if one considers that the growth response may be primarily dependent on the original container plug of soil during the first year. However, some trends are evident in growth and mortality, even after one season. The survival of seedlings was relatively high in all treatments. The combined total mortality for all species and all treatments was less than 9% as of 2 November 1977 (Table 2).

Table 2. Summary of seedling mortality at four dates in 1977.

	Mortality Percentage			
Date	*P. contorta*	*P. flexilis*	*Picea engelmannii*	Total
7/30	6.02%	4.63%	4.17%	4.94%
8/30	6.94%	6.48%	6.94%	6.79%
9/28	7.41%	8.80%	8.33%	8.18%
11/2	7.64%	9.26%	9.49%	8.80%

There were statistically significant differences in mortality that could be attributed to either mycorrhizal treatment or fertilization treatment. For example, *P. contorta* seedlings inoculated with either *Pisolithus tinctorius* or *Suillus granulatus* had significantly lower mortality than the other two mycorrhizal treatments (Fig. 2).

Some trends in response to fertilization were beginning to become apparent. The application of sewage sludge and woodchips resulted in a significantly greater mortality of *P. contorta* and *P. flexilis* than the other fertilization treatments (Fig. 3). Greater mortality in the sewage sludge and woodchips might be partially

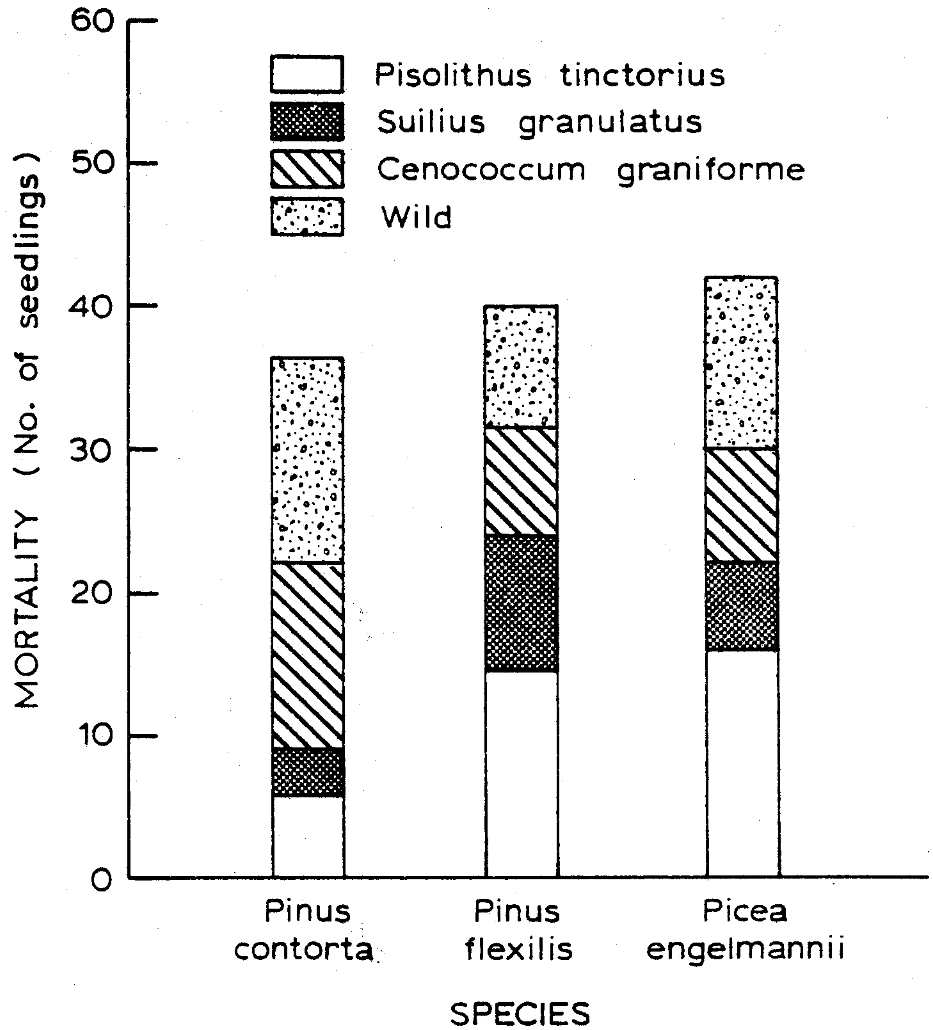

Figure 2. Total seedling mortality during 1977 field season. There were 108 number of seedlings for each tree species-fungus combination.

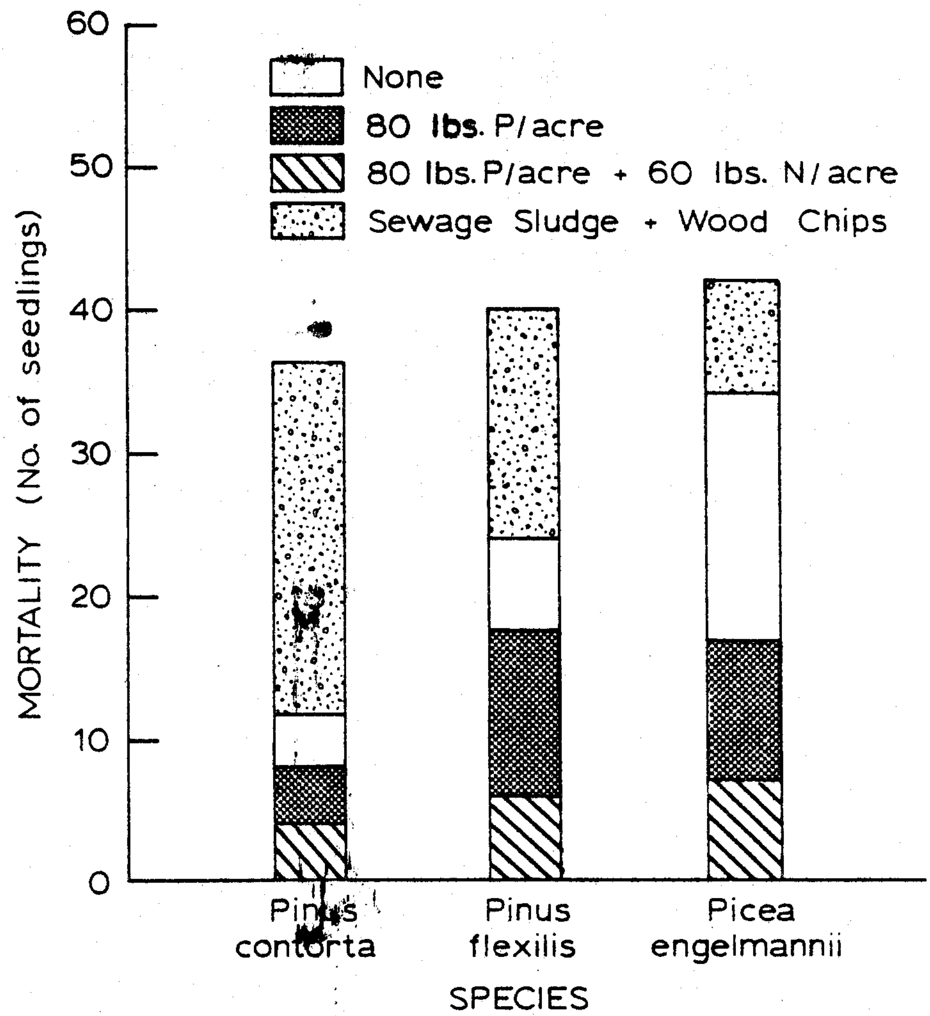

Figure 3. Total seedling mortality during 1977 field season. There were 108 number of seedlings for each species-fertilization combination.

attributed to moisture availability differences created by the difficulty in packing the sludge and chip mixture around the seedling soil plug when planted.

Responses in height and diameter growth did not necessarily parallel the mortality results. For example, height growth in all three species was greatest with the mycorrhizal treatments of *Suillus granulatus* and the "wild" fungus (Table 3). Height growth of seedlings infected with *Pisolithus tinctorius* was generally about one-half of the growth with the best fungal treatment. Stem diameter results were very similar to those of height growth. At this stage in our field evaluation, we cannot conclusively state that the greater growth in the field is a direct result of the mycorrhizal treatment, since the plants inoculated with *Suillus granulatus* and the "wild" fungus were initially bigger when planted on the field site. It will require further statistical analysis of the data to determine if we can sort out initial size effects. Although we have no consistent responses in height and diameter growth to fertilization there are some statistically significant differences between treatments. Perhaps differences in growth due to fertilization will become more evident in the second year of field growth.

Table 3. Effect of mycorrhizal treatment on height growth (cm)[1] of the three conifer species in the field from June-November, 1977.

Fungal Treatment	Tree species		
	P. contorta	*P. flexilis*	*Picea engelmannii*
S. granulatus	0.764	0.724	0.909
Wild type	0.557	0.830	0.857
C. graniforme	0.483	0.600	0.784
P. tinctorius	0.343	0.479	0.466

[1] 2.54 cm = 1 inch

We will continue to monitor growth and survival of these seedlings during 1978. Under greenhouse conditions we are also examining the ability of roots to grow out from soil plug and penetrate the spoil material. Thus far we are encouraged by the field results. Further study will be needed to conclusively establish which mycorrhizal treatments are of greatest benefit on these high-altitude sites.

ACKNOWLEDGEMENT

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DISCUSSION

QUESTION: Was there any watering of the plants in the field?

REID: At planting we watered each seedling. There was no further watering.

QUESTION: Have you looked at the use of mycorrhizae on other kinds of tailings?

REID: No we have not. These are the only field studies that we have done.

QUESTION: Is there a difference in mycorrhizal growth in different types of soil?

REID: Yes, pH has a strong influence on certain fungi. In this study, the pH is about 8. Most of the fungi for the studied tree species tend to be found naturally in soil of about pH 5. We are not sure how the fungi will last in the new environment. The performance of the fungi will likely vary with soil conditions.

HAZARD IDENTIFICATION, CHEMICAL REMOVAL AND REVEGETATION OF A TOXIC CHEMICAL SPILL ON LAWSON HILL, SAN MIGUEL COUNTY

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Telluride Environmental Office
Telluride, Colorado

INTRODUCTION

On July 15, 1977, a chemical tanker truck traveling north-bound on Colorado 145 lost its brakes on the downgrade of Lawson Hill in San Miguel County, elevation 9,000 feet (2,740 m). At the hairpin turn the driver lost control and both tractor and tanker left the road and traveled 75 feet (23 m) down the embankment. The chemical contents of the tanker, copper ammonium chloride ($CuNH_4Cl_3$), were splashed about the slope. From the original contents in the tanker compared to the amount of the chemical recovered, 2,300 gallons (8,700 liters) of this potent biocide were spilled. The great portion of this chemical ran from the ruptured tanker down a dry irrigation ditch and rapidly percolated into the soil. Ground water movement of the chemical immediately threatened livestock and vegetation on site and the important trout fishery in the San Miguel River to the north.

An interdisciplinary approach involving geology and plant ecology was used to monitor and mitigate the effects of the chemical and ultimately to successfully revegetate the effected area by the following fall.

HYDROGEOLOGY AND CHEMICAL REMOVAL

The geology of the Lawson Hill site (Figure 1) is best characterized as an unconsolidated sequence of glacio-fluvial sediments overlying the impervious Cretaceous Mancos shale. Since the Mancos shale is impervious, exhibiting percolation rates on the order of 10^{-7} cm/sec, and the glacio-fluvial materials are locally aquifers, a perched water table condition exists at the geologic contact between the two rock types.

SLOPE PROFILE

VOLUME ABCE = 1/2 65m x 286m x 80m
= 743,000 m^3
VOLUME ABDE = 1/2 65m x 180m x 80m
= 468,000 m^3
VOLUME ABCE - ABDE = 275,000 m^3 (POTENTIAL VOLUME OCCUPIED)

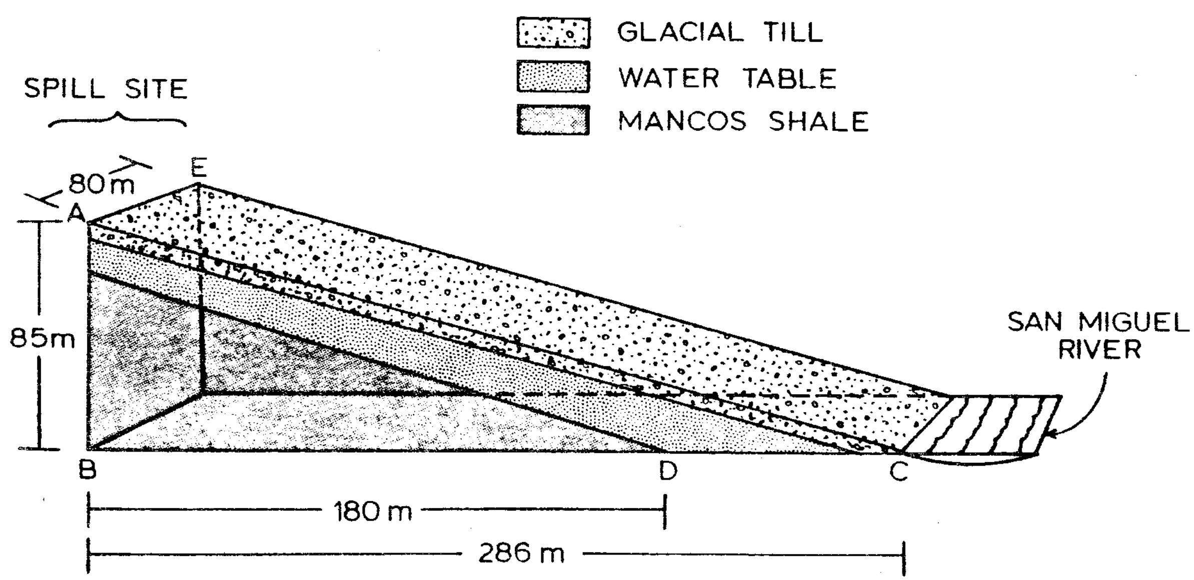

Figure 1. The geology and slope profile of the Lawson Hill site (1 m = 3.28 ft).

The glacial material is Bull Lake (Late Wisconsin) in age and as such, exhibits immature soil profiles wherever exposed. Textural analyses performed on this soil indicate that it is a silty sand soil (Figure 2).

These geologic and soil conditions result in the presence of several springs that have discharges on the order of 10 gpm (gallons per minute) (38 liters per minute) downslope and downdip from the study area. A linear distance of about 500 feet (150 m) separates the contaminated soil horizons and the flowing springs to the northeast.

These springs are fed by the sandier horizons in the glaciofluvial aquifer; they in turn flow directly into the San Miguel River, some 660 feet (200 m) to the north. The sandy, fluvial horizons in the glacial till are texturally classified as sandy soils (Figure 2) and have a calculated porosity of 46% void space. This texturally mature, well sorted sediment is located two-three feet below the ground surface and dips parallel to the topography towards the San Miguel River to the north (Figure 1).

Due to the dry soil conditions caused by the meager rainfall in San Miguel County prior to July 17, 1977, aquifers were depleted of ground water in the Upper San Miguel drainage at the time of the chemical spill.

The sudden introduction of 2,300 gallons (8,700 liters) of liquid copper ammonium chloride ($CuNH_4Cl_3$) into the depleted glaciofluvial aquifer resulted in the influx of a large amount of moisture available for plant root uptake.

Due to the low hydraulic gradient (minimal pore pressure) present at the time of the chemical spill, little aquifer transmission apparently took place until the dry climatic trend was reversed during 17-20 July.

With the introduction of more than 1.5 inches (3.8 cm) of rainfall during this period, a positive hydraulic gradient was reestablished in this aquifer and vegetative indicators confirmed movement of contaminated ground water towards the springs feeding the San Miguel River.

This movement was also substantiated by the conspicuous disappearance of this highly soluble chemical from the contaminated ground surface.

On July 21st, representative soil samples were taken from a point 4 inches (10 cm) below the ground surface and texturally and chemically analyzed. Sample A is characterized by a large concentration of Cu^{2+} ion (Table 1).

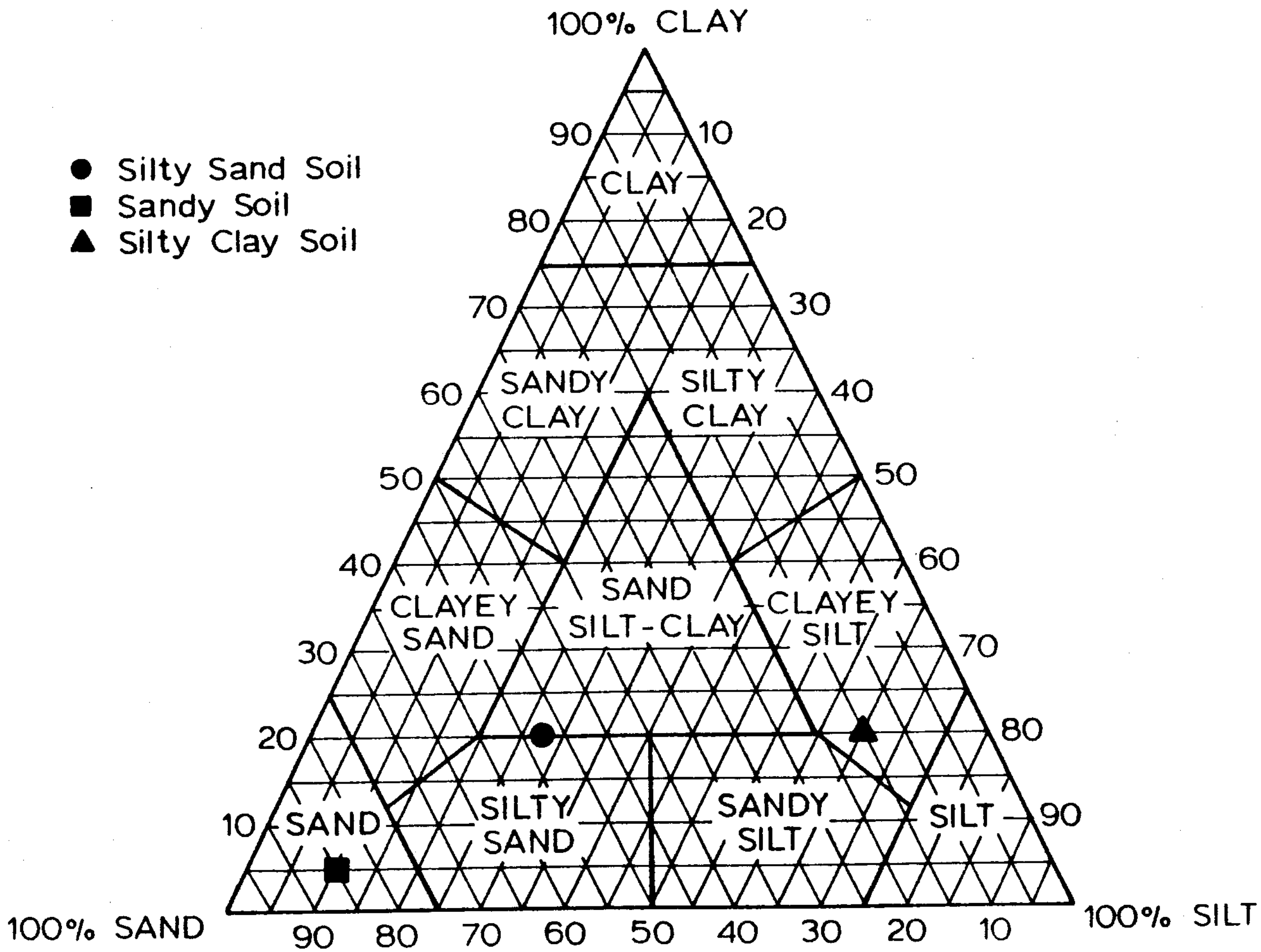

Figure 2. Soil texture classifications.

Table 1. Textural and chemical analysis of soil samples. $\frac{\text{ug of Element}}{\text{gm of Sample}}$ expressed as parts per million (ppm) for soil samples A, B, and C.

Soil Sample	ppm Al	ppm As	ppm Ca	ppm Cr	ppm Cu	ppm Fe	ppm Hg	ppm K	ppm Li	ppm Mg
A	61000.	9.	19000.	100.	1250.	29000.	.30	19000	40.	6700.
B	51000.	10.	10000.	100.	515.	22000.	.31	17000.	40.	5600.
C	41000.	<5.	17000.	60.	20.	18000.	1.38	14000.	30.	5400.

Continued.

Soil Sample	ppm Mn	ppm Na	ppm Ni	ppm Pb	ppm Zn
A	610.	9600.	8.	60.	110.
B	910.	9000.	9.	25.	85.
C	720.	7600.	10.	40.	155.

Note: tests were not made for Au, F, Sb and SO_4.

Chemical Removal

Excavation of the site's contaminated soil began July 25th, some ten days after the event. During the excavation, a representative soil sample was taken of the site and is labelled in Table 1 as Sample B.

A significantly decreased copper concentration was interpreted as signifying effective removal of contaminated soil.

Some 780 cu yd (600 cu m) of soil excavated to an average depth of 5 feet (1.5 m) resulted in a visual inspection indicating virtually no contaminated residual soil. Excavation is located on Figure 3.

Soil Sample C was taken at the end of the excavating procedure and this soil displays a copper concentration of only 20 ppm copper, the normal background level for natural soils of this type (Table 1).

When it was determined that the chemical had been effectively removed; a replacement soil was sought.

Silt reclaimed from a local gravel mixing operation could be easily and cheaply obtained.

This silty clay soil is texturally represented in Figure 2. When the contaminated soil was replaced with the river silt, the revegetation process began.

PLANT INDICATION OF CHEMICAL MOVEMENT AND REVEGETATION

The vegetation of the Lawson Hill site prior to the chemical spill can be divided into three distinct units. The aspen forest with grass and forb understory probably represents the original vegetation prior to the cut and fill alteration of Lawson Hill for Colorado 145. The slope from the base of the highway fill up to the road surface can be characterized as disturbed and contains the widest variety of plant species. Altered moisture regime from the highway cut and fill, placement of the irrigation ditch and overgrazing up to the fence margin lining the irrigation ditch has resulted in an open meadow area with vegetation consisting mainly of *Poa* species. Plant species found in these three vegetation covertypes are listed in Table 2 and are located on Figure 4.

Following the chemical spill, vegetation response served as an accurate indicator of the splashing soil permeation and eventual

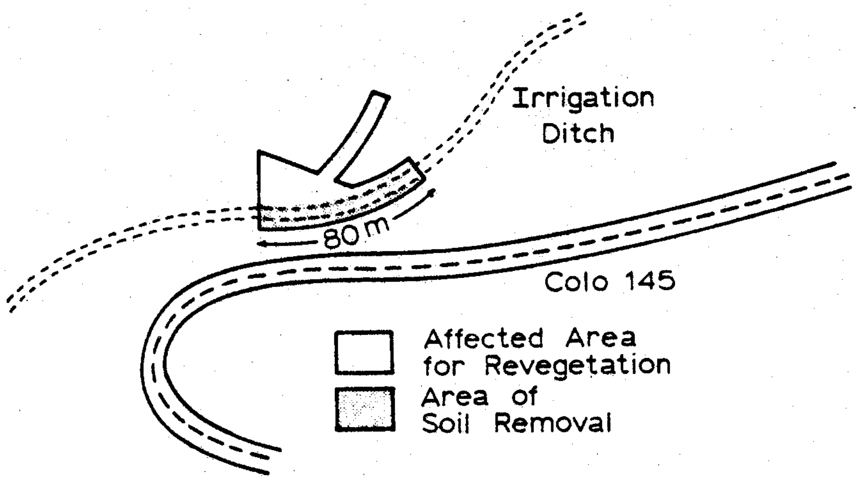

Figure 3. Soil removal area (1 m = 3.28 ft).

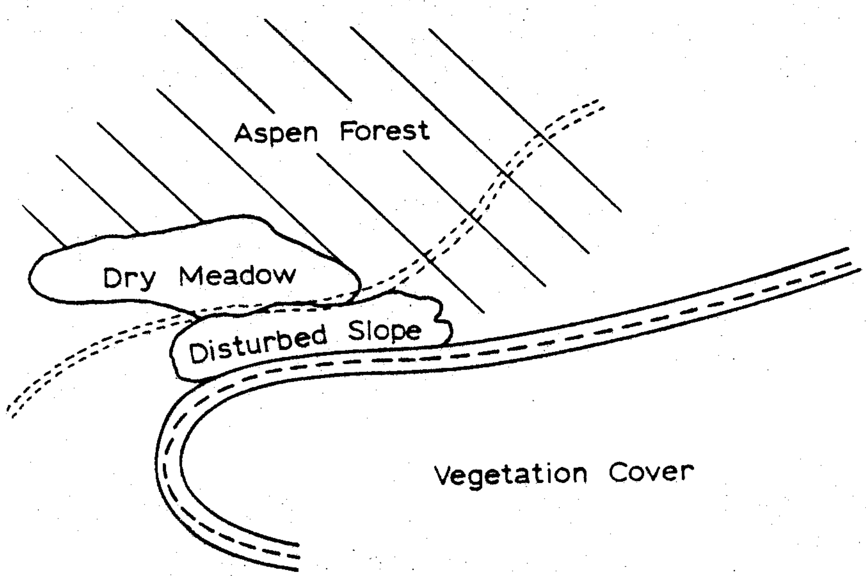

Figure 4. Original vegetation cover.

Table 2. Species list of vegetation at Lawson Hill site.

Species	Covertype: Disturbed slope	Covertype: Dry meadow	Covertype: Aspen forest	Observed response to chemical
**Achillea lanulosa* Nutt.		X		Death after root uptake
Agropyron dasystachyum Hook.			X	Yellowing and die back after splashing
Bromus inermis Leyss.	X	X	X	Yellowing and die back after splashing
Campanula rotundifolia L.			X	Death after root uptake
Chrysothamnos viscidiflorus Nutt.		X		Not in contact with chemical
Festuca arizonica Boivin.		X	X	Not in contact with chemical
Galium boreale L.			X	Death after root uptake
Geranium vichardsonii F&T.	X		X	Death after root uptake
Ipomopsis aggregata V. Grant.	X			Leaf necrosis after splashing
Mahonia repens Lindle.			X	Death following root uptake
**Pedicularis grayii* Nels.			X	Death after root uptake
Penstemon angustifolia Pursh.	X			Necrosis on leaves from splashing
Picia pungens Engelm.	X			Death after splashing and root uptake
Poa agasizensis Boivin.		X		Killed by soaking in irrigation ditch
Poa compressa L.		X		Killed by soaking in irrigation ditch
Poa glauca Vahl.		X		Killed by soaking in irrigation ditch
Populus tremuloides Michx.	X		X	Leaf necrosis following splashing and death following root uptake
Prunus americana Marsh.	X			Leaf necrosis following splashing
Ribes inerme Rydb.	X			Leaf necrosis after splashing

Table 2. (Continued).

Species	Covertype: Disturbed slope	Dry meadow	Aspen forest	Observed response to chemical
Sambucus racermosa L.	X			Leaf necrosis after splashing and dieback
**Symphoricarpos occidentalis* Hook.			X	Death after root uptake
**Taraxacum erythrospermum* Hook.	X		X	Leaf necrosis after splashing and death after root uptake
**Thalictrum sparsiflorum* Muehl.			X	Leaf necrosis at low concentration and root uptake followed by death.
Trifolium repens L.	X			Leaf necrosis after splashing
**Vicia americana* Muehl.			X	Death following root uptake
Poaceae Unknown 1	X			Leaf necrosis following splashing
Poaceae Unknown 2	X			Leaf necrosis following splashing

*Indicator value for copper ammonium chloride soil contamination.

ground water transportation. These effects are tabulated for each plant species in Table 2. Immediate effects were observable from splashes of the copper ammonium chloride solution on the plant parts. Wilting, spotting, and drying of affected leaves and stems were observed 24 hours after the spill. Where the chemical soaked into the soil in and around the irrigation ditch, complete plant death was observed for grasses and forbs the fourth day after the spill. Uptake of the highly concentrated chemical in select branches of the root system caused leaf loss to initiate in aspens and willows as much as twenty feet from the irrigation ditch by the fifth day.

Inspection of sections made of the trunks of affected aspens and one blue spruce showed movement of the chemical through the vascular tissues indicated by a pronounced blue stain in the wood. These stains were localized to the xylem supplied by roots growing in the contaminated soil and appeared as lenses in cross section. No translocation of the chemical in phloem was noted in the trunk sections. This was probably due to rapid tissue death of sensitive leaves in the presence of the chemical transported through the physiologically inactive xylem. However, mobility of either the copper or ammonium ions was fairly complete in aspens showing the effects of high concentration uptake. All branches of affected trees lost leaves, although cross section revealed that the chemical was transported only in localized portions of the trunk.

Several aspen forest understory plants downslope of the irrigation ditch began showing signs of chemical poisoning following the first rainfall after the spill. Of this group of sensitive plants, including *Pedicularis grayi*, *Taraxacum erythrospermum*, *Symphoricarpos occidentalis*, *Vicia americana*, and *Achillea lanulosa*, *Thalictrum sparsiflorum* was the most sensitive and reliable indicator of the chemical movement. Movement of the chemical in a front was indicated in this plant first by necrosis of leaf margins followed by wilting and drying. This movement was measured on five occasions. This data (Figure 5) strongly indicates that rain storms moved the chemical downslope in pulses.

Each of the plants indicating dispersion of the copper ammonium chloride had an average rooting depth to at least eighteen inches. This was within the zone of greatest concentrations of the chemical as determined by the location of the blue stain upon excavation. Grasses growing in the same zone were typically shallow rooted to about twelve inches and failed to show the effects of the chemical.

Bromus inermis and *Agropyron cristatum* Nutt. were chosen for revegetation of the site after removal of the contaminated soil and replacement with sand and gravel tailings. These species were immediately available from a local seed source. From local revegetation work performed at the Telluride Ski Area both of these species were shown to grow well in similar soil and site conditions within

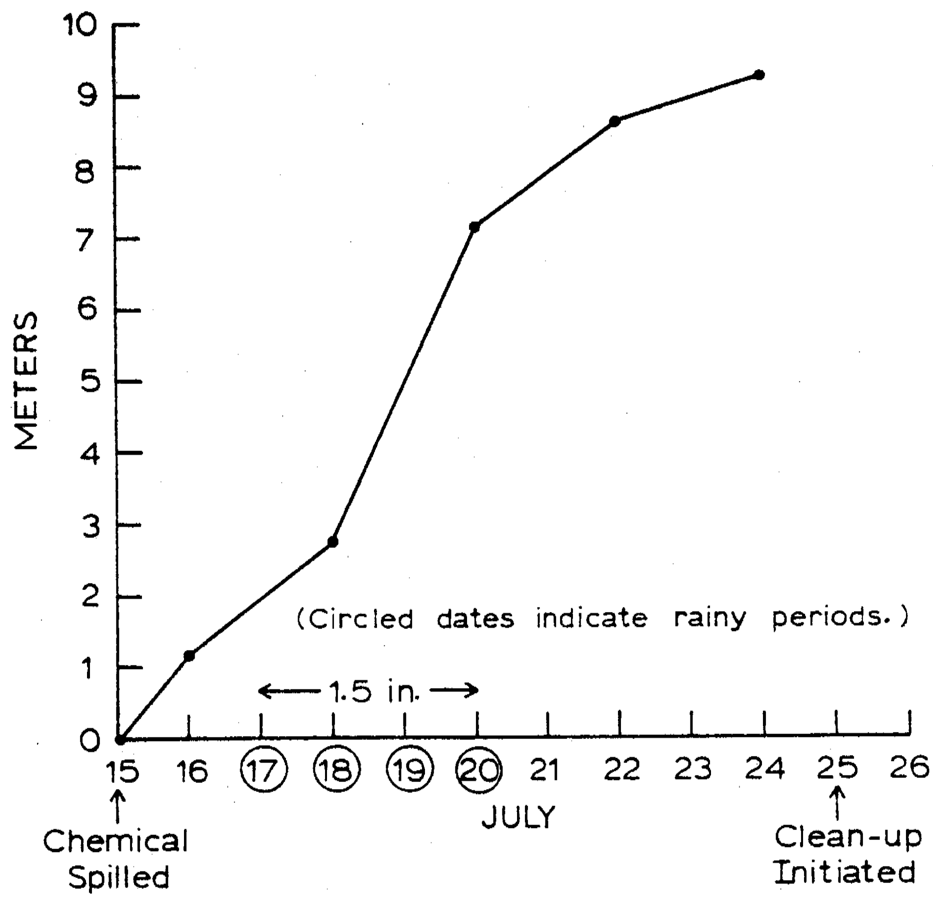

Figure 5. Movement of the copper ammonium chloride as measured by the effects upon *Thalictrum sparsiflorium* (1 m = 3.28 ft).

1.5 miles (2.5 km) of the Lawson Hill site. The seed source was Alberta Canada and so was aclimatized to cool summers found at the elevation of Lawson Hill.

Fifty pounds each of the *Bromus inermis* and *Agropyron cristatum* were hand broadcast over the approximately .25 acre (1,000 m^2) bare soil site prepared for revegetation by smoothing and compacting by caterpillar tractor. After hand seeding was completed, a caterpillar tractor was driven over the seeded area and the original fences were replaced. Within two weeks the reseeded grass showed very good germination and growth mainly in the small troughs impressed by the tractor cleats. The reestablishment of the grass cover was aided by the greater than normal fall precipitation that fell during the two months following seeding.

A follow up investigation will be performed in order to study the gradual reinvasion of the excluded plant species found surrounding the revegetation site. The site has remained protected by snow through the winter. A thick grass cover of the Lawson Hill site is anticipated by the one year anniversary of the spill.

SEED COATINGS AND INOCULANTS

C. Spiva
CelPril Industries
Manteca, California

Seed coatings are not new and have been used for centuries to enable better planting, so actually I am discussing delivery systems (i.e., more than just a coating can be added: *Rhizobia*, fertilizer, growth regulators, pesticides, etc. can be put on the seed with the coating).

Symbiotic species of *Rhizobia*, specific for certain genera of legumes, can fix atmospheric nitrogen into plant available forms and, hence, the effectively nodulated legume can grow without added nitrogen. Although *Rhizobia* are ubiquitous soil microorganisms, the specific species or strains may not be present. Figure 1 shows that when a large number of ineffective *Rhizobia* strains are present, the number of added effective *Rhizobia* must be high to show positive inoculation benefits. Seed coatings were used for proper inoculation of small seeded legumes in difficult planting situations in New Zealand starting in 1962. Traditional inoculation methods failed a high percentage of the time. The reasons were: pre-inoculation left the *Rhizobia* relatively unprotected from heat, ultra-violet light, dessication, toxic substances, etc., and pH variables in the target soils were such that even if the *Rhizobia* survived the first set of hurdles, acid soils were devastating to the *Rhizobia's* survival. Even high pH soils benefited from the neutral coating that was used (pH 6.9). A compromise pH was reached in the immediate germinating zone.

Subsequent to the original successes with coating small seeded legumes, technology was developed to zero in on specific strains for individual varieties or groups of varieties that improved the efficiency of these nitrogen fixing bacteria. Further work consisted of improved coating mechanics, drying, and handling that improved still further the shelf life of the coated-inoculated seed. Today, CelPril has an expiry date on most of the small seeded legumes of one year.

There are many benefits of coated small seeded legumes. The major benefit is a much longer shelf-life than pre-inoculated uncoated seed. Larger numbers of *Rhizobia* are applied and kept alive; inoculation is assured. Specific strains have been developed for many of the varieties of our client's small seeded legumes that fix more nitrogen than those from inoculants obtained off the shelf. Work done by our company and others has shown that the same amount of coated seed can be sown as raw seed in the 15 lb/acre (17 kg/ha) and up range with the same resulting stand. Since the coating consists of about a third of the weight, there is significant seed savings. On acid soils, stands are often obtained where virtually no germination or survival was achieved with raw seed alone. The lime, and other additives in the coating, is equivalent to 200 pounds of lime drilled right with (and in contact with) the seed or 1 to 2 tons per acre if broadcast. The important factor here is one of rhizosphere influence. A small amount, precisely placed is equivalent to a much larger amount dispersed throughout the soil--in the surface acre 6 inches or so. The lime coating does not change the pH in the whole soil mass. If you can, lime should be applied and incorporated into the soil where necessary.

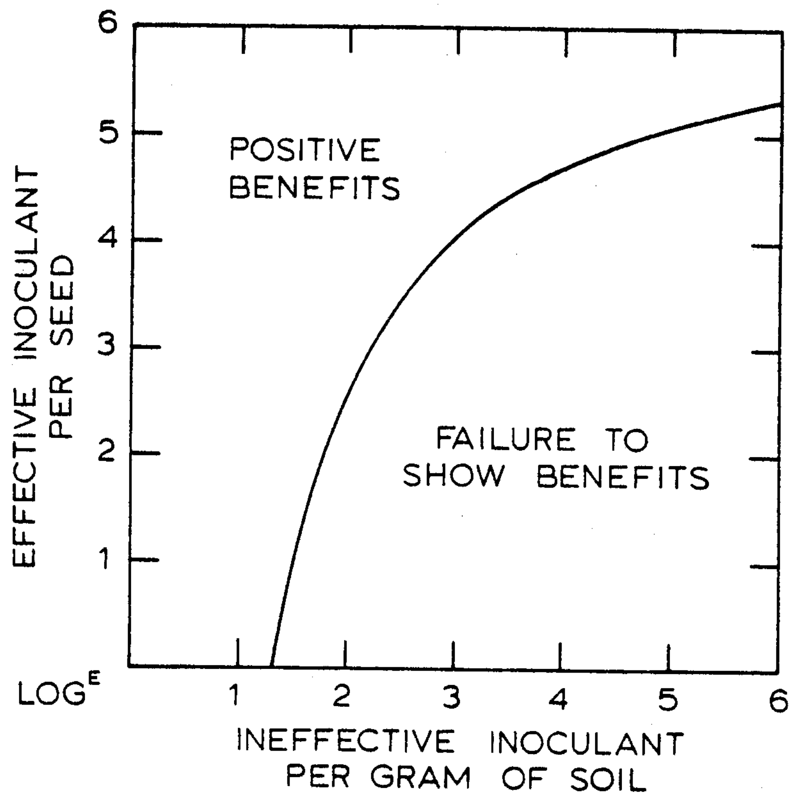

Figure 1. Seed inoculation applied versus existing *Rhizobia*.

One of the major benefits of coating grasses is the improvement of the seed's ballistic capabilities. The seed to coat ratio of grass coatings ranges from 1:1 to 1:3 and even higher for specific needs. Because grass seed varies widely in size, weight, and shape, the added weight and the ability for shaping the finished product provides some very positive benefits--the most important of which is control of application. This would include better planting pattern, when applied by air or ground broadcast seeding, and superior penetration of ashes or residues on soil surfaces. Flow through conventional drills has also been more efficient due to the better shape and weight. This is especially true where relatively small seeding rates are used i.e., 8 to 10 pounds per acre (9 to 11 kg/ha). A rough rule of thumb is about a 25% reduction in the amount of seed required. Thus, if a 10 pound raw rate were in effect, 7 and 1/2 pounds of seed would be used, and if the coating doubles the weight, 15 pounds of material is applied. In addition to the better ballistics, other additives for special needs can be conveniently applied in the coating. These include nutrients, plant growth regulators, slow release agents, and pesticides.

We are investigating the symbiotic relationships of some native plants such as mountain mahogany, bitter brush, and *Ceanothus* to assess including these in our seed coating program. Also in the developmental stage is work with pines and mycorrhizal fungi.

In summary, with seed coatings we are developing delivery systems which improve planting efficiency and subsequent survival. These are especially necessary on critical sites where good seed-bed preparation is impossible and application of seed is difficult.

A reprint package of "hard data" on coated small seeded legumes and grasses is available on request from CelPril Industries, P O. Box 2215, Manteca, California, Attention: Carl Spiva.

DISCUSSION

QUESTION: What is the cost of coated versus uncoated seed?

SPIVA: The seed to coat ratio for small seeded legumes is 1:0.5, in other words, 100 pounds becomes 150 pounds in the case of clovers. For grasses, the ratio ranges from 1:1 to 1:3 up to 1:5. Right now with the efficiencies realized by coating the small seeded legumes, costs may be slightly less or at a break even point. For the grasses, it costs a little bit more, but if you get better establishment, survival, distribution or handling characteristics these make up for the extra cost.

QUESTION: Do you have any difficulty coating small seeded grasses?

SPIVA: No, we can coat bent grass, Kentucky bluegrass, and even tobacco (which is as small as a period (.)) singularly.

PRINCIPLES OF SOIL TESTING FOR FERTILIZER RECOMMENDATIONS

A. E. Ludwick
Department of Agronomy
Colorado State University

Soil testing for fertilizer recommendations is most frequently used in intensive crop production systems. In this capacity considerable research has been conducted over the years on testing methodology and relationships to fertilizer recommendations. The potential of soil testing as a useful tool for other plant-soil systems, including high altitude revegetation, certainly exists. In fact, soil testing is being used in this capacity today, but considerable research is needed to fully develop its potential. To do this, basic testing principles must be clearly understood.

BASIC CONCEPT

Nutrients exist in soil in diverse chemical forms of differing availabilities to plants. Plant roots can absorb only certain of these forms which are usually only a small amount of the total. Therefore, tests are developed to extract only a "portion" of the nutrients from soil--that portion related to plant availability. Such tests frequently are called "availability indexes." Total nutrient content is, therefore, of little concern to a laboratory analyzing soils for the purpose of fertilizer recommendations.

DEVELOPMENT

Development of a soil test involves two steps. The first is the selection (or creation) of a soil extract that will remove an amount of a nutrient from the soil that is proportional to what a plant extracts. This is usually done by conducting experiments in the greenhouse where plants are grown in pots on soils typical of those to be analyzed for fertilizer recommendations. Following the desired growth period(s), the plants are harvested and analyzed.

The amount of nutrient absorbed by the plants is then compared with that extracted by the chemical solutions. The soil extract that compares (correlates) best with plant uptake of the nutrient is selected.

The second step in development of a soil test is called "calibration." This involves determining the appropriate rate of fertilization for a given soil test level. This work must be done under actual production conditions to reflect those same conditions experienced by growing crops. This involves a series of experiments in which fertilizer rates for the nutrient in question are applied from zero to more than adequate for maximum yield. By conducting these experiments on a wide range of soils over a period of time it is possible to relate the laboratory soil test values to actual field yields and rates of fertilizer necessary to achieve maximum yields (or other desired goals). Since various crops have different growth habits and nutrient requirements, the same procedure must be followed for each of those important in the testing area.

ACTUAL PRACTICE

The most serious problem of the CSU Soil Testing Laboratory in its daily operation is obtaining a reliable sample for analysis. This requires both careful sampling of the soil and handling between the field and the laboratory. Fields can be very heterogeneous in plant available nutrients and selecting reasonably uniform areas is difficult. Usually areas for a single composite sample[1/] are grouped based on field history and soil characteristics (color, slope, texture, drainage, and degree of erosion). Other sampling decisions besides determining the area per composite sample include sampling procedure (i.e., random vs. systematic samplings within the selected area), sampling depth, time of year to sample, and handling between the field and the laboratory. Careful attention to each of these is necessary if the soil sample is to be truly representative of the field area.

In order that personnel at the testing laboratory can formulate a proper fertilizer recommendation, they must have specific information on the crop to be grown (whether it be irrigated corn or a grass mixture to revegetate a mine spoil) and its growing conditions. Improper information in this regard can lead to a bad recommendation just as can happen when poor technique is used to obtain the sample in the first place.

[1/] A composite soil sample is the soil mixture representing a single field area composed of a number of individual samples (subsamples).

HIGH ALTITUDE REVEGETATION

There is no question that soil testing can be as useful a tool in high altitude revegetation programs as it has been in crop production for many years. As additional research is conducted its potential (and limitations) will become clear. Certainly research directly calibrating soil tests with the diverse growing situations in high altitude revegetation is important. Attempts are made too frequently to extrapolate information (fertilizer recommendations) developed with other cropping systems. Many problems unique to high altitude revegetation may not be considered and important elements (nutrients or toxic elements) may not be determined by such an approach. The very fact that there have been three High Altitude Revegetation Workshops held at CSU testifies to the unique problems encountered and being dealt with in this area.

DISCUSSION

QUESTION: How does one communicate with the soil test lab and explain needs?

LUDWICK: Forms are available from the lab; a telephone call or a detailed letter explaining your special situation is helpful. If you will be sending in several samples, get to know the director of your lab so he becomes familiar with your situation. The information sheet should be completely filled out and be especially sure to indicate the specific use of the area. For example: do not just write "grass" for the plant to be grown. A grass hay field is vastly different from a lawn. For further information write:

Dr. P. N. Soltanpour, Director
C.S.U. Soil Testing Laboratory
Vocational Education Bldg.
Colorado State University
Ft. Collins, CO 80523

or call Dr. Soltanpour: 303-491-5061

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SOIL SAMPLE INFORMATION

CHECK DESIRED ANALYSIS
(DETAILS ON BACK SIDE)

ROUTINE	$8.00	☐
SUBSOIL NITRATE (ACCOMPANYING SURFACE ROUTINE)	$1.00	☐
SODIUM EVALUATION	$3.00	☐
ROUTINE PLUS SODIUM EVALUATION	$10.00	☐
ROUTINE PLUS COPPER AND MANGANESE	$10.00	☐

LABORATORY NUMBER (DO NOT WRITE BELOW)	FIELD NUMBER	ACRES	IRRIGATION (CHECK ONE)					LAST YEAR'S CROP	YIELD PER ACRE	FERTILIZER USED FOR LAST YEAR'S CROP					
			ROW	FLOOD	SPRINKLER	SUB	DRYLAND			N LB./A	P_2O_5 LB./A	K_2O LB./A	Zn LB./A	OTHER	MANURE TONS/A

FIELD NUMBER	MANURE FOR CROP TO BE GROWN TONS/A	CROP TO BE GROWN	VARIETY (REQUIRED FOR POTATOES AND BARLEY)	YIELD GOAL	HAY AND PASTURE CROPS (CHECK APPROPRIATE BOXES)							
					STAND IS:			COMPOSITION IS:				
										GRASS-LEGUME MIX		
					TO BE SEEDED	PRESENTLY ESTABLISHED	NATIVE SPECIES	ALFALFA	GRASS	UP TO 25% LEG	25-75% LEGUME	MORE THAN 75% LEGUME

COMMENTS: NOTE SPECIAL PROBLEMS, FERTILIZER APPLIED SINCE LAST CROP

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C.S.U. EXTENSION AGENT ______________________

SEND TO SOIL TESTING LABORATORY, VOCATIONAL EDUCATION BUILDING, COLORADO STATE UNIVERSITY, FT. COLLINS, COLORADO 80523. DO NOT PREPAY. YOU WILL BE BILLED AFTER TESTS HAVE BEEN COMPLETED.

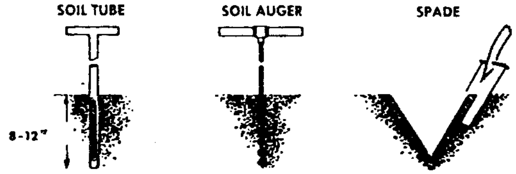
COOPERATING WITH U S D A

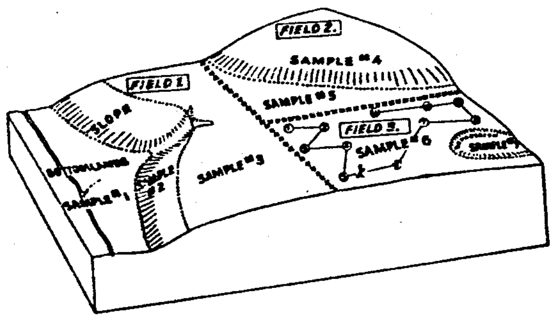
Ludwick

SAMPLING PROCEDURE

SOIL TESTS CAN BE NO BETTER THAN THE SAMPLE ITSELF

1. USE ANY OF THE TOOLS SHOWN BELOW TO TAKE SAMPLES. TAKE SAMPLE TO THE PLOW DEPTH (USUALLY 8-12").





2. EACH SAMPLE SHOULD REPRESENT A UNIFORM AREA. SIZE UP THE AREA AND OBSERVE THESE VARIATIONS:

   DIFFERENCES IN TEXTURE (SAND, SILT, CLAY), COLOR, SLOPE, DEGREE OF EROSION, DRAINAGE, PAST MANAGEMENT (FERTILIZATION, ROTATION, ETC).

3. TAKE 15 TO 20 SAMPLES FROM EACH UNIFORM AREA. MIX THOROUGHLY IN A PLASTIC CONTAINER AND FILL SOIL SAMPLE BAG AT LEAST TWO-THIRDS FULL. THIS IS THE COMPOSITE SAMPLE WHICH REPRESENTS THE FIELD OR AREA. LABLE EACH CONTAINER WITH YOUR NAME AND ADDRESS AND THE NUMBER OF SAMPLE CORRESPONDING TO THE NUMBER ON THE INFORMATION SHEET.

4. AVOID (OR SAMPLE SEPARATELY IF OF INTEREST) SUCH AREAS AS: DEAD OR BACK FURROWS, OLD STRAW PILES, WATERWAYS, TERRACES, FENCE ROWS, AND UNUSUAL SPOTS.

5. REPEAT THE SAMPLING PROCEDURE OUTLINED ON EACH UNIFORM AREA YOU WANT TESTED.

6. AIR DRY THE SAMPLE BEFORE MAILING. DO NOT USE HEAT FOR DRYING.

IMPORTANT:

YOUR SAMPLE WILL BE TESTED FOR AVAILABLE ZINC AND IRON. RUSTY TOOLS WILL CONTAMINATE THE SAMPLE WITH IRON, AND GALVANIZED OR BRASS CONTAINERS WILL CONTAMINATE IT WITH ZINC. THE RESULTANT SOIL ANALYSIS COULD INDICATE A SUFFICIENCY OF THESE ELEMENTS WHEN ACTUALLY A DEFICIENCY EXISTS.

ALL EQUIPMENT MUST BE ABSOLUTELY CLEAN.

SOIL TESTS AVAILABLE

TEST	PURPOSE	COST PER SAMPLE
ROUTINE - pH, soluble salts, organic matter, nitrate - nitrogen, phosphorus, potassium, zinc, iron, lime (estimate) and texture.	Basic evaluation for characterizing the soil fertility status for growing crops. A fertilizer recommendation is given. Normally this test is sufficient unless a special problem is suspected.	$8.00
SUBSOIL NITRATE *	Evaluation of nitrate supply below soil surface. Fertilizer nitrogen recommendation based on routine soil test of surface soil is adjusted if subsoil nitrate is unusually high.	$1.00
SODIUM EVALUATION - sodium adsorption ratio (ratio of sodium to calcium and magnesium), gypsum, and % lime.	Some Colorado soils contain excess sodium. This test determines whether or not chemical amendments such as gypsum or sulfur will be effective and the amounts of these materials needed.	$3.00
ROUTINE plus SODIUM EVALUATION	See above explanations. A recommendation for fertilizer and/or amendments for sodium reclamation is given.	$10.00
ROUTINE plus COPPER and MANGANESE	Routine soil test as explained above plus additional information on the micronutrients copper and manganese.	$10.00

*Price quotation is for each subsoil sample accompanying surface soil sample for routine test. Individual nitrate test is $2.00 /sample.

Information on additional tests (soil, water and plant) is available from your local CSU extension agent or the Soil Testing Laboratory.

STEEP SLOPE DESIGN AND REVEGETATION TECHNIQUES

R. L. Brammer
Principal Landscape Architect
New Mexico State Highway Department

DESIGN

The main facet of good design is the integration of all disciplines involved including not only the construction engineers but revegetation personnel as well. Early involvement in the planning of slope design by plant materials oriented personnel is a very simple concept. Yet, in reality it seems to be a greater task to implement than the actual work of constructing the slope.

The basic physical stability of the material comprising the slope should be appraised for its ability to stand without undue sloughing or major movement. Too many slopes are constructed from material that is not stable.

Geometrics that fit cross-sectioning for volume computations and slope staking are not the most physically stable conditions to retard soil movement by water. Sharp angles are easy for volume calculations, but they are not stable (Figure 1a). Observation of natural slope repose and studies made on constructed slopes demonstrate that a more stable shape is a more conducive environment for emerging plant establishment (Figure 1b). The tops and bottoms of slopes should be rounded during building intead of getting rounding by erosion with subsequent loss of plants. Rounded slopes are more stable. A misconception as to what is a proper shape for a serrated slope is another example of geometrics in staking practices that retards plant establishment, but does not retard erosion. Soil movement down the short faces in combination with the deposition on the flat benches defeats the concept of stability (Figure 2). Unless careful consideration is given to plant species utilized on the benches, the entrapped silt will smother emerging plants or those that do not have the capability of vegetative reproduction.

A rough, ripped surface that does allow mositure to percolate into the soil material and provide for stability (Figure 3) can most effectively be prepared as the slope is actually constructed. This work can be more easily and economically accomplished with large equipment than as a follow-up activity with small accident prone tools.

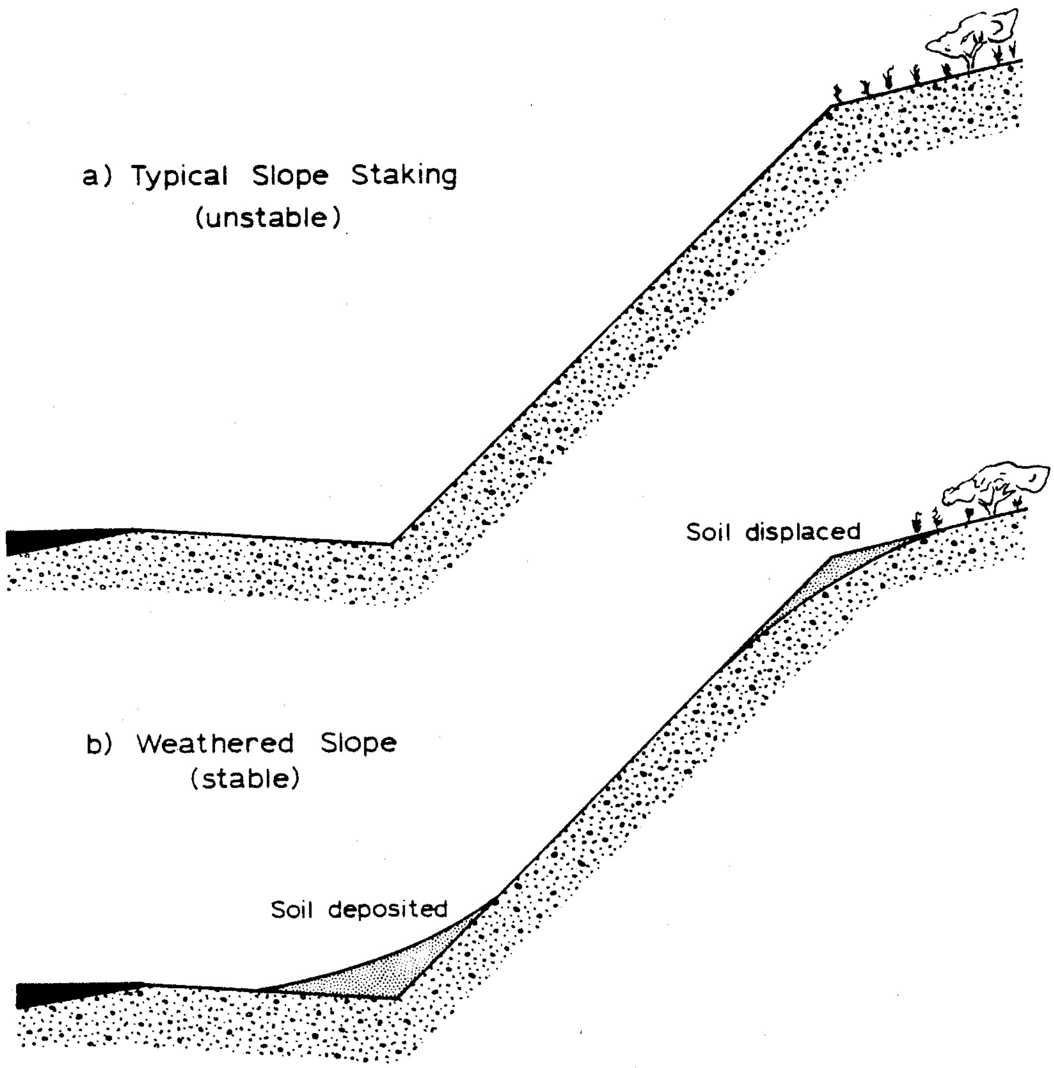


Figure 1. Slope stability cross section. On the unstable slope (a), the velocity of water is increased by the sharp dropping of the slope. At the bottom of the slope, the velocity dissipates and suspended soil is unloaded. From: L. D. Meyer and L. A. Kramer, Relation between land--slope shape and soil erosion. U.S.D.A. Research Service Paper No. 68-749.

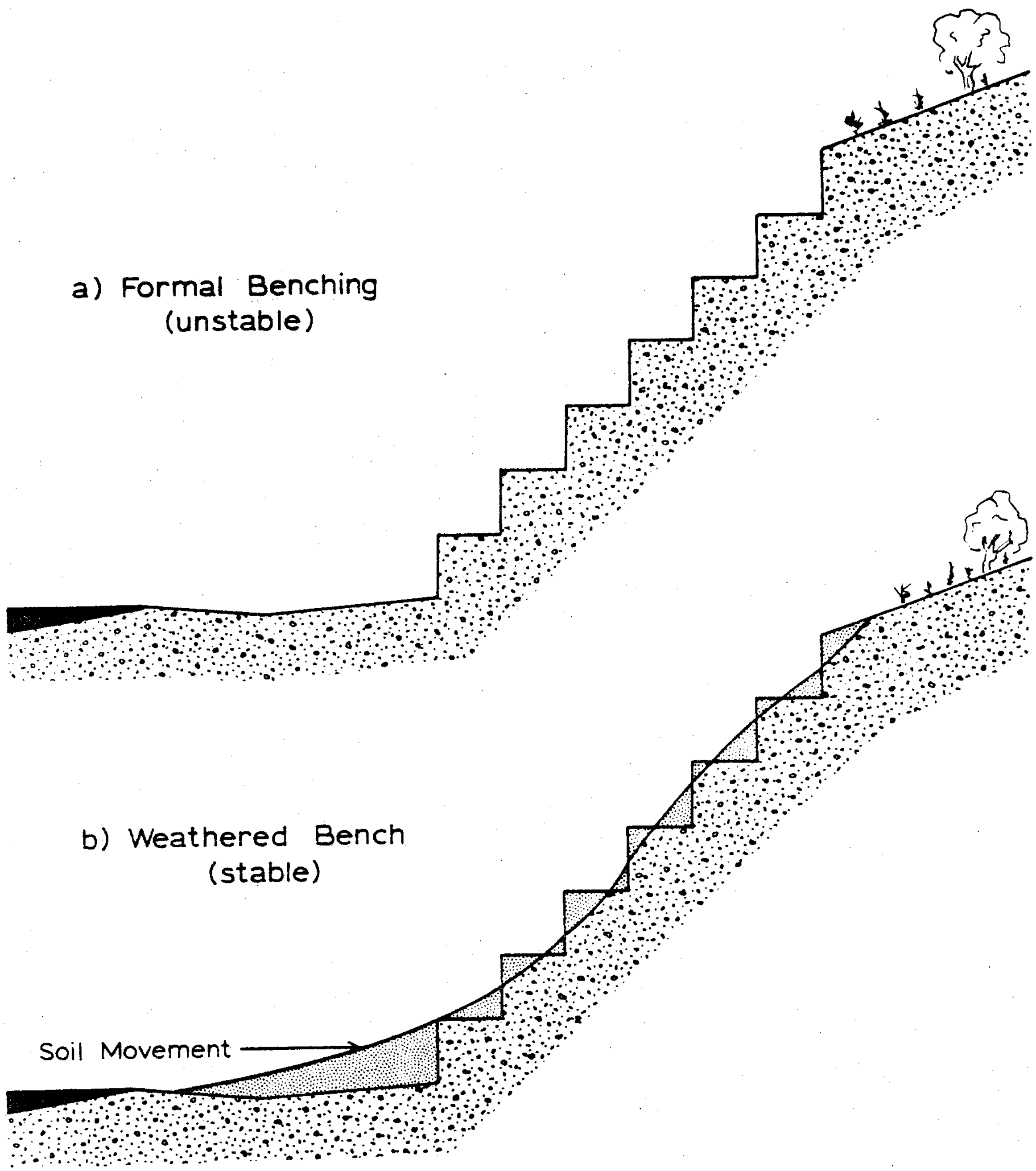


Figure 2. Benched or serrated slope cross section. In a, water velocities increase and dissipate as the water flows over the steps picking up soil and dropping it. The slope is not stable until it is weathered as in b.

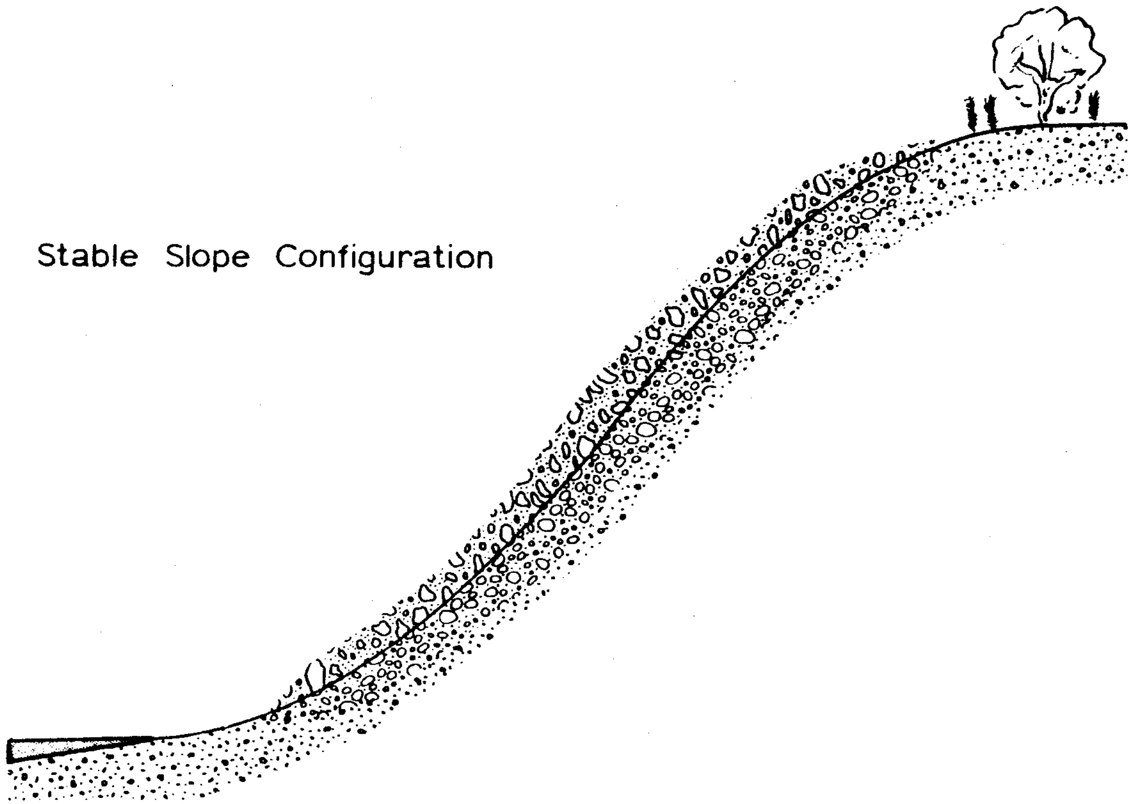


Figure 3. A stable configuration with reduced water velocities that has been roughened deep into the natural ground line at the time of construction offers more potential for revegetation than trying to plow the slope and round it later in the construction phase.

TREATMENT

The basic treatment that has shown the most economical and reliable results has been a hay mulch system. After evaluating everything from jute netting, excelsior blankets, gravel, short wood fibers, and long wood fibers, the following treatments have given the most consistent results for the money in areas of 8-9 inches (20-23 cm) annual precipitation to the good areas of 18 and 20 inches (46 and 51 cm).

After the primary soil preparation has been accomplished, the seed and fertilizer are applied with the standard hydroseeding equipment. This is followed by a pass or two with a slope harrow to provide for the burial of the seed. The hay mulch is then blown onto the slope within the limit of the equipment or in some cases delivered by helicopter and spread by hand.

There are several methods of anchoring the mulch. The most effective on steep slopes is crimping or incorporating the hay into the soil with a flat bladed disc carried by a crane. This method produces the best microclimate. Another system is to apply a mastic or tack as an overspray or through induction nozzles simultaneously with the hay. Some of the glues used are asphalt, petroleum resins, and seaweed extracts. The most effective overspray was a combination of seaweed extract and 200 plus lbs per acre (223 kg/ha) of short wood fibers applied with a hydroseeder. All of these treatments require application over a roughened soil surface or the mulch will roll off with wind action upon the surface.

SUMMARY

Most treatments are designed considering cost and results. The level of results in some instances is dependent upon cost. Hand labor intense systems such excelsior mats, soil treatments such as plating or adding organic material, and irrigation all enhance the results, but the degree to which they are effective depends on the slope being initially compatible with the support of vegetation. Slopes should be designed ahead to be compatable for vegetation. Build slopes rounded, roughened, and laid back as much as possible with the heavy equipment available. One application of seed and mulch should give good results, if slopes are initially stable.

DISCUSSION

CUANY: Do you expect in a 9 inch (22 cm) rainfall zone to be able to get a close cover of plants or do you aim for something like the surrounding area?

BRAMMER: In a 9 inch rainfall area you should not be building steep slopes. No. we do not try to get a close cover: it is foolish to expect and on disturbed soils you will not get it. Seed supply of adapted species are hard to obtain and so we do not seed for a close cover.

COMMENT: I would like to emphasize a few of your points. The design of the back slope is critical. Good proposals, design and subsequent coordination of the program are necessary from the start. Many times it is uneconomical to go back to an area and reduce the slope; pre-planning is important. In the Forest Service we are developing equipment to be used on steep slopes and to use on these older slopes, too. The greatest fluctuation in expense for hydromulching or hydo-seeding is the cost of the water supply.

BRAMMER: An interdisciplinary approach to revegetation is necessary. The Federal Highway Administration in implementation of the Environmental Policy Act requires that each state has an action plan. In that action plan, an interdiciplinary approach is supposed to be followed in the design sequence. Projects that have followed this mandated approach are more oriented towards getting vegetative establishment.

CONSTRUCTION AND GRADING TECHNIQUES AS THEY RELATE TO REVEGETATION

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After the environmental study is prepared, test plots evaluated, financial commitment stated and project work started, the actual method of construction is a primary determinant of revegetation success. Without the proper precautions what happens on the construction site may not be what was reflected on the plans. Site conditions, contractor scheduling and abilities and those last minute design changes can lay waste to the most well meaning revegetation/reclamation plans.

It is the intent of this paper to highlight importance of those construction related aspects of revegetation. Hence, the following text evaluates typical construction site operations (admittedly highway oriented) and relates them to reclamation/revegetative techniques.

ENVIRONMENTAL ASSESSMENTS/PROJECT INITIATION

The environmental studies must be tied to the production of alternative products, addressing potential impacts of the intended disturbance as well as the amount of impact mitigative work necessary. It is recognized in the highway planning process that the earlier the reclamation and revegetative principles are integrated into the process the more successful those principles will be. Therefore, the environmental professionals must closely ally themselves with those that design and construct the project. Then the environmental and engineering (or developer) professional can mutually work on those areas which pose problems and determine the best solution. This interdisciplinary effort is the intention of NEPA and without it we all will just spin our wheels.

DESIGN AND SPECIFICATION

The environmental professional should be concerned with all design aspects of the project. It is in the design and specification of the project that the contractor is told what to do and how to do it. Bids to do work are only representative of the work expected to be performed. Expecting a contractor to perform work not included in his bid (or on the plans) will produce a second best effort which is often more costly. All reclamation and revegetation plans must be straight forward, accurate, and complete for the contractor to know what is expected. If unknowns exist then these areas of uncertainty should be noted in the plans with monies set aside for special on-site solutions.

CLEARING AND GRUBBING

Once the project is started, clearing and grubbing operations are normally begun to break the ground, clear vegetation and create a working area. This construction phase can produce many impacts on or offer many opportunities for future revegetation success.

Although it is known that the least area disturbed the less area there will be to revegetate, many construction operations are not tuned to this fact. Because of the nature of dirt moving construction projects large areas must be cleared before construction begins. Large equipment is apt to venture outside of project limits. Lumbering crews clear trees and brush without regard to possible transplant value and much of this opened site is left for months without being touched. Most impacts in this phase are related to the size of equipment used and the contractors intent to obtain a large working base for a more efficient operation.

Techniques used in this phase are intended to limit the contractors working area. The Department of Highways has successfully accomplished this by reducing the size of project offered, by limiting the total area disturbed at any one time and by "string lining" the project limits. Of all techniques limiting contractor disturbance the "string-line," or the actual marking of project limits by tying a line of baler twine to outside survey markers, is most effective. All the equipment operators quickly recognize the meaning of the string line and the contractor is notified in the plans that the crossing of this line means a financial penalty.

Topsoil and transplant material is also available at this time. Topsoil is often stripped and stockpiled for later uses but soil erosion during this clearing operation can limit the amount and quality of topsoil. A complete erosion control plan must be implemented prior to or early in the clearing phase to secure the topsoil source. Transplants are available but must be tagged to protect them from the over-anxious clearing crews.

Normally it is during or just prior to the clearing operation that slope stakes are set. The slope stake placement is important in determining future slope angle. Although changes are possible later those changes will be more costly and more difficult to obtain.

DIRT MOVEMENT

With the site cleared and topsoil removed the contractor normally establishes access roads at or near the project slope stake lines and begins the dirt or rock movement operation. This operation is often the most extensive part of the construction project and disturbed areas are often left disturbed for the duration of the project. On many highway projects the two step operation of build then revegetate has been eliminated forcing the contractor to revegetate areas disturbed before new areas can be started. On major projects the contractor is limited to exposure of 30 vertical feet at which time he must topsoil and revegetate before continuing. Although this may appear very disrupting to the contractor's operation in actuality the contractor was found to be excavating and revegetating the slopes all in one operation.

Reducing slope exposure also makes many other revegetation techniques easier. Topsoil is easier to spread and work on, mulching and seeding operations can be accomplished more effectively and the landscape contractor has his equipment, nettings, and supplies near his place of work.

Where used, slope roughening is incorporated at this stage. If specified the contractor can leave slopes roughened rather than smooth.

Slope rounding is also accomplished at this time. Slope rounding eliminates the natural undercutting action at the top of cutslopes by smoothing the natural to created slope edge. With improved slope stability revegetation chances are greatly improved.

Slope moulding is suggested to limit long continuous slope faces by laying back or steepening the slope. Although the visual effect achieved is most apparent, slope moulding does tend to channelize cross slope water movement improving the overall slope stability and revegetation success. Slope moulding should accent existing terrain diversity by laying back draws and steepening ridges. Continuously flowing draws should be concentrated and stabilized with rock to minimize soil movement.

If slopes exposed are exceptionally steep and unstable, water bars should be dug above the slope to divert water movement onto the slope from above. Again the desired result is slope stability until vegetation can become established and stabilize the slope naturally.

The revegetative effort is a long term erosion control effort but during construction erosion must be minimized to insure a stable seedbed. Diversion ditches, hay check dams, sediment ponds, sepcial nettings and soil stabilizers are all aspects of temporary erosion control techniques employed to stabilize the disturbed area until the vegetative cover can take hold.

One last important technique used in the dirt movement operation is the on-site environmental planner. As part of the project team the environomental planner can spot problems as they occur and outline corrective actions. The on-site environmental planners can be landscape architects, hydrologists, erosion control/water quality experts, agronomists, ecologists or any pertinent professional but whatever the planner's discipline, he (or she) must be able to function on an interdisciplinary team of geologists, engineers, contractors, and project supervisory personnel. This project team approach has proven most successful on especially sensitive projects where unforeseen problems can crop up.

STRUCTURES

The revegetation effort can be greatly aided through the use of structures. Bridges, retaining walls and drainage structures can reduce the area disturbed and offer flattened slopes for revegetation. Cut slope retaining walls limit the extent of slope exposure by supporting the lower part of the cut. In mountainous terrain this slope reduction can be an important factor. In special cases retaining walls can be designed to support vegetation in planting pockets on the walls.

Bridges are not only used to overpass streams but can also span unstable slopes limiting the area of potentially unsuccessful revegetative efforts.

PROJECT CLEAN UP

As the project comes nearer to completion the contractors are often very anxious to finish major dirt, rock, and structure items while leaving the revegetation efforts to the last. At these project stages revegetation is most important. Insuring all the previously noted techniques are completed to satisfaction before the contractors equipment is removed can be a major bargaining task. It may be necessary to hold up the project until all revegetation efforts are completed.

The end of season work can also reflect this hurry-up philosophy. Careful planning is necessary to insure that when the first heavy winter snow falls, all erosion control, seeding and slope moulding features are completed and secured until spring thaw. Slopes left unseeded in the fall can mean a whole growing season is lost before the slope can be seeded the next season.

MAINTENANCE

On many large public projects, especially on highway projects, money is available for construction but not for extensive maintenance. Where phased projects occur, construction money can be spent on old disturbed and revegetated slopes to reseed where grass stand is poor, to replace lost transplants and to fertilize. Since phased projects are seldom encountered and in the long run all revegetative efforts will be left to support and maintain themselves it is especially important that all revegetation plans be directed toward the production of a self sustaining plant community.

SUMMARY

Although improved revegetation materials and technology are available, much depends on what happens at the project site. Careful planning and on-site monitoring is necessary to insure that the construction activities complement the revegetative effort and that revegetative work is accomplished during the correct construction phase.

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DISCUSSION

CUANY: What species were in the turf you transplanted at 9,800 feet?

TUPA: Pennstar bluegrass sod grown in Denver was used. This variety is for high altitude use.

CUANY: Do you have a special mix which you use in the shade of the bridge pillers?

TUPA: No, we use the same broad base mix in the entire area.

WILLARD: How much more are side-hill structures as opposed to a dirt operation for the same purpose?

TUPA: The side-hill structures cost about four times more than a standard dirt construction. But, when compared to maintenance costs of cleaning up every spring after landslides due to ineffective revegetation or the environmental impact of unstable slopes, then the costs may equalize.

MANAGEMENT APPROACHES TO NITROGEN DEFICIENCY IN REVEGETATION OF SUBALPINE DISTURBANCES

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Deficiency of plant-available nitrogen is a persistent problem in long-term management of vegetation established on subsoils in the subalpine.

With moderate to intensive inputs (seedbed preparation, fertilization, seeding, and mulching) herbaceous cover can usually be established on exposed subsoils and even certain disturbed geological materials. However, it has been our experience that the grasses will become extremely nitrogen deficient after 2-3 growing seasons. The nitrogen deficiency is expressed by light green to yellowish foliage and even purple color in some grasses. The amount of foliage produced and consequently ground cover is drastically reduced. The reduction in ground cover opens some sites to water erosion and has a negative effect on aesthetics.

This paper combines results of small on-going field studies, field observations, and published information in suggesting management approaches to the long-term nitrogen deficiency problem on drastically disturbed lands in the subalpine.

NITROGEN FERTILIZATION STUDIES

Glacial Till - Climax, Colorado

This study was initiated in June 1974 on glacial till exposed by leveling for pipeline installation. The study is on a 20% west-facing slope at an elevation of 11,000 feet (3,350 meters). Although the area had been exposed 6 or 7 years prior to this N-study establishment, only a few plants had become established on the site. There are some large rocks, but most of the material is gravel and soil size, with soil-size material making up 50% of the mass of particles smaller than 1 inch in diameter. The soil-size material is a sandy loam, has a pH of 8.1, is extremely low in extractable phosphorus (NH_4HCO_3 extractable) and moderately low in exchangeable potassium.

Before seeding, triple superphosphate was broadcast over the area at the rate of 150 pounds P_2O_5 per acre (168 kilograms P_2O_5 per hectare). After furrowing the plots were broadcast seeded to a mixture of smooth brome, timothy, red top, red fescue, hard fescue, orchard grass, and white clover. The nitrogen (N) treatments broadcast in June as NH_4NO_3 were:

Control (No N)
60 pounds N per acre applied in 1974 (67 kg N per ha)
60 pounds N per acre applied in 1974 and 1975
60 pounds N per acre applied in 1974, 1975 and 1976
60 pounds N per acre applied in 1974, 1975, 1976 and 1977

Each treatment was replicated 3 times. Good grass stands were established, there were only scattered white clover plants. Ground cover by living plants plus litter was estimated on the plots in August, 1977 with the following results:

Treatment	Total N Applied	% Ground Cover
No N	0	5
60# N 1974	60 #/acre	10
60# N 1974 & 1975	120 #/acre	25
60# N 1974, 1975 & 1976	180 #/acre	33
60# N 1974, 1975, 1976 & 1977	240 #/acre	40

Thus after four growing seasons the residual effect of N applied in 1974 was small. The residual effect of N applied in 1974 and 1975 was considerably greater.

Additional N applied in 1976 or 1977 doesn't appear as effective in producing foliage as the 1975 application. This data indicates that the most efficient N-fertilization program on this coarse-textured till may be to apply N in both the first and second growing seasons and then wait several years until the stand becomes quite N deficient before another N application.

Glacial Till - I-70 near Eisenhower Tunnel

These plots were established on cut slopes adjacent to I-70 in 1974. The till contains an estimated 70% rock and gravel. The sandy loam soil-sized material has a pH of 6.5, is low in extractable phosphorus and moderately low in exchangeable potassium. The N treatments were applied to existing grass stands established 2-3 years previously when the highway was constructed. The stands, dominated by smooth brome and timothy, were visually quite N deficient when the first N treatments were applied in June 1974. The N treatments broadcast in June as NH_4NO_3 were:

Control (No N)
50 pounds N per acre applied in 1974 (56 kg N per ha).
50 pounds N per acre applied in 1974 & 1975
50 pounds N per acre applied in 1974, 1975 & 1976
50 pounds N per acre applied in 1974, 1975, 1976 & 1977

Each treatment was replicated four times. Ground cover by living plants plus litter was estimated in August 1977 and is summarized below:

Treatment	Total N Applied	% Ground Cover
No N	0	10
50# N 1974	50 #/acre	35
50# N 1974 & 1975	100 #/acre	40
50# N 1974, 1975 & 1976	150 #/acre	35
50# N 1974, 1975, 1976 & 1977	200 #/acre	40

Thus the N application increased the ground cover 3 to 4-fold, however, there was no ground cover response to the N applied after 1974. It is assumed the stand was N fertilized and the year of establishment, thus the N applied in 1974 was probably the second N increment applied to these stands.

Our present interpretations of these field studies is that on very N-deficient coarse soil materials N should be applied the first growing season. Then maintenance N applied early in the second or third growing season. Thereafter maintenance N should be applied only when the plant color and decrease in ground cover indicate that N is needed, this might be at 3 or 4 year intervals. How long periodic N fertilization might be needed is unknown, but on critical sites subject to erosion this might be for some years.

So although periodic application of N can maintain ground cover it requires good long-term management and may become expensive in the long run. Also, periodic N application may limit natural succession, possibly of species with lower N requirements. Other approaches to the severe N-deficiency problems on exposed subsoils are:

Conservation and replacement of the surface soil
Use of N-fixing species
Planting species such as lodgepole pine which are less sensitive to N supply

These alternatives might be considered alone or in various combinations including N fertilization. Each of the alternatives are briefly discussed below.

CONSERVATION AND REPLACEMENT OF SURFACE SOILS

Interstate Highway 70 through the mountains west of Denver to Frisco is an excellent visual aid in demonstrating the effectiveness of topsoiling in maintaining vegetation on cuts and fills. Topsoiled areas generally support good stands of vegetation and abundant litter. Areas that have not been topsoiled, although they were initially fertilized and a fair to good plant cover established, support only thin N-deficient grass stands after 4 to 5 years.

Topsoiling can be moderately to very expensive, this depends among other things, upon the slope, vegetation, and type of disturbance. A major item in topsoiling is that it requires planning, good timing, and care during construction and placement. Here we will present information only on the N content of topsoil. The most comprehensive information on N in coarse-textured mineral soil profiles of the subalpine is in the Frazer Alpine soil survey report (USDA, 1962) and in the recently issued Taylor Park soil survey report (USDA, 1977). The N content of the mineral soil profiles analyzed in the above reports averages 2300 pounds per acre to a depth of 24 inches (2578 kg per ha to a depth of 61 centimeters). This is probably somewhat of an overestimate, as coarse fragments probably were discarded and the N analysis made on the soil-size material.

Of total N in the 24-inch (61 cm) depth soil profiles -

1/3 of the N is in the surface 3 inches (7.6 cm)
1/2 of the N is in the surface 6 inches (15.2 cm)
3/4 of the N is in the surface 12 inches (30.5 cm)

The above data does not include N in litter and humus which is commonly several inches thick on subalpine forested soils. Odegard (1974) reported an average of 450 pounds of N per acre (504 kg per ha) in the 10-13 inch (4-5 cm) thick organic horizons of soils supporting lodgepole pine on his study site at 10,000 feet (3,047 meters) in northern Colorado.

Thus conservation and replacement of the organic horizons and the top six inches (15 cm) of soil will result in replacing an average of about 1500 pounds of N per acre (1,681 kg per ha); or the equivalent to 30 applications of 50 pounds (56 kg) of N each. It must be pointed out that there is considerable variability in N content and depth among forested soils of the subalpine.

The forested soils tend to have a wide carbon to N ratio, thus the amount of N available to seedlings is limited. As a general observation, an application of N the first growing season and another several years later will ensure adequate nitrogen for establishment. After this time maintenance N should not be needed.

The N content of subalpine soils developed under herbaceous vegetation may be twice that reported above for the forested soil (USDA, 1977).

Costs of conserving and replacing topsoil will vary greatly. Gregg (1976) reported topsoiling costs on I-70 near Vail pass were $2,130 per acre for a minimum of 4 inches which was removed, stockpiled, and then replaced.

ESTABLISHMENT OF NITROGEN-FIXING SPECIES

Legumes are usually included in seeding mixes used in high-altitude revegetation. However, legume establishment is usually sparse, most stands are dominated by grasses. The problem in legume establishment possibly relates to several factors:

1. The legumes do not have as much seedling vigor as the grasses.
2. Legumes are more sensitive to the marginal plant-available phosphorus and potassium levels sometimes found in the coarse-textured soils.
3. On soils in the pH range of 4.5 to 5.5 grasses will survive but it is too acid for most legumes.
4. Coarse-textured soils have low water-holding capacity and thus are a drouthy media for legumes.
5. Some legume species used are not well-adapted to the subalpine.

After ten growing seasons, cicer milkvetch is the only introduced legume that shows much promise in plantings at 11,000 feet (3,350 meters) at Climax. Here the initial cicer milkvetch stands were sparse and growth was slow the first three growing seasons.

Legume establishment is being studied on 1976 fall seedings at Climax on adequately phosphorus and potassium fertilized disturbed soils and subsoils. All species were seeded at a very high rate (25 lb/acre or 28 kg/ha) and were inoculated with the appropriate *Rhizobium* for nitrogen fixation. After the initial growing season (1977) the results are:

Species	Plants/m of row 1/	Height 1/
Alsike clover	5.4	1 - 2"
Alfalfa	2.4	1 - 4"
Birdsfoot trefoil	2.2	½ - 1"
Cicer milkvetch	15.5	½ - 1"
Red clover	5.7	1 - 4"
White clover	1.3	½ - 1"

1/ 1 meter = 1.1 yard; 1 inch = 2.5 cm.

Thus, in this fall seeding, cicer milkvetch is the only species to show adequate initial stand establishment; although the seedlings are still extremely small after one growing season. Seedlings of all species were nodulcated.

At somewhat lower elevations (9,000-10,000 feet or 2,740-3047 meters) on fine-textured soils alfalfa has grown well on plots established in 1969 at Snowmass, and alsike clover has established well on ski trial seedings at Vail.

Cuany and Kenney report elsewhere in this publication on their studies on these and other legumes including the lupines.

Planting of nitrogen-fixing woody species might also be of interest. We have found nodules on the roots of russett buffaloberry (*Shepherdia canadensis*) in native stands in the subalpine but know of no plantings of this species on nitrogen-deficient sites. Some species within the genus *Ceanothus* are known nitrogen-fixers, thus the native species within this genus might be investigated. Alder is also a known nitrogen-fixer, however, most sites to be revegetated in the subalpine are too dry for the native alder.

ESTABLISHMENT OF WOODY SPECIES

Certain shrubs and trees, although not known to be nitrogen-fixers, appear to be well-adapted to nitrogen-deficient sites. Rose invades some very infertile coarse-textured materials in the subalpine. Lodgepole pine establishes naturally on very infertile sites. Lodgepole plantings made in the early 1970's on coarse infertile soil materials along I-70 east of the Eisenhower Tunnel are now growing well. Thus it appears that much more emphasis should be given to woody plantings on sites where herbaceous ground cover is not needed for erosion control. Plummer (1976) lists 20 woody species that have shown promise in subalpine plantings, however, the fertility requirements are not given.

SUMMARY

In summary, nitrogen deficiency is the most persistent soil fertility problem commonly encountered in revegetation of coarse-textured subsoils and glacial tills in the subalpine. Nitrogen fertilization can temporarily correct the deficiency but in most cases maintenance N application will be required. Our studies indicate that yearly N application is inefficient and that maintenance N should only be applied when plant color and diminishing ground cover indicate that N is needed.

Conservation and replacement of surface soils, establishment of N-fixing species, and/or establishment of less N sensitive woody species are other management approaches to be considered on these N-deficient sites.

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DISCUSSION

QUESTION: What type of nitrogen fertilizer do you recommend?

BERG: In all of our studies we used ammonium nitrate fertilizer. Some studies have been put in on slow release nitrogen fertilizers. The studies are not extensive, but the results so far are not promising. At this time, I can not recommend the use of slow release nitrogen fertilizers.

CUANY: Is the good performance of the lodgepole pine on the disturbed road cut due to mycorrhizal associations?

BERG: In general the mychorrhizal association is known to increase the availability of phosphate. As far as I know, no one has shown that mycorrhizae increase the availability of nitrogen or that they fix nitrogen.

KAY: Do you need to apply 50 pounds of nitrogen each year for 2 years; or could you apply 100 pounds of nitrogen in the ammonium form the first year and get the same results?

BERG: In general, you can not. In my experience on the coarse-textured subalpine soils the extra unused nitrogen will be lost the first year.

MULCHES FOR EROSION CONTROL AND PLANT ESTABLISHMENT ON DISTURBED SITES

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ABSTRACT

Mulching increases plant establishment and protects the disturbed site from erosive forces. Seed coverage (mulching with soil) is the single-most important practice. Mulches commonly used are organic fibers (straw, hay, wood-cellulose fibers applied by hydromulching, wood residues as wood chips and bark), fabric or mats, soil, and rock. Proper use of each mulch is discussed, including rate, method of application, and limitations.

The choice of mulch treatment or product is determined by site characteristics, availability of products, costs, and effectiveness. For the costs involved, straw and hay offer the best results in both protection and encouragement of plant growth if resulting weeds or fire hazards are not a problem. Hydraulic mulching offers a weed-free mulch of low fire hazard, with possible labor-saving in application methods, but it is not always as effective as straw.

Chemical soil binders, humectants, and fiber tackifers may be very effective for initial stabilization. These products are applied hydraulically and are usually improved by the addition of good-quality wood fiber.

Wood residues such as bark or wood chips are less effective per unit of weight than straw and may easily discourage plant growth if applied at excessive rates. Fabrics and mats may be very effective if properly anchored, though problems of maintaining soil contact on rough surfaces sometimes allow excessive erosion beneath the mat.

To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

Soil mulches are very effective, and are often inexpensive to obtain simply by leaving a rough seedbed or by benching steep slopes during construction. Soil mulch may avoid premature germination caused by other mulches in the absence of adequate moisture for continued growth. Gravel mulch reduces erosion and encourages invasion of indigenous plants even on very dry sites.

The effectiveness of mulches for erosion protection and plant establishment is compared with costs. Long fibers (such as straw) are shown to be a good investment compared with short fibers, chemicals, or mats.

I. INTRODUCTION

Mulching nearly always shortens the time needed to establish a suitable plant cover. The conventional mulches of agricultural or industrial residues have recently encountered competition from many chemical stabilizers or mulches introduced largely as supplements to the increasingly popular hydraulic methods (hydroseeding-application of a water slurry of seed, fertilizer, mulch, etc.).

Seed coverage with soil to the proper depth is essential in dry regions. Mulch, particularly hydromulching, is sometimes substituted for seed coverage when moisture is adequate. Showing the most promise in excessively dry areas are mulches applied after seed has been covered to the proper depth with soil, as with a grain drill (Springfield 1971).

Mulches can both protect soil and enhance plant establishment. The soil is protected by shielding it from raindrop impact, retarding water flow and soil movement by trapping silt on the sites, increasing water penetration, and somtimes shedding water. Properly anchored, mulches may reduce wind velocity. They enhance plant establishment by holding seed and fertilizer in place, retaining moisture, preventing crusting, and modifying temperatures.

Mulches on dry sites may also encourage plant suicide! Properly mulched seeds may often be fooled into germinating with the first rainfall and soon die from lack of sufficient moisture for continued growth. The use of soil mulch (seed coverage) is probably the best insurance against such a calamity. Soil which is sufficiently wet for a long enough period to effect germination is more likely to sustain plant growth than is a surface organic mulch or chemical. Also planting as near as practical to a date when adequate moisture is expected may avoid this problem.

II. ORGANIC MULCHES

Organic mulches are often an agricultural crop residue or industrial by-product. The price usually reflects transport and handling cost more than any intrinsic value of the product.

Most organic mulches require additional nitrogen to compensate for the tie-up of nitrogen in the decomposition process.

Effectiveness is roughly related to the size and shape of the mulch particles. Long narrow particles are superior to finely ground products. Following is a discussion of the organic mulches commonly used.

A. *Straw and Hay*

Straw and hay are the mulches used most often in the West. Cereals are a major crop in dry regions of the United States, and straw left on the site of production is often considered a liability because its decomposition ties up nitrogen needed for the next crop. Straw availability should be increased by current restrictions on removing this crop residue by burning in place. Clean grain straw, free of noxious weeds, is preferred. The straw can be expected to contain 0.5 to 5.0% cereal seed by weight, which may result in considerable plant cover in the first year. This provides additional erosion protection but may also be prohibitively competitive with the planted erosion-control or beautification mixture. Rice straw is sometimes used because neither the rice nor associated weeds can be expected to grow on most unirrigated disturbed lands. In areas where cereal crops are not common, hay is sometimes used but is normally more expensive than straw. Wild-grass hay may be a valuable source of native plant material if cut when the seeds are ripe but not shattered.

The mulch effect of straw can be expected to increase plant establishment. Meyer et al. (1971) obtained fescue-bluegrass establishment of 3, 28, and 42% with respective surface straw mulch treatments of 0, 1, and 2 tons/acre. Comparisons of straw with hydromulch show that straw mulch produced the best grass stands (Kay, 1974; Perry et al., 1975) (see Table 2 of this report).

Straw can be applied with specially designed straw blowers or spread by hand. Commercial mulch spreaders or straw blowers advertise a capability of up to 15 US tons/hour and distances to 85 ft. The length of the applied straw may be important and can be controlled in most blowers by adjusting or removing the flail chains. Baled straw may also be relatively long or short, depending on agricultural practices. Straw to be crimped or punched should be relatively long to be incorporated into the soil effectively and still leave tufts or whisker dams. Rice straw is wiry, does not shatter readily, and consequently does not blow as well as straw of wheat, barley, or oats. It may come out of the blower in 'bird nests.' Blown straw (other than rice) lies down in closer contact with the soil than hand-spread straw and is anchored more successfully with a tackifier (substance sprayed on straw to hold it in place). Wind is a serious limiting factor in applying straw, though it can be an asset in making applications downwind. Dust, a problem in urban areas, can be overcome by injecting water into the airstream used to blow the straw.

The amount of straw to be used will depend on the erodability of the site (soil type, rainfall, length and steepness of slope), kind of straw (Grib, 1967), and whether plant growth is to be encouraged. Increasing rates of straw give increasing protection. Meyer et al. (1970) show that as little as 1,000 lb/acre reduced soil losses by two-thirds, while 4 US tons/acre reduced losses by 95%. Straw to be crimped is commonly used at 2 US tons/acre, while straw punched into fill slopes in California is at 4 US tons/acre in a split application and rolling operation (2 US tons/acre each). Straw to be held down with a net should be limited to 1.5-2 US tons/acre, and straw held with a tackifier at 1-1.5 US tons/acre if plant growth is important. Too much straw may smother seedlings by intercepting all light or forming a physical barrier. Also, some grass straw (notably annual ryegrass, Lolium multiflorum) may contain inhibitors that have a toxic effect if used in excess. A good rule of thumb is that some soil should be visible if plant growth is wanted. Higher rates of straw may of course still satisfy these requirements if the straws are vertically oriented (like tufts) by crimping or punching. Excessive straw on the surface may be a fire hazard.

Straw or hay usually needs to be held in place until plant growth starts. The problem is wind, not water. Water puddles the soil around the straw and helps hold it in place. Also, wet straw "mats down" and is not easily moved. Common methods of holding straw in place are crimping, disking, or rolling into the soil; covering with a net or wire; or spraying with a chemical tackifier. Swanson et al. (1967) found similar protection from prairie hay applied as a loose mulch or anchored with a disk packer (crimper).

Crimping is accomplished with commercial machines which utilize blunt notched disks which are forced into the soil by a weighted tractor-drawn carriage. They will not penetrate hard soils and cannot be pulled on steep slopes.

Rolling or "punching" is done with a specially designed roller. A sheepsfoot roller, commonly used in soil compaction, is not satisfactory for incorporating straw. Specifications of the California Department of Transportation contain the following provisions (State of Calif. 1975): "Roller shall be equipped with straight studs, made of approximately 7/8 inch steel plate, placed approximately 8 inches apart, and staggered. The studs shall not be less than 6 inches long nor more than 6 inches wide and shall be rounded to prevent withdrawing the straw from the soil. The roller shall be of such weight as to incorporate the straw sufficiently into the soil so that the straw will not support combustion, and will have a uniform surface."

The roller may be tractor-drawn on flat areas or gentle slopes, whereas on steeper slopes with top-of-slope access the roller may be lowered by gravity and raised by a winch in yo-yo fashion, commonly from a flat-bed truck. Requirements are soil soft enough for the roller teeth to pentrate, and access to the top of the slope. This is a common treatment on highway fill slopes in California. It can be used on much steeper slopes than a crimper. Punched straw may not be as effective as contour crimped straw, because of the staggered arrangement of tucked straw instead of the "whisker dams" made by crimping (Barnett et al., 1967).

A variety of nets have been used to hold straw in place: twisted-woven kraft paper, plastic fabric, poultry netting, concrete reinforcing wire, and even jute. Price and the length of service required should determine the product used. These should be anchored at enough points to prevent the net from whipping in the wind, which rearranges the straw.

Perhaps the most common method of holding straw, particularly in the eastern U.S., is use of a tackifier. This method may be used on relatively steep slopes which have limited access and soil too hard for crimping or punching. Asphalt emulsion, the tackifier used most commonly, is applied at 200-500 gal/acre--either over the top of the straw or applied simultaneously with the straw blowing operation. Recent tests (Kay, 1976) have shown that 600 gal is superior to 400 gal, and that 200 gal/acre is not satisfactory. Wood fiber, or new products used in combination with wood fiber, have been demonstrated to be equally effective, similar in cost, and environmentally more acceptable (Table 1). Terratack I is a gum derived from guar, Terratack II is semi-refined seaweed extract, and Ecology Controls M Binder is a gum from plantain, *Plantago insularis*. The remaining products are emulsions used in making adhesives, paints, and other products. Though wood fiber alone is effective as a short-term tackifier, glue must be added to give protection beyond a few weeks. Increasing the rate/acre of any of the materials will increase their effectiveness.

Table 1. Effect of tackifier products on wind stability of barley straw broadcast at 2,000 lb/acre.

Product	Rate/acre Chemical	Fiber-lb	Water-gal	Wind speed (mph) at which 50% of straw was blown away
None				9
SS-1 asphalt	200 gal			40
SS-1 asphalt	400 gal			80
SS-1 asphalt	600 gal			84++
Fiber only		484		47
Fiber only		736		84
Fiber only		986		84++
Terratack I	45 lb	150	750	68
Terratack II	90 lb	300	1500	84++
Ecology Control M-Binder	100 lb	150	700	84+
Styrene butadiene copolymer emulsion	60 gal	75	400	84
Polyvinyl acetate	100 gal	250	1000	54
Copolymer of methacrylates and acrylates	100 gal	250	1000	76

B. *Hydraulic Mulching*

Hydraulic mulching, or hydromulching, is a mulch applied in a water slurry. This same slurry may also contain seed, fertilizer, erosion-control compounds, growth regulators, soil amendments, etc., and is increasingly popular because of low labor requirements. Mulches must have a particle size small enough for ready pumping through 0.5-inch nozzles, and must not be too buoyant to remain in suspension with moderate agitation. Used most commonly are specially manufactured fibers of alder and aspen. Hemlock, also used, is more difficult to pump. Many recycled paper and agricultural products have been marketed or tested. Among those marketed are office waste, corrugated boxes (PFM), chopped newspaper, and seed screenings. Also tested by the author were whole and ground rice hulls, ground cereal straw, and washed dairy waste.

The most important quality of a hydromulching material is that it must adhere to the soil even on steep slopes and hold the seed in place during heavy rainfall impact and wind. If it fails in those functions, other characteristics (water-holding capacity, appearance, cost, etc.) are not important.

Hydromulching materials have been tested (by the author) by applying them to the surface of greenhouse flats of 13 x 19 in. filled with decomposed granite. The flats were inclined at 45^{o} (1:1 slope) and subjected to artifical rainfall of 3-mm drops falling 15 feet from a 1-inch grid at 6 in. of water/hr. Virgin wood fibers of aspen and alder offered considerable soil protection and were consistently superior to all other products. The only recycled products to approach their effectiveness were the PFM products made from corrugated boxes. One lot of these fibers had been separated on the basis of length, with the shorter fibers being recycled into other paper products. These longest fibers were at least equal to the virgin wood fibers. Tests of commercial PFM products, however, do not always produce such satisfactory results, apparently because they contain a high proportion of short fibers. Commercial materials made of office waste, newsprint, and seed screenings are vastly inferior. These and other recycled materials wash from the slope with the first raindrops. A satisfactory material could probably be made from recycled material if more attention were paid to fiber length.

Working with Mr. Tom Miles of the Oregon Field Sanitation Committee, we found that a satisfactory hydromulch can be made from fibers of grass or cereal straw. Fibrated straw is manufactured by presteaming chopped straw and refining this through rotating close-tolerance discs and drying. Tests show that the process effectively eliminated the allelopathic (germination-depressing) characteristics of ryegrass straw. Fibrated rice straw also makes a satisfactory hydromulch, more resistant to raindrop impact than fiber made from ryegrass.

Another important property of mulch is its moisture-holding characteristics. A standard procedure for measuring this characteristic has been developed by the California Department of Transportation (Hoover 1976). In general, products with the longest fibers and best slope-adhering characteristics also have the highest moisture-holding capacity.

Commercial fibers are usually dyed with a fugitive green dye which lasts only a few hours or days. This visual aid assists in obtaining an even distribution on the slope.

Rates of hydromulch vary from 500 to 3,000 lb/acre. The rate of 500 lb/1,500 gal water is suggested as necessary to disperse seeds evenly in the slurry, and to protect seed in passing through the centrifugal pumps commonly used in hydraulic seeders (Kay, 1976). This would cover one to three acres, with best coverage on one acre and possible distribution problems if used on three acres. A minimum of 1,000 lb/acre is necessary to hold the seed on a slope. An inconsistent "mulch effect" has been observed with less than 1,500 lb/acre. Currier (1970) expressed some concern that "60-70% of the seed hangs up in the mulch and has little or no chance to get its primary roots into mineral soil." Studies with wood fiber (Kay, 1973) showed that under conditions of adequate moisture, small grass seeds such as Durar hard fescue could emerge through as much as 9,000 lb and readily emerge from between two 1,000-lb layers. Placing the seed on top of 2,000 lb speeded emergence and total germination of orchardgrass and did not reduce emergence of any of the other five species tested.

Under conditions of limited moisture, created by applying the mulch over seed broadcast on greenhouse flats filled with various problem soils, inclining the flats at slopes of 1:1, 1.5:1, or 2:1 (horizontal to vertical measurement) and exposing them to natural rainfall yielded the data in table 2. On the steepest slopes (1:1 and 1.5:1), 1,000-2,000 lb of fiber was necessary to hold the seed in place. Without that amount, no seedlings were established. On the flatter 2:1 slope, the 1,000-lb rate did not improve the stand whereas 2,000 lb did. Increasing the rate to 3,000 lb increased the number of seedlings on the most severe test with either decomposed granite or fine sand. In recent tests by the author near Lake Tahoe, California, 4,500 lb resulted in good grass stands, while 3,000 lb produced only a few seedlings, because of excessive frost heaving.

Wood fiber is an essential addition to most hydraulically applied chemicals, including straw tackifiers. Many soil-binding chemicals will not hold seed, fertilizer, or straw to a slope unless wood fiber is included.

Table 2. Effect of hydromulch fiber rate or straw on emergence of blando brome (*Bromus mollis*) on different soils and slope gradients.

		No. seedlings/ft^2					
		Decomposed granite				Clay loam	Fine sand
Treatment	Approx. lb/acre	2:1	1.5:1	1:1	1:1	1:1	1:1
None		7	1	0	0	0	0
Wood fiber	1,000	6	13	10	0	86	0
Wood fiber	2,000	26	29	27	14	262	3
Wood fiber	3,000	35	35	20	58	300	16
Straw + tackifier	2,000	119	131	155			
LSD 0.05		11	8	8	11	68	10

C. Wood Residues

Wood residues (woodchips and bark) can be used effectively if locally available as a waste from the forest-products industry or chipped on the site during land clearance. Smaller wood-residue particles, such as shavings or sawdust, would be subject to wind loss. Woodchips and bark can be applied with a conventional straw-blower to a distance of 18 m (Emanuel 1971). The rate must be twice that of straw to obtain the same soil protection (Meyer et al., 1972) or even as much as 6 times the straw rate (Swanson et al. 1965). Observations in California indicate that uneven distribution often results in poor or no plant establishment in the heavier (100% ground cover) applications.

D. Fabric or Mats

Fabric or mats, including jute, exelsior, and woven paper or plastic fibers, are provided in rolls to be fastened to the soil with wire staples. Fiberglass roving (which is blown on with compressed air and tacked with asphalt and emulsion) is also available as a nonbiodegradable substitute. Use of these products is limited by their cost and effectiveness. The rolls require high labor inputs for installation, cost at least four times as much as tacked straw, and are not adapted to fitting to rough surfaces or rocky areas. Erosion from beneath these products is common because they do not have intimate contact with the soil. They must be heavy enough or anchored in enough spots to prevent wind whipping. Several reports indicate they are not as effective as straw (Springfield, 1971). They have the advantage of being weed-free but may be unsightly, a fire hazard, or (in some cases) nonbiodegradable or too rapidly biodegradable to be effective. Dudeck et al. (1970) found excelsior mat or jute to yield the best seedling grass of eleven mulch treatments tested. Swanson et al. (1967) found jute, excelsior, and priairie hay or fiberglass anchored with asphalt emulsion to be the best of all treatments.

Mats would be used only on small areas, such as to repair failures of other treatments, where time and cost factors are of secondary importance. They should be maintained, repairing tears, etc., before wind or water can cause extensive damage.

III. CHEMICALS

Chemicals to be used as a mulch, humectant (a substance that absorbs or helps another substance retain moisture), or soil binder are usually applied in a water carrier or as part of a hydraulic seeding slurry.

They are expensive and very specialized, and must be used correctly for maximum effectiveness. They are not substitutes for sound agricultural or engineering practices, regardless of glowing advertisements. Products are discussed here as either fiber tackifiers (including humectants) to be used as part of a seeding, or plastic emulsions which may be used with a seeding or alone as a soil binder.

A. *Fiber Tackifiers*

Fiber tackifiers are generally advertised to hold fiber in place, promote germination, hold moisture, and retard erosion. Most sales literature acknowledges that fiber should be used with the product. Within this group we have tested Ecology Controls M-Binder, Kelgum, Terratack I, Terratack III, Styrene butadiene, Super Slurper, PVA, and Verdyol Super.

Although virgin wood fibers as a hydraulic mulch adhere well to slopes without the addition of glues or tackifiers, interest continues in products which would improve their resistance to wind or rain. Of the variety of products previously tested, only a few improved the fiber characteristics, and then only slightly or inconsistently. Most products do make the slurry easier to pump, allowing the addition of more fiber/load.

Most existing products are sensitive to fertilizer. Adding 16-20-0 ammonium phosphate-sulfate at 500 lb/acre to 1,500 lb of wood fiber greatly reduced the effectiveness of Terratack III (an alginase), Ecology Controls M Binder (husk of Plantago insularis), PVA (polyvinyl acetate homopolymers or vinyl acrylic copolymers), Super Slurper, and SBR (styrene butadiene) (Figures 1 and 2). These and all following tests involved applying treatments to greenhouse flats, inclining the flats at 1:1 after curing, and exposing them to artificial rainfall of 3-mm drops at 6 inches/ hour.

New Products

Two new products promise to be much more effective than those previously tested. The two products are of very different composition, an improved SBR (styrene butadine) and Super Slurper, an absorbent polymer made from starch. Several SBR products are sold for erosion control. The available SBR products differ considerably in pH (acidity) and can therefore be expected to perform quite differently. The product tested in the current studies is XFS 4163-L Dow mulch binder, a liquid which utilizes a dry powder modifying agent (methyl cellulose). Super Slurper, a USDA patent, promises to have many uses. This dry powder is

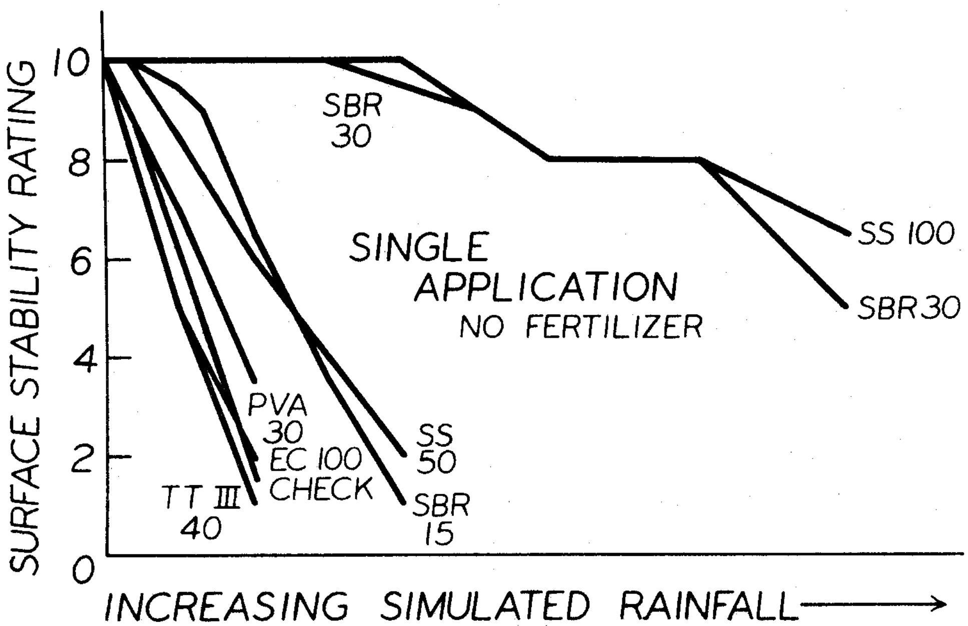

Figure 1. Effect of increasing exposure to simulated rainfall on the surface stability of decomposed granite surfaces treated with erosion-control chemicals without fertilizer. EC (Ecology Controls M Binder, 100 lb/acre), PVA (Amsco 3011, 15 gpa), TT III (Terratack III, 40 lb/acre), SS (Super Slurper at 50 and 100 lb/acre, and SBR (Dow XFS-4163-L at 15 and 30 gpa). Surface stability is rated from 1 (no protection) to 10 (completely stable).

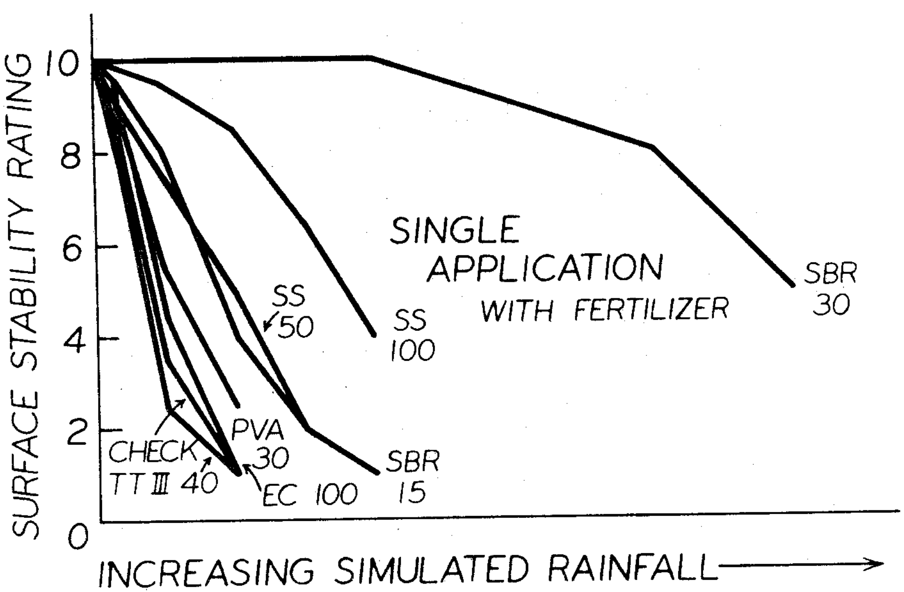

Figure 2. Same treatments as figure 1 except slurry contained fertilizer (16-20-0 at 500 lb/acre).

reported to be able to absorb up to 1,000 times its weight in water. The sample tested is SGP absorbent polymer from General Mills.

Applications of Super Slurper or Dow SBR without fertilizer in a slurry with 1,500 lb/acre fiber have shown their superiority to other products (Figure 1). Super Slurper at 100 lb/acre is comparable to SBR at 30 gal/acre, but even one-half these amounts is superior to the old products. Super Slurper will require use of about twice as much water/acre as would normally be used to apply wood fiber at these rates.

Super Slurper in a fiber slurry is much less effective when used with fertilizer (Figure 2). SBR, in contrast, is made only slightly less effective by fertilizer. Previously tested was another SBR product which was seriously affected by fertilizer in that rubber balls were formed when fertilizer was added.

These two products are quite different in the form they take. SBR cures to a crust or film, whereas Super Slurper does not cure, but forms a viscous water-absorbing surface if moisture is present.

New Methods

Recent tests have shown that applying a quality glue after the hydro-seeding-mulching operation, in the same manner that tackifiers are applied to straw, is many times as effective as including the glue in the hydro-seeding-mulching slurry. Particularly effective was the Dow Mulch Binder XFS 4163-L. Rates as low as 20 gpa with 0.75 lb modifier and 86 lb of wood fiber in 344 gal water as a tackifier over 1,500 lb of fiber with seed and fertilizer gave a surface that was more resistant to rainfall impact than 60 gpa applied in the single slurry (Figure 3), or resistant for a much longer period than 20 gal in a single application (Figure 4). Similarly PVA applications were improved by a split application. Super Slurper performance was similar in single or split applications (Figure 5). Plant emergence or growth were not adversely affected by splitting the application of any material. Germination may be reduced and delayed by use of fertilizer with SBR. Using higher rates of seed will compensate for this loss. The low total volume of SBR required will call for careful application.

There is a hazard to the seed in using highly effective mulches or additives. These products or combinations may retain enough moisture to allow germination when the moisture in the soil is too low to permit establishment. Simply covering the seed with soil may be more effective in that the seedbed will remain dry until enough moisture is available for both germination and growth. Where enough moisture for growth is present or can be provided, Super Slurper might help keep the soil surface moist during the germination period.

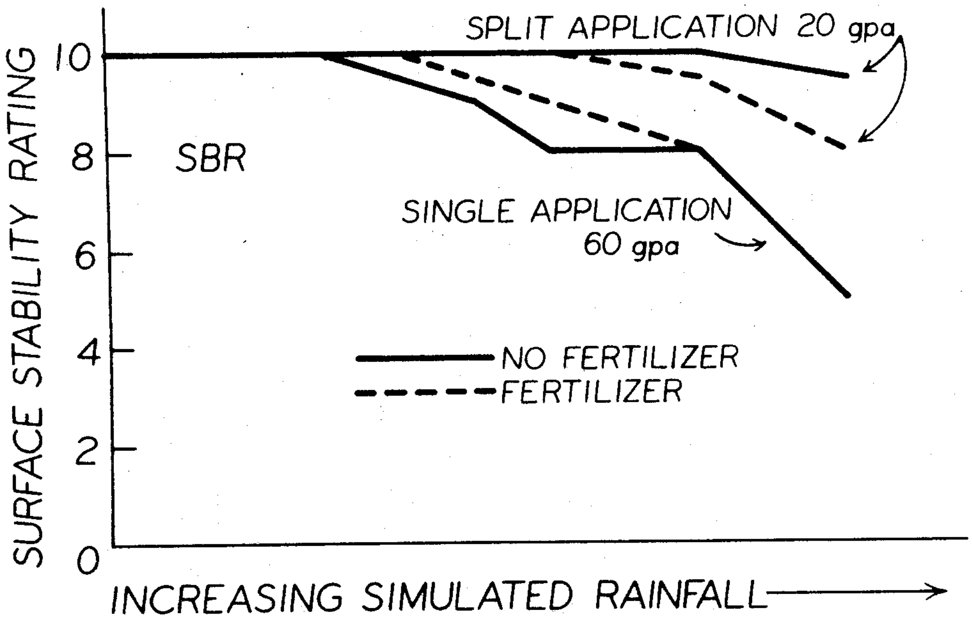

Figure 3. Effect of increasing rainfall on surfaces treated with a single application of SBR at 60 gpa and split applications of SBR at 20 gpa, with and without fertilizer.

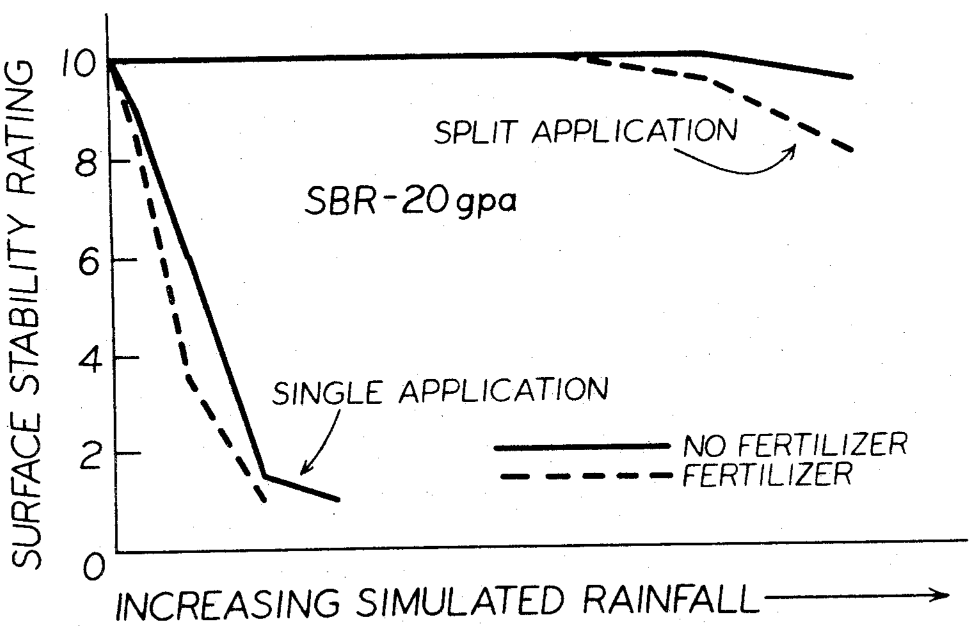

Figure 4. Effect of increasing rainfall on surfaces treated with SBR at 20 gpa, comparing single and split applications with and without fertilizer.

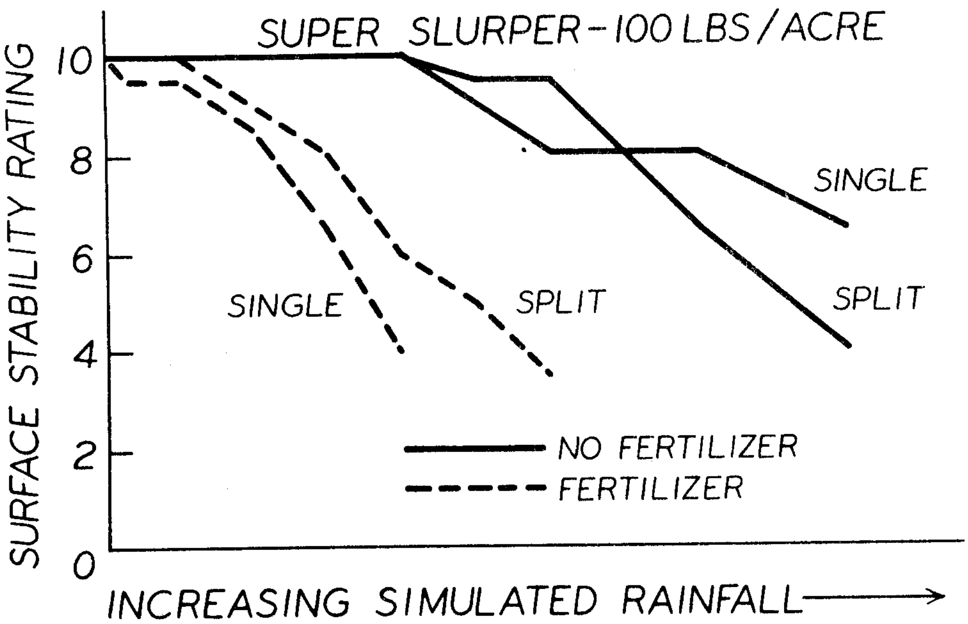

Figure 5. Effect of increasing rainfall on surfaces treated with Super Slurper in single and split applications, with and without fertilizer.

B. *Soil Binders*

Plastic emulsions have been used for about a decade to bind surface soil particles for protection from wind and water erosion. Their use has been limited, however, by relatively high cost and by numerous reports of ineffectiveness and negative effects on plant establishment (Sheldon and Bradshaw 1977). Among the emulsions used are polyvinyl acetate homopolymers or vinyl acrylic copolymers, generally called PVA. Commercial versions are Aerospray 70, Crust 500, Curasol AK, Enviro, MGS, Stickum, Terra Krete, and Soil Bond. Soil Seal, similar in effectiveness, is a copolymer of methacrylates and acrylates. Another chemical group is styrene butadiene (SBR). All are an intimate mixture of high-molecular-weight polymeric particles dispersed in a continuous aqueous phase. They are basic ingredients in paint, glue, and other products.

1. Effectiveness and rate

Plastic emulsions give better initial protection than do other commonly used erosion-control practices. The optimum rate determined by the California Department of Transportation is 1,000/lb acre of dry solids (about 200 gpa) for the polyvinyl acetates (750-1,100 lb/acre on various soils). Most emulsions are about 9 lb/gal and 55% solids. Recent tests compared PVA with an experimental SBR from Amsco Division

Union Oil Company at rates of 500 and 1,000 lb/acre solids, SBR at 500 lb was similar in effective ness to PVA at 1,000 lb.

2. Dilution rate

All products tested to date are sold as a liquid concentrate to mix with water. The amount of water used is critical. Figure 6 illustrates the relative effectiveness of dilution rates of 5:1 (water to PVA concentrate) to 40:1 at 1,000 lb of PVA solids per acre.

Dilutions of 5:1 to 10:1 PVA are obviously far more effective than higher dilutions (Fig. 6). Comparison of dilution rates of 1:1 with 10:1, show 4:1 to be too little water, with 5:1-7:1 optimum, 8:1 and 9:1 satisfactory, and 10:1 less effective. All of the above tests were conducted on dry sand. Emulsions were applied to a horizontal surface of 13 x 19 inches and allowed to cure at about 60 F for at least two days. The surface was then inclined at 1:1 (steeper than the natural angle of repose of sand). The surface was then exposed to artificial rainfall at 6 inches/hr, 3-mm drops, or 6 inches/hr composed of 2 inches/hr, 2-mm drops, plus 4 inches/hr as a mist. Some treatments survived over 120 inches of the latter type of rainfall.

The optimum dilution rate could be expected to be different with other products, on other soil materials, and with other soil-temperature and moisture conditions. Optimum dilution is far less critical for SBR. Tested were 6:1, 12:1, 24:1, and 36:1 at 500 lb/acre soilds. The lower three dilution rates, all equally effective, were superior to the 36:1 dilution.

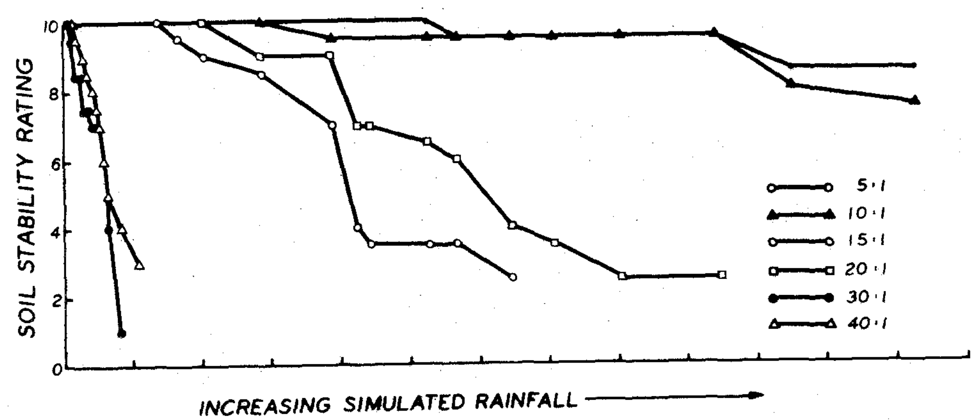

Figure 6. Effect of simulated rainfall on the surface stability of sand treated with 1,000 lb/acre PVA solids at various dilution rates.

The poor performances of commercial applications can often be traced to the use of too much water. When the emulsion is applied as a component of hydroseeding, a frequent practice, the water required to carry the wood fiber and other components is often greater than the desired PVA dilution. Hydroseeding machines will normally pump 3-5% fiber by weight. If the contract called for 1,500 lb fiber and 200 gpa PVA the dilution rate would be 30:1 at 3% and 18:1 at 5%. (Both the liquid and solid effect of the PVA as well as the possibility of an easier pumping effect of PVA are ignored in these calculations as a safety factor to avoid a plugged hydroseeder full of expensive components.) This means that the PVA must be applied separately--after the first application (containing the fiber, seed, and fertilizer). A material which is less restrictive as to dilution rates would then be advantageous by allowing a single rather than split application. However the benefits discussed earlier of split applications allowing reduced chemical rates should easily make up for the cost of a second application.

3. Curing of emulsion film

A primary limitation of emulsions is the restriction placed on curing. The minimum curing temperatures generally recommended are 55 F for PVA and 40 F for SBR. Also required are proper drying conditions. Fog will prolong by many days the curing time of either emulsion, and rain before the emulsion is properly cured may prove the crust to be ineffective. A logical use of the materials would be when the construction project is halted for the winter. Unfortunately, however, weather conditions which halt construction are the same as those which slow the curing of emulsions.

4. Effect on plants

Plastic emulsions are not generally toxic to plants even if sprayed directly on them. They commonly reduce establishment, however, and delay emergence of grass seedlings. Grass seedlings may have a tip burn. These problems are apparently the effect of fertilizer used with the emulsion and seed, rather than the emulsion itself, and are particularly a problem on sandy soils, and not on clay soils. Fertilizing separately, after seeds have germinated, has avoided the problem of fertilizer burn.

The most practical way so far of offsetting reduced seedling numbers has been to increase the seeding rate. Doubling the rate of Blando brome from 50 lb to 100 lb/acre has generally compensated for plant losses due to fertilizer, and sometimes resulted in an increase in numbers, ground cover, and pounds of grass growth. Wood fiber is an essential part of an emulsion treatment, particularly if seeds are used. PVA emulsions will not stick seed or fertilizer to a soil slope. Unless a fiber is added the seed and fertilizer will wash off readily. Do not apply fiber and seed after the emulsion, for they will wash off.

5. Other considerations

Freezing temperatures destroy all uncured emulsions. Biological activity also may limit the storage life of emulsions. Crusts formed by emulsions may shed most of the rainfall. Therefore they may limit plant establishment and growth in low-rainfall areas and soils of low water-holding capacity. Crusts are not self-healing. The treated area must be protected from vehicles and animals, and breaks should be repaired. Crusts will not survive frost heaving. The emulsion could be used very effectively with transplanted shrubs. A soil-active herbicide could be used with them to provide a weed-free erosion-control program.

IV. SOIL AND ROCK MULCHES

Soil and rock mulches are often overlooked as the most practical solution to plant establishment and soil protection problems. The microsites created by rough seedbeds or rock provide seed coverage, separation of seed and fertilizer, and a mulch effect.

The importance of microsites to the establishment of plants was illustrated by Evans and Young (1972). In their Nevada study, seedling emergence and the growth of downy brome, medusahead, and tumblemustard were favored by seed burial, pitting of the soil surface, and soil movement. Air temperatures were continuously measured at the soil surface and 3 cm above, and soil moisture from the surface to 1 cm deep, and at 3 cm. Results showed that depressed sites retain moisture longer at the surface and have more favorable atmospheric moisture and temperature regimes than the flat soil surface. Conditions are also created for more adequate soil coverage of the seeds, which in turn further modified their environment.

A practical approach on steep slopes, such as highway cuts, is the use of benches, serrations, or simply rough grading. The rough effect can often be achieved by simply eliminating the final grading operation. Special pitting equipment is available for nearly-level sites. "Track walking" (walking a tractor on a slope to create cleat marks) is widespread and very effective.

Mulches of crushed stone or gravel one inch deep provided more effective erosion control than 4,000 lb/acre of straw, and heavier rates of stone were even more effective (Meyer et al., 1972). Field observations in Nevada and California also show a ground-cover of gravel to be effective for reducing wind and water erosion and encouraging invasion by indigenous plant species.

V. RELATIVE EFFECTIVENESS AND ECONOMICS

Mulching practices vary considerably in cost and effectiveness. Sometimes the characteristics of the site to be stabilized determine the only practical treatment. Usually, however, there are alternative methods which should be considered.

Seed coverage and mulch should be the first consideration. Seed germination and plant establishment will be improved more by seed coverage than by any other treatment. Mulch treatments increase in effectiveness with both the amount of mulch per acre and the length of the fiber. While it is possible to apply excessive amounts of mulch, economic considerations usually prevent it. The importance of fiber length, however, should not be overlooked. Increasing the fiber length (as from wood cellulose fiber to straw) may greatly increase the effectiveness of erosion control and germination (Kill et al., 1971; Perry et al., 1975). This relatively large increase in effectiveness can be achieved at little or no increase in cost. Even increasing the length of wood-cellulose fiber from a recycled paper product to virgin wood fiber improves results with little effect on cost. Table 3 (adapted from Kay, 1976) compares relative effectiveness and costs as observed on roadside erosion-control projects in California. Ranges of cost figures are based on conversations with contractors and review of California Department of Transportation contracts bids (all bids, not just low bids) for the 1973-1975 period. Labor costs are at union scale.

The most expensive practice is not necessarily the most effective. For example, straw plus a tackifier is more effective for both erosion control and plant establishment than many of the more expensive treatments. A rough seedbed or covering the seed may be the cheapest and most effective treatment for establishing vegetation.

Table 3. Summary of methods and costs of common erosion-control practices.

Treatment	Comments	Pregermiation erosion effectiveness*	Effectiveness on plant establishment*	Approx. cost per acre $**
1. Seed and fertilizer broadcast on the surface, no soil coverage or mulch.	Inexpensive and fast. Most effective on rough seedbeds with minimum slope and erodability where seed will cover naturally with soil. Suitable for remote or critical areas where machinery cannot be taken.	1	1-4	250
2. Hydroseeding or hydromulching (seed + fertilizer) with 500 lb wood fiber, 1,500 gal water/3 acres.	Similar effectiveness to braodcasting seed and fertilizer. Not enough fiber to hold seed in place or produce a mulch effect. Seed distribution would be improved by increased volume of water.	1	1-4	250
3. Seed and fertilizer broadcast and covered with soil (raking or dragging a chain, etc.).	Does not require special equipment. Generally a very effective treatment. Labor cost is high on areas not accessible by equipment.	1	3-4	320
4. Hydromulching with 1,500 lb/acre wood fiber (plus seed and fertilizer).	Most common hydromulch mix in California. Advantages include holding seed and fertilizer in place on steep and smooth slopes where there may not be an alternative method. Only a minimal mulch effect. Cost is much higher than 2.	2	3-5	425-520
5. Hydromulching with 1,500 lb woodfiber plus an organic glue: Ecology Control, Terratack III etc., plus seed and fertilizer.	The addition of an organic glue will sometimes improve fiber holding and germination. Does not increase labor or machinery cost.	2+	3-6	550-650
6. Hydromulching with 2,000-3,000 lb/acre wood fiber plus seed and fertilizer.	Produces a true mulch effect and some erosion protection. Commonly better results than 1,000 lb fiber or fiber plus glue.	2-3	4-7	530-750
7. Seed and fertilizer broadcast and covered with soil as in 3 above, but followed with hydromulch of woodfiber at 2,000-3,000 lb/acre.	Very effective, combines advantages of seed coverage and mulching.	2-3	6-8	680-865

All of the above treatments offer only minimal protection from the impact of raindrops and water flowing over the surface, but are all weed free.

Table 3. (Continued)

Treatment	Comments	Pregermination erosion effectiveness*	Effectiveness on plant establishment*	Approx. cost per acre $**
8. Straw or hay broadcast with straw blower on the surface at 3,000 lb/acre and tacked down (asphalt emulsion, Terratack II, etc.). Seed and fertilizer broadcast with hydroseeder or by hand.	Common elsewhere in U.S. Very effective as energy absorber, mulch; and straw forms small dams to hold some soil. May be weedy depending on straw source. Not for cut slopes steeper than 2:1. Cost would increase significantly if slopes over 50 feet from access, or application is uphill.	5-7	8-10	650
9. Straw broadcast 4,000 lb/acre rolled to incorporate (punched) another 4,000 lb straw broadcast and rolled, seeded and fertilized. Seed and fertilizer broadcast with hydroseeder or by hand.	Common on difficult fill slopes in California. Very effective. Not possible on most cut slopes. Very weedy. Cost would increase significantly if slopes over 50 feet from access.	6-8	8-10	877-1070
10. Roll-out mats (jute, excelsior, etc.). Held in place with wire staples. Seed and fertilize as in 1 or 2.	Some are a good mulch, weed free, adapted to small areas. Can be installed any season, cuts or fills. Unsightly. Difficult to install on rocky soils.	5-7	5-10	2400-2700
11. Polyethylene sheets. (4 mil) Seed and fertilize as in 1 or 2, use clear plastic, black if no seed is used.	Useful for temporary control. Can be installed any season. Unsightly, wind is a problem in installation and maintenance. May be difficult to establish plants.	10	?	2400-2700
12. Seed and fertilizer broadcast, or hydromulched with fiber (treatment 2 or 4), followed by erosion control chemical such as polyvinyl acetate at 6:1 dilution (6 parts water) at 1,000 lb solid/acre (approx. 200 gal. PVA).	Very expensive, but will hold soil and seed in some very difficult conditions. May restrict penetration of water into soil. Will not cure below 55°F. Not effective on soils which crack. Will not support animal or vehicle traffic.	10	?	1070-1370

* 1 = minimal, 10 = excellent.

** Assumes seed plus fertilizer $150.00, fiber $150/ton, Ecology Control $1.25/lb., PVA $3.00/gal, 1,500 gal hydroseeder with 2 man crew $55.00/hr, labor $13/hr, straw $50/T, straw mulcher with 4 man crew $64/hr (applies 2 T/hr) and markup of 30% for overhead (including equipment depreciation), and profit. Cost figures were derived from conversations with contractors, and by review of recent Caltrans contracts.

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DISCUSSION

MITCHELL: Do you have any problems mixing fertilizer with the seed in the hydromulcher?

KAY: This is a common concern of agronomists. On clay soils, there is no problem. Sandy soils do create many problems. A good solution is to put seed on the soil and after germination come back and apply the fertilizers. We have experimented with split applications and with slow release fertilizers. Split applications did not reduce problems. The slow release fertilizers either limit plant growth or extend plant growth to create fire problems in the California climate.

MITCHELL: Did you work with amounts of fertilizer?

KAY: Yes. In California we have a sulfur deficiency in addition to nitrogen and potassium. We usually use 500 pounds of 16-20-0, ammonium phosphate sulfate. This is 80 pounds of nitrogen. The 1,000 pound rate reduced plant numbers, but gave a greater ground cover with fewer plants because of more rapid growth. A rate of 250 lb/acre reduced seeding number similar to 500 lbs/acre and had less growth.

QUESTION: Is the crimper you used available commerically?

KAY: The crimper is a notched disk with a weight on it. Some crimpers are available commercially. Others are being developed and have been used experimentally. The U. S. Forest Service Equipment Development Center at San Dimas, California 91773 is working on machines useful on slopes.

QUESTION: Was your straw roller working both going up and going down the slope?

KAY: Yes. The yo-yo arrangement is working in both directions tucking straw. A sheep's foot roller cannot be used both up and down a sandy slope.

QUESTION: Are there any readily available common materials which can be obtained locally as a tacking agent for straw mulch? In some locations the common asphalt emulsion is hard to get.

KAY: Asphalt is readily available from road contractors; wood fiber can be applied with a hydromulcher to hold down the straw. All commercial materials are available by phone.

COMMENT: You could use sand. Two shovels of sand per square yard to anchor worked well in the sand hills area of Nebraska. It is a manual job, but perhaps useful in some locations. Another approach is to tuck the straw by jabbing with a dull, round-nose shovel.

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