Province of
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Ministry of Mines and
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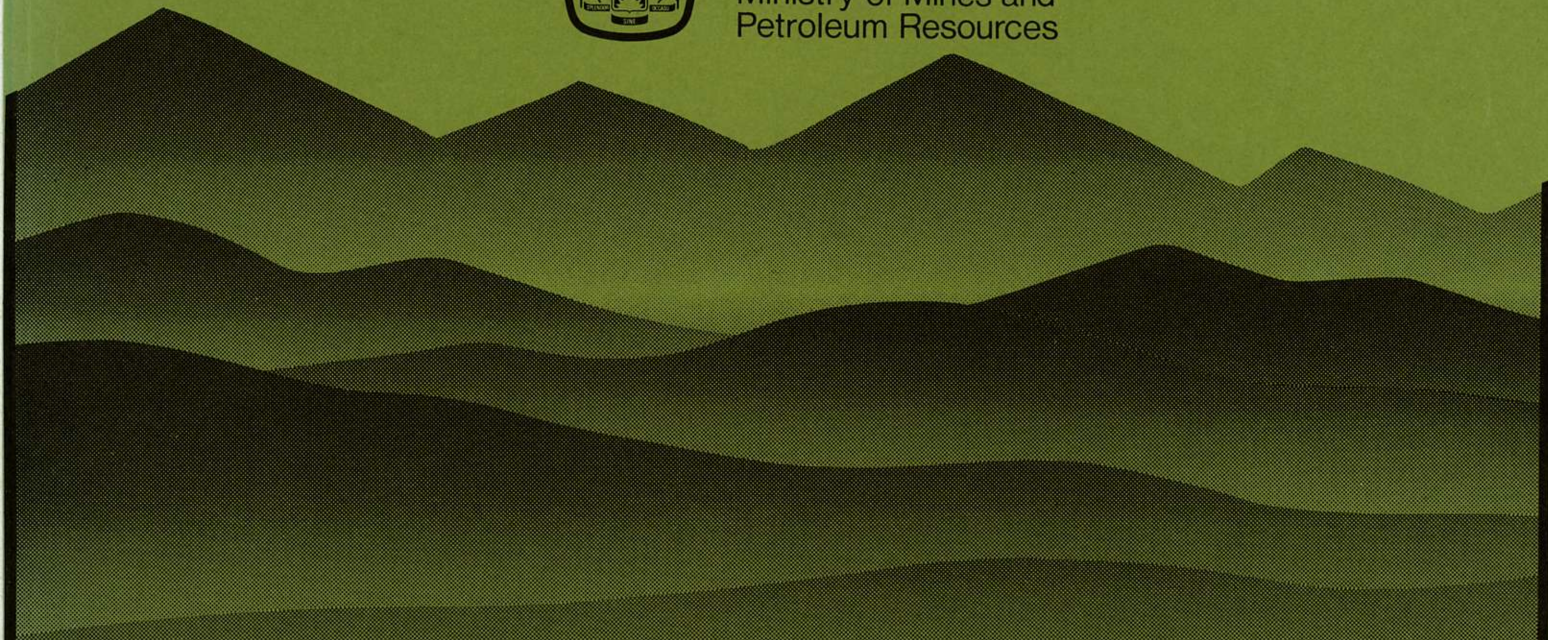
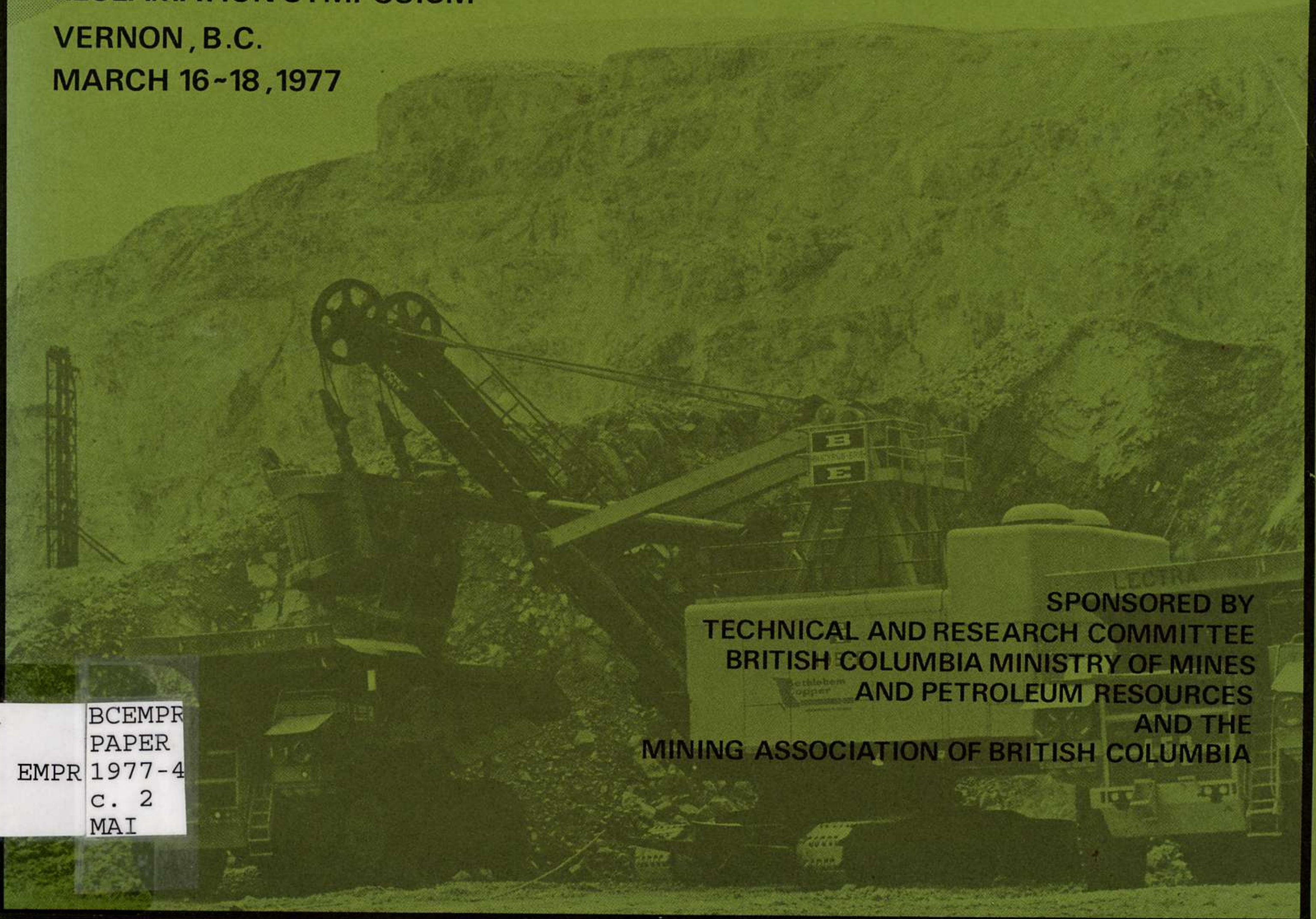


RECLAMATION OF LANDS DISTURBED BY MINING

PROCEEDINGS OF THE BRITISH COLUMBIA MINE RECLAMATION SYMPOSIUM

VERNON, B.C.

MARCH 16-18, 1977



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BRITISH COLUMBIA MINISTRY OF MINES
AND PETROLEUM RESOURCES
AND THE
MINING ASSOCIATION OF BRITISH COLUMBIA

PREFACE

The Ministry of Mines and Petroleum Resources is pleased to have played an active role in the sponsoring of this Reclamation Symposium.

We are pleased to encourage both a stong mineral and coal development policy in the Province of British Columbia, and a capable reclamation program.

It is a particular pleasure to observe that communications are taking place between the industry and environmental groups.

In our opinion communication is the first step in obtaining solutions in areas of resource concern.

James R. Chabot

Honourable James R. Chabot,
Minister,
Ministry of Mines and Petroleum
Resources.

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INTRODUCTION

The Vernon Reclamation Symposium was sponsored by the Reclamation and Technical Research Committee which functions under the auspices of the Ministry of Mines and Petroleum Resources and the Mining Association of British Columbia.

The purpose of the symposium was the furtherance of communication and development of knowledge among those concerned with mine reclamation.

The '77 symposium was divided into four sessions, which were oriented to: The Company side, Exploration and Inspection, Research, and Impact on Resources and Uses.

A 'round table' workshop session followed each series of lectures. Findings which achieved consensus at the individual tables were read at the conclusion of each session and have been summarized in these proceedings. In summarizing the findings of the workshops, those findings appearing most often have been listed first.

Near the beginning of the conference all participants were asked to submit their definitions of reclamation and these are summarized in these proceedings. During the final workshop session, participants were asked to comment on this symposium and to recommend ways to improve future symposiums.

The opportunity was taken at the Banquet to present the first annual Mine Reclamation Award. This award was presented to Kaiser Resources Ltd. and a Citation went to Placid Oil Ltd.

OPENING REMARKS BY CHAIRMAN

J.D. McDonald

I would like to welcome all the delegates to this Reclamation Symposium. It is gratifying to see the large turn-out of representatives of industry, government, universities, consultants and other allied fields. I would like to welcome the large contingent of students who are assisting us in the presentation of this symposium.

The four sessions will deal with different aspects of reclamation and the study groups after the presentation of the papers will give an opportunity to develop a dialogue between industry, various government agencies, academics, and consultants. Communication is essential in developing techniques, research, guidelines relating to reclamation and it is hoped that this symposium will make considerable progress in this field.

This is the first symposium developed by the Technical Research Committee on Reclamation and it is hoped that this will be an annual event. Future symposiums will have to relate to different phases of reclamation in order to avoid being repetitive.

As Chairman, I would like to thank all those people on the committee, and especially Murray Galbraith for their contribution in making this symposium a success.

RECLAMATION DEFINITIONS

One hundred and sixteen definitions of reclamation were submitted and one hundred and five were serious replies. The definitions fell into the following general categories:

The most common concept of reclamation concerns the return of disturbed land to a useful state. Thirty-two of the definitions mentioned this with most referring to pre-determined land use objectives.

> "Reclamation is the development of disturbed land to a state which is substantially in keeping with pre-planned, acceptable site-specific land use."

The second most common definition followed the theme of returning the land to its natural state. Twenty-seven of the definitions included this idea with reference to either the original state of the land or the state of the adjacent undisturbed land.

> "Reclamation is returning a mining site to its natural state using native species of plants."

> "Reclamation is to return disturbed land to a use and/or productivity comparable to adjacent undisturbed land."

> "Reclamation is continual planning and implementation of current technology in restoring an area disturbed by mans activities to a natural state that existed prior to his involvement in the area."

The third most common theme was the idea of returning the disturbed area to a land use that was acceptable to the public. Fourteen of the definitions included this idea.

> "Reclamation is to restore the environmental aspects (land, air, water, etc.) to an optimum level of suitability for use by mankind."

> "Reclamation is the restoration of the ecological balance of an area that has been or is being exploited (for mineral, timber, etc.) so as to restore the site to an equal or better value to the community aesthetically and economically."

Another theme, which was found in eleven of the definitions, was the idea that the disturbed area must be returned to a state where the vegetation was self-sustaining.

> "Reclamation is the restoration of land and water resources preferably to a self-sustaining state for purposes of mitigating unnatural disturbances."

> "Reclamation is the restoration of disturbed land to a self-sustaining state that approximated the original conditions unless a better or more pro ductive use can be made of that particular piece of land."

Ten of the definitions said that the disturbed area must be returned to a state where other land use options are available.

> "Reclamation is the restoration of a disturbed area to a level such that further land use is not impeded seriously."

> "Reclamation is the restoration of a disturbed area to a non-injurious state."

Five of the definitions said that the disturbed area must be mitigated but with the economics clearly in mind.

> "Reclamation is the return of disturbed lands to their previous state, or to some previously agreed land use or form within the economics of the project and common sense."

> "Reclamation is the returning of disturbed land to a useful condition at a reasonable cost."

Five of the definitions said that the disturbed area should be mitigated to the point where nature can take over.

> "Re-creation of soil and contour to a stable state where natural succession of vegetation can occur. The area reclaimed should be capable of supporting climax flora and fauna appropriate to the site."

Five of the definitions made reference to erosion control.

> "Reclamation is in the broad sense returning the land to some land use (wilderness, agriculture, wildlife habitat, etc.) so that mining becomes a short term use. Erosion control and slope stability are immediate concerns so that other habitats are not affected adversely."

Some of the definitions said that pre-planning is an essential part of reclamation.

> "Reclamation is the planning and execution of a program to develop disturbed land to a state which is substantially in keeping with pre-planned acceptable site-specific land use."

The two phrases "by practical means" and "common sense" were found in many of the definitions. The concept of "land use objectives" was also highly prevalent. Many of the definitions used "mining areas" or "sites" while others used the general term "disturbed land". In a couple it referred specifically to "land disturbed by man".

THE COMPANY SIDE

Chairman - L.J. Cherene, Kaiser Resources Ltd.

Wednesday, March 16, 1977

Afternoon Session

RECLAMATION PROBLEMS AT HIGH ELEVATIONS

KAISER RESOURCES LTD.
Sparwood B.C.

A.W. Milligan
R.J. Berdusco

February 1, 1977

RECLAMATION PROBLEMS AT HIGH ELEVATIONS

ABSTRACT

Kaiser Resources Limited operates a 4 million ton per year surface coal mine in the southeastern corner of British Columbia.

Since 1969, Kaiser's Environmental Services Department has been responsible for the rehabilitation of some 1400 acres of land disturbed by mining and exploration from valley bottom elevations of 3300 feet to steep mountain terrain at 6900 feet elevation.

Some of the reclamation problems encountered, especially at elevations above 5000 feet, are very steep slopes, dark, highly erodible spoils and the availability of suitable revegetation species.

The use of modified agricultural and forestry techniques has provided an encouraging degree of success in both establishment and maintenance of initial ground cover.

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Location and History

In 1968 Kaiser Resources Ltd. announced its intention to develop extensive coal deposits in the southeast corner of British Columbia. The public reaction to this announcement, because of the fear of wilderness destruction, was responsible for the formulation of provincial regulations controlling reclamation, specifically Section 8 of the Coal Mines Regulation Act and Section 11 of the Mines Regulation Act. Initially this applied, in the case of coal, only to open pit disturbances, but was later amended to include disturbances by exploration and underground mines.

At the present time firm regulations have not been established as to what constitutes an acceptable level of reclamation. This is due to the wide range of climate and topography within the province which create situations that are not easily defined within one set of regulations. Thus each operator has to determine and develop on a site specific basis the reclamation programme which will provide the most successful results.

The property owned by Kaiser Resources Ltd. consists of two separate areas, the larger being in the Crows Nest Coal Field and the second part of the Elk River Coal Field. The Crows Nest Field covers some thirty (30) miles in length and about twelve (12) miles in width near the centre of the basin. This field contains about twelve (12) mineable seams that outcrop within a 2,500 foot stratigraphic sequence primarily along the western slopes of the Rocky Mountains. The second field, a portion of the Elk River Coal Field, is approximately eight (8) miles in length and four (4) miles in width, it contains approximately seven (7) mineable seams that outcrop within 1,500 foot sequence of coal bearing measures. The coal measures in both fields range in thickness from five (5) to fifty (50) feet and vary in elevation from 3,500 feet to 7,000 feet in the Crows Nest Field and from 4,500 feet to 7,000 feet within the Elk River Coal Field.

The overburden on both coalfields is composed mainly of sandstone and carbonaceous shale with some conglomerate and calcareous shales. The pH of this material ranges from 4.2 to 7.8. The coal itself is a low volatile bituminous type with a sulphur content of 0.3 to 0.4 per cent.

The reclamation department was established in 1969 and became fully operational in the spring of 1970. The development of the programme has continued since that time and to date 1,420 acres of disturbed land have been vegetated. Initially the direction of the reclamation programme was based on the Canada Land Inventory, Land Capability Analysis, however practical experience has shown that the best approach to reclamation is to start a natural succession at the primary level of grasses and shrubs rather than attempt to replace, for example a high yield forest with similar material. The agronomic grasses used provide not only initial ground cover but provide a high quality forage to replace the feeding areas alienated by the ongoing mine operations.

When Kaiser Resources Ltd. acquired the property it was fortunate, from a reclamation viewpoint, that several dormant mine sites were also acquired. These areas were available for immediate reclamation and it was on these sites that techniques and species were developed and selected. These sites have proved more informative over the years than would have a series of smaller test plots. All the problems of slope, aspect, and diverse spoil materials can be evaluated on one site. It was possible to study on these areas the use by wildlife. This last being an important factor in an area where major wildlife habitat is being disturbed.

Mining and Exploration Methods

Mining

Presently, approximately 80 per cent of Kaiser's coal production is derived from surface mining and 20 per cent from underground methods, predominantly hydraulic. Although there is some surface disturbance which requires reclamation associated with underground mining, the majority of land disturbance is attributed to surface mining and exploration. These areas will be the basis of discussion in this report.

Kaiser's present approach to surface mining is a shovel and truck method. First the overburden is drilled and blasted and then it is excavated by large shovels, loaded into 200 ton trucks and hauled to dump sites. At the dump, the spoil material is disposed of in benches or terraces, each terrace wrapping around the slope below the preceding one. Where feasible, spoil is backfilled into dormant areas or natural depressions.

As the overburden is removed in roughly 60 foot benches, the coal is exposed. This is then ripped and pushed up for front end loaders which load 100 ton trucks that haul coal from the pits to be processed.

Exploration

Until 1974, Kaiser's coal exploration techniques closely resembled those used by most mining concerns. The general approach was extensive access road construction followed by seam tracing, trenching and test pit and adit sampling. This approach is no longer used at Kaiser.

Since 1974, the exploration approach has changed to one of access construction followed by drilling and more intensive geological mapping. Seam tracing and trenching techniques are no longer used. Adits are still driven but these are carefully located to avoid sedimentation of watercourses. Also adit waste, previously dumped at the most convenient place, is now salvaged for sale or is dumped into natural depressions and resloped to allow revegetation. All access roads and secondary drillsite roads are plotted on sensitivity maps and altered to minimize environmental damage. They are then flagged and inspected prior to construction. All roads that encounter merchantable timber are prelogged before final road building thus salvaging the timber resource and eliminating the fire hazards of roadside slash.

Description of the High Elevation Ecotype

The main mining and exploration areas fall within a biogeoclimatic zone described by Krajina (1965) as the Engelmann spruce-Alpine fir zone at elevations from 4,500 to 7,000 feet. Treeless areas above 6,500 feet are designated as Alpine zone.

For the purpose of discussion, the term "high elevation" in this report will refer to the 5,500 to 7,000 foot range of the Engelmann spruce-Alpine fir zone. This zone is characterized by an overstory of Engelmann spruce, Alpine fir, Lodgepole pine, Alpine larch, and Whitebark pine forests on west to southeast aspects and, usually, grass-shrub communities on south and southeast aspects.

Typically, the slopes of this zone are very steep and the terrain rugged. The "in situ" soils can be described as regosolic, acid brown and brown wooded and usually form a shallow mantle over bedrock or glacial till of varying depths. Typically the pH range is from 5.2 to 7.0. The climate is continental cold, humid (Koppen), characterized by long, cold winters and short, cool, dry summers.

Description of Reclamation Problems

The biogeoclimatic zone described is plagued with a host of reclamation problems. These include the three main areas of: soil, slope and aspect, and species.

Soil Problems

After industrial disturbance, soils in this zone undergo dramatic change in chemical status, color, and structure, all of which frustrate revegetation efforts.

Chemical change is a general raising of pH to the 6.5 to 8.5 range accompanied by a lower nutrient level, especially in available nitrogen. These changes of course bring the pH range beyond the desirable range for tree species and some other native plants.

One other change caused by disturbance is a color change. The incorporation of dark marine shales and coal into the disturbed soil tends to make it much darker than the native soils. This trait decreases the albedo and hence increases heat absorption causing mositure levels, in a soil that already lacks moisture, to decrease. In an environment where available moisture in the growing season is so critical, color change can be a significant factor limiting revegetation of desirable species.

Finally, and certainly not the least important change in soil following disturbance in the Engelmann spruce-Alpine fir zone is structure. In general terms, large disturbed sites such as overburden dumps or roads are characterized by a reduction in both organic matter and fine particles, mainly due to burying. This reduces moisture retention and decreases cation exchange capacity of the growing medium. However, there are some advantages to an exposed soil that is coarse. This soil is well drained and its potential for erosion is significantly lower than an exposed soil with high fines content. It is also important to note that gravitational sorting takes place in dump construction, with larger particles forming a crude filter at the toe of the dump. The friable nature of the exposed shales also allows soil building to proceed at an accelerated rate, especially when revegetation occurs concurrently.

Slope and Aspect Problems

Most disturbed areas usually end up, in general terms, somewhat steeper than "in situ" soils. These steep slopes present problems for regeneration because of surface creep, erosion, and other related items. Dumping procedures and other practices which disturb large areas of land in mountainous terrain generally tend to make slopes more uniform, that is with fewer microsites and less variation in aspect. Also, drainage patterns tend to be diminished by filling of gulleys and low areas. The significance of these phenomena is that is makes revegetation more difficult especially if the final aspects left after disturbance are south or southwest facing. Mainly because of temperature and related moisture stress, these aspects have been found to be more difficult to reclaim.

Species

The new and markedly different edaphic and induced climatic conditions of the dump slopes have resulted in a new environment for life. Unfortunately, some of the new conditions no longer suit the requirements of some of the previous users. For example, because of the increased pH and lowered organic matter content, most native tree species do not fare well. Paper birch and Black cottonwood are two notable exceptions. As far as native shrubs are concerned, this is an area where great voids exist in the information available on requirement for growth and for seed stratification and propogation methods. Much research and experimentation is required in this area.

The importance of using native grasses and legumes has been emphasized and debated by many authors in range and reclamation research. Although Kaiser has and continues to use agronomic species of both grasses and legumes, recognition is given to the theory that this approach may not be the most suitable in the long run. Presently, both native grasses and legumes collected over the past two years are being tested for viability in germination and growth tests. The use of native species will receive greater emphasis in reclamation work in the years to come, especially at higher elevations.

Reclamation Methods

Mining

The most important phase of any reclamation programme must be site preparation. The primary objective of this is to re-establish watershed values on the disturbed sites and at the same time provide favourable conditions for the establishment of vegetation. At Kaiser Resources Ltd. the final disposition of spoil for reclamation is included in the overall mine plan. Because of the natural topography most spoil material is formed into large dumps with long steep slopes. Where this material is mainly fine spoil, a continual creep of this fine surface material prevents vegetation from becoming established. Experiments in the early days of the programme indicated that the maximum angle for successful revegetation on fine material is 28 degrees. In Kaiser's programme, 26 degrees was the slope angle aimed at since it not only resulted in better seedling establishment but facilitated the subsequent operations of seeding, harrowing, and fertilizing. The angle of 26 degrees was aimed at in the smaller inherited pits where the plan was to contour the spoil dumps into the configuration of the surrounding landscape. On the dumps formed by the operating mine this procedure is not feasible due to to their slope lengths and massive size. An operating practice of forming dump terraces in a wrap around fashion as the mine is lowered, greatly facilitates the reclamation plans for this site. The incorporation of these dump roads as terraces when resloping will reduce surface erosion and retain moisture for establishing vegetation. The first areas were resloped using 26 degrees as a maximum slope angle. However, as the work progressed, it was felt that this particular spoil material could be left at a steeper angle. This proposal was based on the fact that the material under the dump was solid, the spoil material itself was coarse and relatively free of fines. It was felt that the underlying and dump material would be stable and the coarse surface material would prevent surface creep, thus the slope angle could be left at 30 degrees.

After a year there was no sign of erosion and vegetation had established successfully. Obviously the steeper angle has to be a factor of the spoil material, but where possible this represents a considerable cost saving in leaving spoil in place.

After resloping the spoil, the standard approach is the sowing of seed and fertilizer by hand using cyclone seeders. This is then harrowed under the surface using very heavy duty harrows which are drawn across the slope. This procedure serves a dual purpose, primarily covering the seed, and secondly the harrows and dozer crossing the slope create a series of small terraces which aid in erosion control and contain surface water for use by vegetation.

The grass species used are all agronomic and the mixture of grasses is the result of test plot and annual vegetation assessments of reclaimed sites over the life of the programme. The aim is to cover the spoil with vegetation as soon as possible to reduce erosion, provide organic material and to provide grazing for wildlife. Ideally, through succession, native species will invade these seeded areas. Questions have been raised as to their suitability over the long term. To date studies carried out on earlier reclaimed sites at lower elevations up to 5,500 feet indicate that once established agronomic species continue to reproduce and in fact ground cover and plant biomass have been on the increase. At the higher elevations it may be necessary to introduce native grasses to provide a suitable vegetation on a continuing basis. It may also be necessary to include native seeds with the initial seeding.

One optimistic note is that a test plot established in 1971 on Harmer at an elevation of 6,900 feet has shown an increase in certain species over the life of the plot.

On dark spoil the seeds require covering to protect them during germination and the methods that have proved most successful are harrowing or providing a wood fibre mulch using a hydroseeder. This approach stresses the value of an initial cover of grasses. It is felt that once this cover has been achieved then native shrubs and trees which have been grown from seed or cuttings in the greenhouse and nurseries can be planted on site. These seedlings can be held in the nurseries until they are of a suitable size to be field planted. To date approximately 350,000 trees have been planted on reclaimed sites.

The application of fertilizer to established vegetation has been on an annual basis. No definite time limit has been established as to the number of years this may be necessary until the vegetation becomes self-sustaining. Too little is known about the use of added nutrients. A better understanding of the nutrient cycle of these plant communities will allow for a more efficient use of fertilizer. To this end a study was initiated to follow the flow of nutrients through the soil, plant, and detritus compartments of the nutrient cycle. Also being studied are nutrient cycles of adjacent native grasslands to compare the 'stable' communities with the introduced communities.

Exploration

Since 1974, Kaiser Resources Ltd. has employed exploration techniques that differ greatly from the extensive land and water disturbing practices previously used. Once techniques such as seam tracing and trenching were used almost exclusively to provide geological information. The revised technique used at Kaiser eliminates the need for this and with the use of drillhole information and geological mapping, as well as planned access roads and adits, more geological information can be obtained with less unnecessary disturbance. Prior to any exploration disturbance taking place, all exploration proposals are plotted on sensitivity maps and aerial photographs. This enables Environmental Services personnel to evaluate the effects of the proposed work and to request alteration or elimination of undesirable proposals. In the field, all roads, drillsites, and adit sites are flagged and inspected prior to construction. This enables site specific changes to be made to avoid sensitive areas that did not show up on the sensitivity maps or aerial photographs. Once construction has been approved, experienced operators, most of whom have attended a Kaiser sponsored course on Environmental awareness and protective techniques in Exploration, carry out the work. Whenever merchantable timber is encountered, pre-logging of the road right-of-way is carried out. Merchantable timber is decked and later sold to local mills. This technique avoids costly and dangerous slash abatement at a later date and provides a monetary return as well as the utilization of a natural resource.

Apart from pre-logging, supervision and monitoring of proposed and on-going exploration, reclamation of past exploration work is carried out by Kaiser's Environmental Services Department. Some of the work done includes slash abatement using powersaws and a woodchipping machine, ripping and seeding of dormant roads, backfilling of trenches, seam traces, test pits and adits, and re-establishment of watercourses.

Conclusions

High elevation reclamation in the Engelmann spruce-Alpine fir zone appears to be successful by presently used techniques of resloping, seeding, planting, harrowing, and fertilizing. Although the general approach to resloping is to aim at a maximum of 26 degrees, recent small scale attempts at 30 degrees have resulted in favourable revegetation levels.

Native trees and shrubs have been used successfully on reclamation projects. However, some sites are not suitable for these plants because of changed soil conditions. On such sites, agronomic species of grass and legumes are the only species used. The use of native species of grass and legumes is being investigated at Kaiser. Present research on the subject in general indicates that it may be necessary to use native species more extensively at high elevations either in initial seeding or in supplementary seedings. This is expected to ensure longevity of desirable species.

The techniques presently being used in the exploration-reclamation section, that is pre-planning of disturbances on sensitivity maps, monitoring and supervision of exploration work, resloping, terracing, ripping and seeding, and watercourse restoration are resulting in a more orderly and less damaging exploration program. Recent innovations widely used include the use of a woodchipping machine for slash abatement, pre-logging of exploration roads, terracing, and salvage of adit waste.

Most fundamental to the Reclamation program in general is pre-planning. The experience at Kaiser indicates that the most effective and productive approach to reclamation is with research programmes complementing the ongoing field programmes, not substituting for them.

RECLAMATION IN THE INTERIOR DRY BELT

BETHLEHEM COPPER CORPORATION LTD.
Highland Valley

J.R. Walmsley

1977

The Interior Dry Belt of British Columbia's Southwest Interior is characterized by the "rain shadow" effect which exists on the east side of the Coast Range Mountains. It is a region of limited precipitation, reduced cloud cover, abundant sunshine and frequent, strong, surface winds. Summers tend to be very hot and dry in the lower valleys with moderation at the higher elevations. Maximum summer temperatures in excess of 100° Fahrenheit are not uncommon in the communities of Ashcroft and Spences Bridge. Annual precipitation in these communities varies between seven and ten inches. Natural vegetation along the Thompson River at these localities is sparse, consisting of sage brush, juniper, and small cactus, an assemblage typical of semi-desert conditions. Benchlands above the river are dotted with Ponderosa pine.

Just a few miles to the east lies the Highland Valley which geographically occurs within the Interior Plateau land form at elevations ranging from 3,000 feet to 5,000 feet above sea level. This is a forested area of gently rolling hills with grassy meadows along the valley floor. Precipitation here ranges between 9 and 25 inches per year, most of which occurs during the winter months in the form of snow. Summer temperatures here are moderate with average maximum temperatures of 82° Fahrenheit. Winters tend to be long and occasionally very cold. Strong southwesterly winds are prevalent during the months of April through June.

The valley borders two biogeoclimatic zones; the Interior Douglas fir zone of Douglas fir, Ponderosa and Lodgepole pine; and the Engelmann spruce-subalpine fir zone. Lower slopes of the drier north side of the valley are forested with Ponderosa pine and Douglas fir. Lodgepole pine are also present depending upon the fire history of the area. Higher up the north side of the valley, the forests are predominantly Lodgepole pine with an Engelmann spruce component. Native plant species other than those which have already been mentioned include dwarf juniper, willow, trembling aspen, sedge, pinegrass, bluebunch wheatgrass, bluegrass, soapberry, wild rose, white hawkweed, lupine, chickweed, twin flower, strawberry, timber milk vetch, and goldenrod, only to name a few.

Mining is the predominant industry in the Highland Valley and currently employs in excess of 1,000 persons directly. Forestry and cattle ranching are also important industries in the area. The valley is not a primary recreational area but several small lakes in the district are very popular with tourists and sports fishermen.

Mining is not a newcomer to the valley. Records indicate the first staking of copper claims at the turn of the century in an area that is now a part of the Bethlehem Copper operation. This area saw limited production during the years 1915-1917. However, mining as we know it today, did not commence until 1962 when the present Bethlehem plant came on stream. Since then the Lornex property which is situated on the opposite side of the valley has also been brought into production.

With the advent of large scale open pit mining, selected areas of previously forested land are being disturbed in order to exploit the low grade copper deposits.

Current mine production at Bethlehem is 30,000,000 tons of ore and waste per year. Most of this material is waste and is deposited on the waste dumps during mining operations or in the tailings pond after processing and removal of copper in the concentrator. The open pit mines with their associated waste dumps, presently occupy 1,600 acres including the plant and tailings disposal area. Development of a reclamation program that will eventually include all of this disturbed land is now in progress.

Prior to the establishment of open pit mining in the valley, the predominant land use was that of a wildlife habitat, with the valley bottom being used for grazing domestic farm animals during the summer months. In view of the past land use and the poor soil conditions which exist on many of the disturbed land areas, the reclamation program at Bethlehem has concentrated upon the selection and development of self-propagating species of grass and legume that will help to speed up the formation of soil and, at the same time, provide a food source for wild or domestic ungulates. Once these grasses and legumes become established, a natural invasion of native shrubs and trees is anticipated. This would be supplemented with a tree planting program in certain areas.

The Bethlehem mine and plant site are located on the north side of the valley on a rounded summit approximately 1,500 feet above the valley floor. Most of the land areas which have been disturbed face toward the west or southwest directly in the path of the prevailing winds and the rays of the summer sun. Many sites although terraced have intermediate slopes approaching the natural angle of repose for the material from which they are constructed. Average annual precipitation during the time since record keeping has been maintained is 13 inches, most of which occurs during the winter months as previously mentioned. These factors combined with normal warm temperatures tend to create drought conditions throughout the summer.

Disturbed land areas can be divided into three main groups: plant and service areas, including access roads; open pits and mine waste dumps; and tailings dams and ponds.

The first of these groups presents fewer difficulties for reclamation in that much of the original topsoil is still in place. Consequently, reseeding can be done with a minimum of site preparation. In some of the deeper excavations, the topsoil has been removed and the underlying glacial till exposed. This material, although relatively infertile and somewhat alkaline, can be satisfactorily reclaimed. The degree of success in reclaiming such areas can be related to the physical location of the site. Sites which have a north or easterly aspect are sheltered from the prevailing winds and direct sunshine. They generally exhibit better moisture conditions and consequently show evidence of more vigorous growth, whereas, the opposite is true for sites which have south or westerly aspects.

Reclamation of exhausted open pits and their associated waste dumps presents a difficult problem at Bethlehem. The Bethlehem operation consists of four separate mines or pits which will have final wall slopes varying from 38 to 50 degrees. Final depths of these pits will range between 400 and 1,000 feet. Wall material is essentially fresh unaltered bedrock. Three of these pits are presently in production, the fourth was exhausted in 1976 and is presently being backfilled with waste material. The close proximity of this exhausted pit to current production areas has provided an economical waste disposal site and will allow dumping space for an estimated 50,000,000 tons of waste rock. Reclamation of the final surface will be essentially the same as that required for a waste dump. No definite plans have been formulated as regards to the reclamation of the remaining pits upon their exhaustion. However, consideration is being given to the possibility of their being used to store tailings from the concentrator. Should this approach prove to be practical and meet with the approval of the Ministry of Mines and the Pollution Control Branch, final reclamation would be similar to that of a tailings pond.

Wherever mining plans permit, waste dumps are constructed in a terraced fashion with the berms providing future access for reclamation personnel and equipment. Unfortunately, this is not always possible because of space limitations and the mine configuration that results from the ore bodies being located on the top of a hill as opposed to a side hill or flat location.

Material composition of waste dumps is variable and ranges from overburden and topsoil to fresh shot rock. The blasted rock is normally coarse textured and contains only a small percentage of fines, often insufficient to provide an adequate seed bed. It also has poor moisture retention characteristics. For this reason overburden and topsoil removed during mining operations are stockpiled whenever possible for future use in resurfacing waste dumps which are lacking topsoil.

There are presently two tailings dams in use at Bethlehem, one has been constructed with mine waste rock in lifts similar to a waste dump. It is faced on the downstream side with overburden removed during mining operations and on the upstream face with cycloned tailings sand. This structure is approximately 350 feet high at its deepest section and has an overall length in excess of 6,000 feet. The dam contains approximately 29,000,000 tons of waste rock. Near Bose Lake, a second smaller tailings dam has been constructed from compacted glacial till. It has a maximum height of 100 feet and a length of 2,000 feet.

Reclamation of the tailings pond beach upon the pond reaching design elevation should be straight forward. The final beach surface will be almost flat providing easy access to an area that can farmed with conventional agricultural equipment. Until the tailings beach becomes stabilized with a grass-legume cover, the prevailing winds will continue to erode the beach surface. Particle movement will have extremely abrasive effects upon established vegetation. To minimize wind effects, a combination of windbreaks and irrigation will be used. Experimental work done on a one acre test site using this approach has provided encouraging results. Snow fencing was used for the windbreak, however, a wind row of waste rock or other stable material would have provided the same effect. The planting of Siberian Pea plants and Caragana shrubs have also been suggested for future windbreaks.

Conventional farming equipment is used for grass seeding and fertilizer spreading on all areas that are accessible. Recently a four wheel drive tractor of 45-50 hp. rating was used with a harrow for seed bed preparation. This was followed by seeding with a tractor mounted broadcast seeder and harrowing. Results obtained using this equipment have been good and less costly than alternative methods. Hydroseeding has been used extensively on those areas not accessible with conventional farming equipment. This method has proven successful providing that seeding is done when moisture conditions are not too dry. Under dry conditions, much of the seed is blown away by the strong winds which frequent the district. Our experience suggests that hydroseeding just after the disappearance of the last winter snow gives good results. Mulches are included in all hydraulic slurries and contribute to the effectiveness of the hydroseeding application. At the present time, a silva-fibre mulch is used. Several chemical binders have been investigated but none has been used very extensively.

Since the inception of our reclamation program several species of grass and legume have been investigated among which are the following: Nordan Crested Wheatgrass, Streambank Wheatgrass, Pubescent Wheatgrass, Tall Wheatgrass, Smooth Brome Grass, Siberian Wheatgrass, Timothy, Kentucky Bluegrass, Canada Bluegrass, Russian Wild Rye, Perenial Ryegrass, Sainfoin, White Blossom Sweet Clover, Yellow Blossom Sweet Clover, Rambler Alfalfa, Tall Fescue, Creeping Red Fescue and Crown Vetch.

Several of these varieties have proven successful including Nordan Crested Wheatgrass, Streambank Wheatgrass, Pubescent Wheatgrass, White and Yellow Blossom Sweet Clover, Tall Fescue and Hard Fescue. In the meantime, all varieties under test are reviewed periodically.

A recent hydroseeding application consisted of the following mixture:

Nordan Crested Wheatgrass	30%
Streambank Wheatgrass	30%
Tall Fescue	20%
Creeping Red Fescue	10%
Rambler Alfalfa	10%

This mixture was applied at a rate of 50 pounds per acre along with silva-fibre mulch at a rate of 800 pounds per acre. A 13-10-10 fertilizer was applied at 150 pounds per acre at the same time.

Fertilizers are applied in varying amounts at all reclamation sites at the time of initial seeding. The type and amount of fertilizer required (if any) are determined by the requirements at the specific site under review. Maintenance fertilizer is applied whenever it is necessary.

During the initial years of our reclamation program, several attempts were made at reforestation. Approximately 1,800 Lodgepole pine, Douglas fir and Spruce seedlings were planted on various disturbed sites where little or no site preparation had been done. Needless to say, the results were not good. Since these early trials, an additional 3,450 seedlings of mixed variety have been planted at a site on which a good grass-legume cover was established prior to the tree planting. The results of this planting are very encouraging. On another site where good grass-legume cover has been established there is substantial evidence of natural invasion of willow and aspen species. This would appear to be the route to go.

TAILINGS REVEGETATION EXPERIENCE AT COMINCO LTD.

METAL MINES IN BRITISH COLUMBIA AND THE NORTHWEST TERRITORIES

COMINCO LTD.

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1977

A fellow "reclamationist", with experience primarily in coal mine reclamation, recently commented that revegetation of tailings was less of a challenge than coal mine waste because tailings were relatively uniform and limited in area. In terms of certain factors, such as particle size and slope conditions, this may be true; however, as I hope to illustrate, tailings and tailings properties which influence plant life can be extremely variable, and not only among sites but within tailings deposits and with time. Cognizance of this fact is an important prerequisite to development of effective and efficient tailings revegetation programs and to the formulation of realistic guidelines, standards or regulations for tailings reclamation.

Information to illustrate variability in climate, mineralogy, chemical and physical characteristics, factors limiting plant growth and in cultural techniques for mitigating growth limiting factors and establishing vegetation on tailings from Cominco mining properties at Benson Lake, Pinchi Lake, Salmo, Kimberley, Pine Point and Yellowknife is presented.

1. Variability in Tailings Characteristics and Factors Limiting Plant Growth

Cominco mining properties are distributed among several biogeoclimatic zones in British Columbia and the Northwest Territories which represent a wide range of climatic conditions which influence plant growth (1, 2, 3) (Table 1). Economic and gangue minerals as well as size of the tailings deposit vary among mining properties (Table 2). At some properties, more than one type of tailings exists. In most disposal sites, partial segregation or redistribution of the various mineral and size fractions occurs during deposition, resulting in a deposit with variable chemical and physical characteristics both over the surface and with depth. Variation in tailings characteristics can develop over time as result of modifications in mining, milling and disposal techniques and physical, chemical and biological reactions which occur within the tailings deposit following exposure to the atmosphere. The variation in tailings physical and chemical characteristics, evaluated to assess the suitability of tailings as growth media for plants, and more specifically, to identify potential growth limiting factors, is demonstrated (Tables 3, 4, 5). Available supplies of essential plant nutrients, tailing reaction, salt concentrations, total S, calcium carbonate equivalence, cation exchange capacity, particle size distribution, particle and bulk density and available moisture holding capacity vary both within and among tailings deposits and with time. The specific relationships between certain tailings physical and chemical characteristics as determined by analytical techniques and the potential for sustaining plant growth on tailings are not well defined. However, by comparing tailings values with those of soil with known plant growth potential, at least the nature, if not the degree of severity, of certain growth limiting factors can be identified.

Growth limiting factors associated with Cominco tailings include: deficiencies of one or more essential plant nutrients including N, P, K, Ca, Mg, B and possibly others; extremes of acidity and possibly alkalinity; excessive concentrations of salts and, in areas of limited precipitation, moisture stress (Table 5). Surface crusting, formation of hard, impermeable strata, movement of tailings by wind action and limited pore volume are growth limiting factors observed during site inspection. Usually more than one growth limiting factor has been identified within a specific tailings disposal area. Some care and caution must be exercised when sampling tailings and interpreting analytical data. Sampling sites should be representative of the range of conditions existing near the surface and with depth. Chemical and physical characteristics of recently deposited tailings containing reactive sulfide minerals can change substantially within a short time period and may continue to change for an indeterminate period to time. Under semi-arid conditions, salt concentrations near the surface of saline tailings deposits change during the growth season, generally increasing during periods of low precipitation and high evaporation.

2. Amelioration of Growth Limiting Factors Associated With Tailings

Improving tailings as a growth medium for plants is one of the first alternatives considered in developing a revegetation plan. Other alternatives include selection of plant species having tolerance of specific growth limiting factors and covering the tailings with a more suitable medium. Experimenting with alternative techniques for ameliorating chemical and physical conditions which severely limit plant growth on tailings is a major part of Cominco's reclamation program. However, in most situations encountered to date, selection of specially adapted plant species in combination with improvements to the growth medium, either by addition of amendments or by covering with a less toxic growth medium, may be required for effective and efficient reclamation.

2.1 Deficiencies of Essential Plant Nutrients

Plant growth on tailings is severely limited by deficiencies of one or more essential plant nutrients. All Cominco tailings evaluated to date have "plant available" nitrogen and phosphorus concentrations in the "very low" range (Table 3). Growth room investigations have confirmed that application of both nitrogen and phosphorus is essential for satisfactory growth of grass on tailings. "Available" potassium concentrations are generally in the "very low to low" range, however, eliminating potassium from a nutrient mix applied to tailings does not limit grass growth as severely as eliminating nitrogen or phosphorus. "Available" magnesium concentrations range from "very low" to "very high", however, as was observed with potassium, plant growth was not severely limited when magnesium was not added to tailings. Tailings deficient in magnesium are generally acid in reaction. Application of dolomite to improve tailings reaction will generally provide sufficient magnesium for plant growth.

In contrast to tailings, gypsum, a waste product of phosphoric acid manufacture, contains "very high" concentrations of phosphorus and satisfactory growth of grass and legume species was possible without addition of phosphorus. Grass growth on gypsum was, however, limited by deficiencies of nitrogen, potassium and magnesium. Alfalfa developed symptoms characteristic of boron deficiency when growing on gypsum limed with dolomite.

In addition to limiting growth of agricultural species, nutrient deficiencies restrict natural revegetation of non-toxic tailings deposits by native plant species. Application of a nutrient mix containing nitrogen, phosphorus and potassium to Pinchi Lake tailings initiated establishment of native herbaceous and woody plant species within the fertilized area. Similarly, native grass species have invaded fertilized experimental areas on slightly to moderately saline Con tailings in which seeded species did not establish or sustain growth. Growth of native species was observed on tailings supplied by nutrients released by mineralization of plant residues originating from vegetation growing adjacent to the tailings deposit and from decaying trees partially submerged within the tailings deposit.

Chemical fertilizers are a convenient source of plant nutrients for promoting growth on tailings. Growth room and field investigations have demonstrated that excellent plant growth can be established and sustained on non-toxic tailings by applying fertilizers. However, specific information for planning effective and efficient fertilizer use in tailings revegetation programs is limited. Improperly planned fertilizer programs can be costly in terms of wasteful use of an important limited resource, unnecessary applications and increased potential for surface and groundwater contamination. Fertilizer nitrogen can be lost as result of leaching, volatilization and denitrification. Careful consideration of nitrogen source, rate, time and method of application can minimize losses. Since tailings are generally coarse textured, with a very low cation exchange capacity, leaching of potassium and magnesium fertilizers from the root zone is possible. Phosphorus fertilizers react with mineral constituents of tailings forming reaction products of low water solubility. Following reversion, phosphorus is relatively immobile. Efficiency of phosphorus use is dependent, therefore, on solubility of the reaction product and position of the reaction product relative to absorbing roots. At the Land Reclamation short course, held at U.B.C. in March 1974, Dr. Beaton, Chief Agronomist at Cominco, presented an excellent discussion of soil-plant nutrient relationships together with general comments on more effective use of fertilizers in mine and mill waste revegetation programs (Table 4). Dr. Beaton's comments were based on many years of research and experience with fertilizer use in agriculture. To improve efficiency of fertilizer use in tailings revegetation programs, however, more research is required to improve fertilizer recommendations and application techniques.

In addition to improving the efficiency of fertilizer use, alternative sources of plant nutrients should be considered. Agricultural and municipal organic wastes, if conveniently situated, have potential as sources of plant nutrients, as well as for improving physical properties such as infiltration and retention of water. Care should be taken not to select organic residues with C:N ratios in excess of 20 to 25:1. Addition of substantial amounts of organic residues with wider C:N ratios would likely induce or aggravate nitrogen deficiency since available nitrogen in tailings would be used by micro-organisms responsible for organic matter breakdown.

Addition of plant nutrients can be reduced by establishing plant species with the capacity of symbiotic associations with soil micro-organisms capable of assimilating alternate or less available forms of a limiting plant nutrient. To illustrate, a significant deterioration in grass stands growing on tailings occurs when annual nitrogen applications are discontinued. This suggests a necessity for a maintenance nitrogen program for an, as yet, undetermined number of years to sustain satisfactory growth of grasses. Vegetation with a significant component of nitrogen-fixing species can, however, sustain satisfactory growth without maintenance nitrogen. The use of nitrogen-fixing plant species is a less costly alternative to a maintenance nitrogen program. Similarly, the availability of residual organic and inorganic forms of phosphorus may be increased by the selection of plant species capable of a symbiotic association with mycorrhizal organisms.

2.2 Acid Tailings Reaction

Normal growth of most plant species is severely limited on soil with a pH less than 5. Very few species of plants can survive on soil with a pH less than 4. Weathered tailings from Cominco's Benson Lake and Sullivan properties have a pH in the range of 2 to 3.5. Development of an extreme acid reaction in tailings is generally the result of chemical and biological oxidation of iron sulfide minerals, forms of which have been identified in all Cominco tailings materials. An extreme acid reaction can develop relatively soon after deposition and exposure to the atmosphere. For example, freshly deposited sulfide tailings have a neutral to slightly alkaline reaction, however, within a matter of a few months, extreme acidity may develop. The severity of the acid reaction is dependent, in part, on relative quantities of reactive iron sulfide minerals and minerals capable of neutralizing acid generated during oxidation, such as calcite and dolomite. The phytotoxic effects of extreme acidity can be alleviated by application of appropriate quantities of liming materials such as calcite, dolomite, hydrated lime and marl. However, analytical techniques normally used to estimate "lime requirement" of acid soils do not provide a realistic estimate of "lime requirement" of acid or potentially acid tailings (Table 6). Less convenient and relatively long term incubation and growth studies have demonstrated that the lime requirement of acid tailings is extremely high relative to that of acid soils and that it bears no relation to tailings pH. For example, quantities of $CaCO_3$ required to maintain a near neutral reaction throughout a combined growth and incubation period of one year, were 40, 97 and 125 mg/gm of Benson Lake tailings, Sullivan oxidized siliceous tailings and Sullivan oxidized iron tailings, respectively. Converted to tons per acre-foot, the values are equivalent to 92, 185 and 301 tons per acre, respectively. The amount of $CaCO_3$ required to maintain a near neutral reaction in fresh actively oxidizing siliceous tailings appears to be greater than that of oxidized siliceous tailings. Addition of 110 mg $CaCO_3$ per gm of fresh siliceous tailings was not sufficient to prevent tailings pH from dropping to 5.5 during a 54-week growth and incubation period. Without addition of $CaCO_3$ tailings pH decreased from 6.2 to 2.6 during the same period.

Oxidation of iron sulfide minerals can also result in increased salt concentrations, surface crusting and formation of hard impermeable strata at or near the tailings deposit surface. Revegetation of acid tailings, therefore, requires amelioration of other growth limiting factors which, in some instances, may be more difficult and costly to mitigate than the acid reaction. Sullivan iron tailings are a case in point. In addition to nutrient deficiencies and an extremely high lime requirement, iron tailings are strongly saline and have a hard, impermeable layer, up to 3" thick, either at or within nine inches of the surface. Effective incorporation of liming materials is essentially prevented by this adverse physical condition. Tailings immediately below the impermeable layer are unoxidized, saturated and thixotropic, with insufficient bearing strength to support equipment. As an alternative to improving iron tailings as a growth medium, a less toxic industrial waste from Cominco's fertilizer operations at Kimberley is currently under evaluation.

Gypsum, referred to earlier in this presentation, is disposed of on land immediately adjacent the iron tailings disposal area and has potential as a relatively low cost material for covering iron tailings. Gypsum also has an extremely acid reaction, however, relative to iron and siliceous tailings, the lime requirement is low. Growth room studies have demonstrated that nitrogen-fixing legume species alfalfa, birdsfoot trefoil and alsike clover, will grow satisfactorily on gypsum limed with 15 mg of dolomitic limestone per gm of gypsum and fertilized with up to 155 ppm potassium and 4 ppm boron. In field investigations initiated in the spring of 1976, birdsfoot trefoil, rambler alfalfa, hard fescue, tall wheatgrass, western wheatgrass and crested wheatgrass established satisfactorily on gypsum limed with the equivalent of 6 ton/acre-foot of hydrated lime. Increasing hydrated lime rate to 18 ton/acre-foot did not improve seedling establishment and growth during the first year, however, gypsum pH was maintained at a higher level of 7.4 compared to 6.0 for the lower lime rate. Application of up to 22 ton/acre-foot of dolomitic limestone did not raise gypsum pH above 5 1. Only grass species established satisfactorily on gypsum limed with dolomite. In addition to low lime requirement, gypsum is non-saline, "very high" in available phosophorus and does not possess the undesirable physical characteristics described for iron tailings. Gypsum does, unfortunately, contain minor amounts of fluoride. Legume and grass forage grown on gypsum limed with hydrated lime and sampled at the end of one growing season contained 80 to 310 ppm fluoride-F. Plants and plant products usually range from less than 1 to 16 ppm fluoride-F (5). Fluoride contents considered safe for animal consumption range from 30 to 400 ppm fluoride-F and depend on the form of fluoride and the type of livestock (5, 6).

2.3 Saline Tailings

Plant growth on tailings can be severely limited by high concentrations of water soluble salts. Salt concentrations in soils and other growth media are measured and expressed in terms of the electrical conductivity of the soil solution. Conductivities are usually measured on saturation extracts and expressed in terms of millimhos per cm at 25°C. Plants vary in sensitivity to salts and once concentrations exceed 8 mmhos/cm, only salt tolerant species such as several wheatgrass species, tall fescue, Russian wild rye, birdsfoot trefoil and sweet clover grow satisfactorily. At conductivities above 16 mmhos/cm, only a few very tolerant plants grow satisfactorily.

In addition to saline acid tailings, high salt concentrations occur in alkaline tailings at the Con mine at Yellowknife. Conductivities for 43 surface tailings samples collected in July and August 1976 ranged from 2 to 54 mmhos/cm and averaged 25 mmhos/cm. Eighty-three percent, 67% and 47% of samples collected had conductivities greater than 8, 16 and 24 mmhos/cm, respectively. Conductivities decreased with depth averaging 6 mmhos/cm below the surface foot. Discharge of saline mine water to the tailings pond has contributed to development of a saline growth medium. Subsequent evaporation of tailings moisture results in upward migration and accumulation of salts in surface layers of tailings.

In growth room studies, saline tolerant tall wheatgrass grew satisfactorily on tailings with a conductivity of 16 mmhos/cm. Leaching with 1 cm water per cm depth of tailings or addition of 75 mg peat moss per gm of tailings was necessary for growth of creeping red fescue, a less salt tolerant grass specie, to yield more than 50% of creeping red fescue yield on a non-saline agricultural soil.

Field studies on slightly to moderately saline tailings have demonstrated the capability of several grass species, including creeping red fescue, meadow foxtail, red top, reed canarygrass and crested wheatgrass to sustain growth for at least three years under severe climatic stress in the Yellowknife area The highlight of the 1976 field program, however, was the successful establishment of four grasses and one legume on tailings which had proven too saline for seeding growth during two previous years Favourable early season precipitation is believed to have contributed to establishment of salt tolerant tall and western wheatgrasses, cold tolerant arctared creeping red fescue and foxtail barley and a salt tolerant legume, birdsfoot trefoil. Incorporation of up to 40 tons peat moss per acre-foot did not improve germination of first season growth. At the end of the first growing season tailings conductivities were similar for all peat rates and were in the order of 20 to 24 mmhos/cm. A large deposit of peat exists adjacent the tailings disposal area and has potential for use as a tailings amendment on an operational scale if field studies demonstrate that peat moss is effective for reducing salt concentrations.

In addition, a visit to the Salt River alkali flats, in Wood Buffalo National Park, was made in mid-July and seed from a number of saline tolerant native plant species was collected for growth room and field evaluation.

2.4 Accumulation of Potentially Toxic Metals by Vegetation Growing on Tailings

Tailings generally contain metals in quantities greater than normally found in non-contaminated soil. Monitoring vegetation growing on tailings for potentially toxic metals cannot be overlooked when assessing the suitability of tailings as a growth medium or, for that matter, when assessing vegetation as an acceptable tailings reclamation alternative.

Vegetation grown on tailings at Cominco mining properties is being monitored for metals of concern to the specific area. As indicated earlier, elevated levels of fluoride accumulated in vegetation grown on gypsum. Vegetation grown on Con tailings contains arsenic in widely ranging concentrations from 10 ppm to 260 ppm. By comparison, vegetation grown on soil in the Yellowknife area ranged from 6 ppm to 44 ppm As. Grass forage grown on limed, actively oxidizing siliceous tailings in a growth room environment averaged 865 ppm Zn. Addition of the equivalent of 100 and 200 tons of sewage sludge per 1,000 tons of tailings increased Zn content of forage to 1,370 ppm and 1,814 ppm, respectively. In contrast, grass grown on limed siliceous tailings which has been exposed to atmospheric conditions for 30 or more years, averaged only 59 ppm Zn. Grass forage grown on an uncontaminated soil during the same experiment contained 50 ppm Zn.

The mercury content of twenty-eight grass and legume forage samples grown on Pinchi Lake tailings during 1976 ranged from 0.1 ppm to 1.5 ppm and averaged 0.4 ppm. Mercury contents of terrestrial plants ranged from 10 to 200 ppb on normal soils and from 0.5 to 3.5 ppm in the vicinity of mercury deposits (7). Warren (8) reported mercury content of vegetation growing in the vicinity of mercury mineralization in B.C. ranging from 2.2 to 30 ppm.

The copper content of grass forage grown on Benson Lake tailings during the 1975 growing season ranged from 5 ppm to 40 ppm. Normal range suggested for plants is 3 ppm to 40 ppm Cu (5).

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Table 1: Geographic Location and Biogeoclimatic Zones of Several Cominco Mining Properties

Operation	Sullivan	Pinchi Lake	H. B.	Benson Lake	Con	Pine Point
Location	Kimberley	Ft. St. James	Salmo	Port McNeil	Yellowknife, N.W.T.	Pine Point, N.W.T.
Latitude: Longitude:	49°42'N 116° 2'W	54°38'N 124°26'W	49°8'N 117°10'W	50°21'N 127°14'W	62°27' 114°22'	60°49' 114°28'
Biogeoclimatic Zone	Interior Douglas Fir	Sub-Boreal Spruce	Interior Western Hemlock	Coastal Western Hemlock	Boreal Forest (Northwestern Transition)	Boreal Forest (Upper Mackenzie)
Climate	Montane	Sub-Boreal	Montane	Marine	Boreal	Boreal
Elevation (m)	1,020	720	884	152	152	205
Mean Annual Precipitation (mm)	378	470	762	3,200	254	330
May-September Precipitation (mm)	163	218	160	475	125	178
Extreme Minimum Temperature (°C)	-44	-49	-27	-13	-51	-52
Extreme Maximum Temperature (°C)	42	37	39	34	30	36
Mean Annual Length of Growing Season (days)	180-200	140-160	180-200	260-280	120-140	120-140

Table 2: Economic and Gangue Mineralogy and Areal Extent of Tailings

Operation	Economic Minerals	Gangue Minerals	Area (Acres)
Sullivan			
Iron Tailings	Pb, Zn, Ag	pyrrhotite, pyrite, galena sphalerite, quartz	594
Siliceous Tailings	Pb, Zn, Ag	pyrrhotite, pyrite, quartz, calcite, chlorite, mica, garnet, feldspar, tourmaline	276
KFO Gypsum	Phosphoric Acid	gypsum, phosphate rock, phosphate slimes, phosphoric acid, fluorosilicates	150
Pinchi Lake	Hg	calcite, dolomite, ankerite, quartz, sericite, graphite, cinnabar, hematite, pyrite, barite, stibnite, chalcopyrite	67
H. B.	Pb, Zn	calcite, dolomite, talc, tremolite, pyrrhotite, pyrite	61
Benson Lake	Cu, Fe	magnetite, andesite, garnet, pyrrhotite, calcite, epidote	7
Con	Au	quartz, ankerite, chlorite, carbonate, arsenopyrite, pyrite, stibnite, sphalerite	150
Pine Point	Pb, Zn	calcite, dolomite, pyrite, marcasite, galena, sphalerite, pyrrhotite	1,000

Table 3: Available Plant Nutrient Concentrations in Tailings

	Available Nutrients			
	NO_3=N	P	K	Mg
	ppm			
1. Sullivan Concentrator				
Iron Tailings-Unoxidized	<1	<2	<25-45	40-125
-Oxidized	<1	3-8	<25	<25-500+
Siliceous Tailings-Unoxid.	<1	2-3	<25-65	30-270
-Oxid.	<1	2-3	<25	500+
KFO Gypsum	<1-2	135	<25-65	<25
2. Pinchi Lake				
Tailings	<1-3	4-13	<25-100	45-500+
Tailings Slimes	<1	4	70	215
3. H.B.				
Tailings	1	2-9	<25	85-130
Tailings Slimes	1	5-14	<25	200-225
4. Benson Lake				
Tailings -1972	<1-3	<1-2	50-85	30-40
-1975	<1	2-6	<25	30-220
Tailings Slimes - 1972	<1	< 2	110	60
5. Con				
Con Tailings	<1	2-10	<25-80	50-500+
Negus Tailings	3-6	6-10	95-100	500+
6. Pine Point				
Tailings	<1	2	<25	150-275
Tailings Slimes	<1	2	<25	240

Table 4: Certain Chemical Properties of Tailings

	pH	Total S (%)	$CaCO_3$ Equiv. (%)	CEC (meq/100g)	ECe (mmhos/cm)
1. Sullivan Concentrator					
Iron Tailings-Unoxidized	5.8-6.1	34	25	1-3	2- 4
-Oxid.	2.0-2.5	7	0	1-6	2-36
Siliceous Tailings-Unoxid.	5.6-6.9	11	12	1-8	2- 5
-Oxid.	2.4-2.8	4	0	6	6-20
KFO Gypsum	3.5-5.0	12	0.5	1	2- 4
2. Pinchi Lake					
Tailings	8.0-8.6	0.2	43	1-3	1- 6
Tailings Slimes	8.1	0.1	52	3	1
3. H.B.					
Tailings	7.6-8.7	1.4	84	1	1- 3
Tailings Slimes	7.7-7.9	3	71	2	1- 3
4. Benson Lake					
Tailings-1972	6.4-7.3	4	6	2	2- 3
-1975	2.5-3.8	4	1	-	2-36
Tailings Slimes-1972	7.2	4	17	3	3
-1975	7.5	2	-	-	2
5. Con					
Con Tailings	7.6-8.3	0.6	21	-	4-54
Negus Tailings	7.7-8.3	0.8	24	-	2-45
6. Pine Point					
Tailings	7.6-7.9	10	25-68	-	3- 7
Tailings Slimes	7.3	-	-	-	4

Table 5: Physical Properties of Tailings

	Particle Size Sand	Silt (%)	Clay	Bulk Density (g/cm^3)	Particle Density (g/cm^3)	A.W.S.C. (%)
1. Sullivan Concentrator						
Iron Tailings-Unoxidized	33	64	3	2.4	4.3	16-20
-Oxidized	20-29	45-60	20-26	1.2	2.8	11-28
Siliceous Tailings-Unoxidized						
-Oxidized						
KFO Gypsum	-	-	-	1.0	2.2	29
2. Pinchi Lake						
Tailings	30-87	11-64	2-7	1.6	2.7	11
Tailings Slimes	0	81	19	1.0	2.7	-
3. H.B.						
Tailings	36-40	50-58	5-10	1.6	2.9	11
Tailings Slimes	0-1	87-88	11-12	1.2	2.9	24
4. Benson Lake						
Tailings	78-86	14-19	0-4	1.7	3.5	13
Tailings Slimes	47-58	38-49	4-5	1.6	3.4	35
5. Con						
Con Tailings	13	77	10	1.3	-	-

Table 6: Total S, $CaCO_3$ Equivalence and Lime Requirement of Selected Reactive Tailings Materials

	Initial pH	Total S (%)	$CaCO_3$ Equiv. (%)	Lime Requirement: $BaCl_2$-TEA (mg/g)	Lime Requirement: Incubation - Growth Tech. (mg/g)	Lime Requirement: Incubation - Growth Tech. (ton/ac.-ft.)	Final pH
Sullivan Concentrator							
Iron Tailings							
Oxidized	2.2	5.7	0	44	215	301	6.9
Unoxidized	5.8	36.0	25	2	n.a.	n.a.	n.a.
Siliceous Tailings							
Oxidized	2.4	2.5	0	25	97	185	6.9
Unoxidized	6.2	20.0	11		110+	268	5.5
Benson Lake							
Tailings	2.6	2.0	1	12	40	92	7.0

RECLAMATION AT ISLAND COPPER

UTAH MINES LTD.
Rupert Inlet, B. C.

C.A. Pelletier - Chief of Environmental Quality
R.J. Hillis - Environmental Supervisor

March, 1977

RECLAMATION AT ISLAND COPPER

ABSTRACT

Utah Mines Ltd. operates a large open pit copper mine located on the north shore of Rupert Inlet on the northern end of Vancouver Island.

Since 1970 the Environmental Department at Island Copper has been responsible for mine reclamation studies and operations. Initial studies included a detailed assessment of soils and forest productivity in the area. Initial operations included planting 60 acres of disturbed ground around the plant facilities and access road. Subsequent operations have included test plots and stabilization of waste dump outslopes.

RECLAMATION AT ISLAND COPPER MINE

Introduction

First I would mention that this is not a research or scientific paper but a general description of reclamation at Island Copper Mine.

Island Copper Mine is situated on the north shore of Rupert Inlet on the northern end of Vancouver Island and is the largest open pit operation located in coastal British Columbia. The mineral reserves indicate approximately 280 million tons of recoverable ore with a grade of 0.52% copper and 0.018% molybdenum.

The mine is capable of moving 160,000 tons of rock per day by the conventional truck and shovel method.

The milling operation can process 40,000 to 50,000 tons of ore per day and produce up to 1,000 tons of copper concentrate and 15 tons of molybdenum concentrate.

Recoverable by-products in the concentrate include gold, silver and rhenium.

The ore reserves are such that a single pit of approximately 8,000 feet by 4,000 feet with an eventual depth of 1,000 feet below sea level will be developed in the twenty year life of the mine. The total area occupied by the pit will be approximately 500 acres. The estimated average stripping ratio for the twenty year operation will be 2.42 tons of waste for each ton of ore.

In a low grade open pit operation large volumes of waste have to be removed and disposed of in an environmentally acceptable manner. To this end engineering and environmental planning are of the essence for a successful mining venture.

A basic reclamation plan was developed at Island Copper with both short-term and long-term objectives.

The short-term objectives of the reclamation plan were to:

1) Reduce erosion and subsequent siltation of natural waters through stabilization of disturbed areas with vegetation, and,
2) Maintain asthetic quality around the mine site.

The long-term objectives or land use consideration for the area are:

1) Recreation
2) Wildlife habitat
3) Forestry
4) Watershed, and
5) A combination of the above.

The present land use in the intermediate area, other than the mine operation, is wildlife habitat and recreational fishing. The area surrounding the mine is designated as prime forest yield region and is presently utilized by local forest companies.

Before the mine started the topographic relief in the pit area was moderate with elevations ranging from sea level to slightly more than 400 feet above sea level. The area was covered by second growth hemlock with minor amounts of spruce, cedar and fir. The trees varied in size from 15 to 25-inch stumps and heights of 100 to 150 feet. These stands were merchantable timber. In the lower elevations there were minor stands of mature cedar, and fir associated with non-merchantable timber in the swampy area.

The ore body was overlain with varying thicknesses of overburden. The eastern end of the pit had over 300 feet of till cover.

General Discussion

The initial reclamation research was to assess the soil overlaying the till material.

The perhumid climate of the area, (80 inches of ppt/year) which includes a considerable amount of precipitation even during summer months, strongly engenders chemical weathering. Soil development occurs even on well drained sites because water, the medium for chemical reactions, is abundant. With a high moisture content, the end products of various chemical reactions are efficiently leached from the soil system. Moderate temperatures, year round, with only rare periods of ground freezing, further engenders the weathering of soil materials.

The north central area of the pit was a depression where restricted removal of soil water occurred. Due to the humid climate and the relatively flat landform, the soils were saturated for most of the year. As a result, anaerobic conditions prevailed and a considerable amount of organic material developed.

Truly xeric sites were not to be found on the rock outcrops that occurred on the west side of the pit. This is because soil water storage capacity is not absolutely necessary in such a humid climate.

Two groups of soils were encountered in the area: podzols and organic soils.

The dominant soil of the area is a moderately well drained Duric Humo - Ferric Podzol which developed in the glacial till. This soil is characterized by accumulation of surficial organic materials overlaying a meter or more of a reddish brown Bf horizon. The transition to relatively unweathered till is abrupt, although the uppermost ten centimeter of the till, the duric horizon, is more platy and harder than the till at greater depths.

The surface organic horizons, L, F and H contain little incorporated mineral compounds and are strongly acidic (pH of 3.0 to 4.0) and contain the bulk of nutrients available to the forest ecosystem.

The Bf horizon is loamy, somewhat finer textured than the parent till as a result of weathering. This horizon is acidic, low in bases, but enriched with iron and aluminum. Since in this podzol the organic matter content of the B horizon is low, levels of nitrogen, sulphur and phosphorus are also low. Although the native vegetation is adapted to such an inherently low fertility status, the use of exotic species in reclamation obviously demands significant fertility amendments.

The organic soils are associated with relatively flat landform with the water table at or very near the surface year round. This type of soil covers approximately 10% of the pit area. These soils are poorly drained Typic Mesisol and poorly drained Typic Fibrisol. The acidity of these soils ranged from a pH of 2.7 to 2.9.

The soil-vegetation relationships in the area are distinct. The podzol soils developed in till, support dense forest communities dominated by western hemlock and balsam fir with minor admixtures of Sitka spruce, red cedar and Douglas fir. The organic soils support red cedar and sedges.

The forest capability of the area according to C.L.I. forest capabilities maps, ranged from 1d (258-300 c.f./ac-yr) for western hemlock in the podzols to 3W (major limitation to forest growth and excessively high water table) for red cedar in the organic soils. The site index for western hemlock in the area is up to 180 while the site index in poorly drained sites drops to 50 for red cedar.

Reclamation Operation

As mentioned earlier, the objectives of the reclamation program are in the short term, to stabilize the disturbed areas and to prevent erosion. In an area of high rainfall with 3 inches in a day not uncommon, erosion is a serious problem.

In the spring of 1971 approximately fifty acres of the construction site area and 10 acres of road allowance were seeded by aircraft and hand-held cyclone seeders. The areas covered did not receive any special preparation prior to seed and fertilizer application. A mixture of annual rye grass, perennial rye grass, creeping red fescue, red top, northern perennial rye, white dutch clover, alsike clover, bent grass and meadow fescue was applied at a rate of 60 lbs/acre. Fertilizer (20-20-10) was applied at a rate of 300 lbs/acre at the time of seeding.

By fall, the first germinating plant species such as clover and annual rye had produced a viable seed and an excellent ground cover. A well developed root system had developed by the following summer.

In early 1971 pre-stripping of the pit area started. An attempt was made at stockpiling the organic soils from the lower regions of the pit. The soil being saturated was soupy and impossible to stockpile with the equipment that was used for the stripping. At this time it became evident that stockpiling organic topsoil in an area of high precipitation would be very difficult and even impractical.

A test plot was developed to establish the potential of till as a growth medium. The till used was representative of the material that would eventually cover dump surfaces.

The test plot was divided into 9 equal areas and treated with varying amounts of seed and fertilizer.

A general view of the macro plots after five years is shown here. No additional fertilizer was added to the macro plot after initial seeding. Good plant growth is evident in plots that were fertilized. Macro plot without fertilizer did not produce a good vegetation cover even with 80 pounds of seed per acre.

The test plot served to identify optimum seeding and fertilizer rates and established that till material can be used as a medium for revegetation.

This slide is of a rock causeway before it was seeded in 1971. The ground preparation involved spreading till on top of the rock base. This is the same causeway a year later. An interesting observation here is that alfalfa has taken over as the dominant species even though it was seeded at only 5 parts per 100 originally.

These slides taken last summer indicate that grass seeded in 1971 is continuing to be an effective means of erosion control without any major maintenance cost. Evidence of native species invading seeded areas is shown in these slides. As part of our reclamation program we have been documenting natural revegetation in areas disturbed but not seeded. The dominant tree species are red alder and western hemlock. The dominant shrubs include red elderberry and salmonberry. Some native grasses, forbs, sedges and ferns have been identified.

In the waste dump areas there has been an effort to reclaim dump surfaces as well as dump outslopes. Some of the work is for short-term benefits and documentation because most of the dumps are not in a completed form.

Approximately 15 acres of the beach dump has been prepared for seeding. The ground preparation consists of regrading the waste rock, covering with a mixture of topsoil and till material and finally grading to a relatively smooth surface.

A six acre plot was seeded in 1976. This slide shows the plot as it looked this winter. The cost of preparing and seeding this area was approximately $1,200.00/acre.

Another area seeded in 1973 was a small waste dump north of the pit. This plot was prepared with organic soil and has a very thick growth of grass. The cost per acre of this reclamation effort was approximately $1,500.00

Research on revegetating steep outslopes of waste dumps greater than 37° is in progress. The method employed consists of over-burden material being deposited at the top of the dump and pushed over the side by bull-dozers. The overburden slides down the dump face filling in crevices between boulders on the way down. The dump face is then hand-seeded and fertilized at a rate of 60 and 200 lbs per acre respectively. A heavy matted growth of grass was established on slopes of 35° to 40° as is shown in this slide. On slopes greater than 55° failure occurred during a heavy rainfall in December 1976. The slopes that failed were areas that had a 3-foot layer of overburden and poor surface drainage. We found that it is important that a very thin layer of overburden be deposited along the slope and that water be diverted from the dump crest.

This winter a number of alder and hemlock seedlings have been transplanted along dump slopes previously seeded. The transplanting of alder during the winter has been very effective. Growths of over 200% a year have been documented. Transplanted hemlock seeding have also done well.

This dump was planted last September. This slide was taken three months later.

A program of collecting alder cones was started in 1974. The cones were processed to obtain some 2 million alder seeds a year. Laboratory tests on these seeds have indicated over 50% germination. The procedure is now to include alder seed with the grass at a rate of approximately 1 part per 100.

No attempts have been made in monitoring metal levels in the vegetation covering disturbed areas because of problems in standardizing an acceptable distribution of species to monitor. We do plan to monitor the forage that the deer have been grazing on and comparing it to some standard from a control area.

This is a salt lick station covered to protect the salt from dissolving in the rain.

Metal levels of rodents that inhabit revegetated areas are being monitored. The deermouse being the most abundant is used as an indicator. The tissue of the specimens collected have been analyzed for copper, molybdenum, lead, zinc, cadmium and arsenic.

The average copper is 2.50 ppm, molybdenum 0.35 ppm, lead 0.20 ppm, zinc 22 ppm, cadmium 0.05 ppm, and arsenic 0.50 ppm. There is no difference between animals caught in the revegetated areas compared to animals from the control site outside mine area.

Other chemical monitoring associated with reclamation has been the water quality program of surface runoff surrounding the pit area. A small lake adjacent to the pit has been monitored for the past seven years without showing any impacts of the operation.

In conclusion the short-term objectives of erosion control and aesthetic enhancement of the plant site are being attained. In the longer term it is encouraging to note that in an area such as Rupert Inlet there is evidence that vegetation including trees can readily colonize even bare rock.

WORKSHOP SUMMARIES
THE COMPANY SIDE

CONCERNING COMMUNICATION IN AND BETWEEN AGENCIES

At least two viewpoints were expressed.

A. insufficient communication

- found at all levels; federal, provincial and industry
- improvements needed between Victoria and Regional Resource Committees, the operations end of a company and the government body responsible for regulating the activity of a company, and between inter-governmental offices.
- an associated problem is the lack of administrative connections between research experts and mine officials--a problem that seems to increase with the distance of the mine from Victoria.
- another associated problem is the excessive waste of time which occurs between a company's policy change and approval or notice of disapproval by the overseeing government agency.
- the production of forms and circulation of these between agencies was considered an insufficient system for good communication.
- need face to face communication for maximum efficiency.

B. adequate communication

- seems to be "pretty good" communication between the mining companies themselves on the research level.
- there seems to be no real drastic lack of communication between government and the mining companies as both are in a sense pioneering reclamation.
- communication problems that might result might be on the lower levels such as communication between operations and reclamation researchers.
- there is good rapport in British Columbia between the government agencies and the mining companies.

CONCERNING INTER AGENCY CO-OPERATION GROUP APPROACH

- need to work collectively
- companies would prefer to deal with one agency
- this agency should be regionalized such that recommendations would be approached at a local level and made by people familiar with an area.
- this agency could act as a more central one person clearing house that can bring in experts.

CONCERNING SITE SPECIFIC NATURE OF RECLAMATION

- reclamation is site specific and each site has its own unique problems
- subsequent to this, the broad objectives of the reclamation guidelines should be in accord with the biophysical state of the mine site.
- industry should have more say in the formation of guidelines due to a more basic knowledge of the practical elements involved.

CONCERNING EVENTUAL (SUBSEQUENT) LAND USE

- the eventual land use should be within reasonable limitations of the site.
- planning for eventual land use is site specific and should be done before the mining actually takes place.
- the ultimate land use should be up to the people in the area of the mine to decide, and not the people back in Victoria.

CONCERNING GOALS AND RATIONALE FOR RECLAMATION

- there is a need to restore the land to use but restoration shouldn't be undertaken if the land is going to be re-opened in the future.
- reclaiming land before it is finished with is a waste of time and money if it is only for cosmetic and public relations reasons; there may be value in this, however, in plant species succession or stability.
- mining companies should not be into reclamation for public relations purposes.
- there is a growing committment in the mining industry in developing reclamation as a moral necessity.
- the land should be restored to as near to equal usefulness, or better, but not necessarily the previous use, for the value of particular land or uses may vary with time.

- the question of reclaiming land to equal or better than original is idealistic.
- nature and especially aquatic resources is where reclamation should be directed. The aesthetic appeal of man should be secondary.
- need a clarification of responsibilities and priorities --i.e. no mine company should be made to feel guilty for damaging natural conditions; rather, problems should be brought out into the open and solved, if possible.
- must establish objectives of reclamation; is it

  a) restoration (exact)
  b) reclamation (similar) or
  c) rehabilitation (new use).

CONCERNING DURATION OF RESPONSIBILITY FOR RECLAMATION

- length of reclamation is subjective.
- who is to decide how long a company must monitor its reclamation site after closing down mining operations?
- suggest that it should be up to the government agencies involved to decide on the length of reclamation.
- also suggested that reclamation should continue until vegetation is self-sustaining in cases other than acid tailings ponds.

CONCERNING COSTS OF RECLAMATION

- reclamation should be considered a production cost and detailed cost benefit analysis should be undertaken before any mining proceeds.
- reclamation procedure must be refined as the mining company is obviously concerned with overall financial profit.
- the two major obstances to the mining industry in carrying out restoration of mine sites are 'costs of reclamation' and 'technology available to deal with reclamation'.

CONCERNING PRE-LEGISLATION OPERATIONS

- must treat existing mines differently from starting mines when establishing reclamation procedures.
- many old mine disposal sites not chosen with reclamation in mind.
- there is not sufficient base line data to deal with changes in reclamation objectives that result during the course of mining operations.

CONCERNING BONDING

Two different views were evident:

A.

- a system of performance levels should be used instead of security B.C. Hydro bonds.
- bonds tie up company cash that does not necessarily have to be tied up.
- some unfairness in the amount of bonds required for individual mines is evident.
- can you put a price or value on the land?

B.

- mining development is becoming more controlled through bonding.
- bonding should cover the cost for stability and erosion control to engineering standards.

CONCERNING RECLAMATION STANDARDS

- are the guidelines fair for all resource users or is mining being utilized as the test species.
- should have one agency for reclamation for all resource users.

CONCERNING USE OF NATIVE PLANT SPECIES

- need a native plant material center with necessary variety of native species as well as species from other areas.
- there is a lack of information on natural seed.
- need joint effort by government and industry to make available speciality seed types.

CONCERNING EDUATION/INFORMATION

- need education of companies and education of the public as to the developments in reclamation.

CONCLUSION OF DAY 1

BANQUET - SMORGASBORD

KEYNOTE ADDRESS BY DR. WALI

(Text unavailable but centered on the necessity of developing total mine planning with practical objectives)

EXPLORATION AND INSPECTION

Chairman - A. O'Bryan, Ministry of Mines and Petroleum Resources

Thursday, March 17, 1977

Morning Session

RECLAMATION IN THE PEACE RIVER COALFIELD

R. George, Ministry of Mines and Petroleum Resources

ABSTRACT

A summary of reclamation of past exploration work is provided with comment on the direction of exploration and reclamation.

Some problems and sensitivities of alpine regions and coal exploration are looked at in particular. Information on reclamation headway resulting from research and inspection in 1976 is provided. An accompanying slide presentation is made.

R. George's presentation was in the form of slides not suitable to written reproduction.

RECLAMATION OF EXPLORATION DISTURBANCES AT KAISER RESOURCES LIMITED, SPARWOOD, B.C.

R. Berdusco, Kaiser Resources Ltd.

ABSTRACT

Since the formation of the Exploration-Reclamation Section of the Environmental Services Department in 1974, Kaiser Resources Limited has carried out an intensive program of reclamation on land and water-courses affected by past and ongoing coal exploration activities. To date, 277 acres of land have been reclaimed. This includes exploration roads, trenches, seam traces, test pita, drill sites, adits, slide areas and other related disturbances.

To accomplish this work, a number of innovative techniques are utilized including terracing of steep dump slopes, pre-logging of exploration roads, slash disposal using a portable woodchipping machine and total removal of adit refuse. A number of other techniques and refinements are still in the research and development stages.

A system of pre-planning and monitoring of ongoing exploration work has also been used effectively. This system reduces damage to environmentally sensitive areas and virtually eliminates unnecessary disturbance.

R. Berdusco's presentation was in the form of slides not suitable to written reproduction.

PLANNING, ENVIRONMENTAL PROTECTION AND RECLAMATION TECHNIQUES ON THE SAXON PROJECT, PEACE RIVER COAL BLOCK

Denison Coal Limited
Calgary, Alberta

Geoff Jordan and Georgia Hoffman

PLANNING, ENVIRONMENTAL PROTECTION AND RECLAMATION TECHNIQUES ON THE SAXON PROJECT, PEACE RIVER COAL BLOCK

Geoff Jordan and Georgia Hoffman

ABSTRACT

The Saxon property of Denison Coal Limited is located adjacent to the Alberta Provincial Boundary in the eastern foothills of the Rocky Mountains within the Peace River Coal Block of British Columbia. Exploration on the property was first carried out in 1970, at which time drill intersections of a high quality metallurgical coking coal were made. A long range plan of exploration commenced in 1975 with a program of detailed geological mapping being followed by intensive exploration aimed at completing a feasibility study towards the end of 1977.

Long range planning has not only allowed the precise objectives of the exploration program to be determined, but also allowed strict measures for environmental protection to be imposed. Consequently, a significant reduction in the amount and cost of reclamation of disturbed surface area is anticipated.

Hand trenching, helicopter drilling, bridge construction and other techniques have already made significant contributions to reduction of surface disturbance, and new techniques are currently being employed to further reduce surface disturbance and the cost of reclamation, as well as to reduce exploration costs in some instances.

INTRODUCTION

An Exploration Reclamation Philosophy

The approach taken towards an exploration program and subsequent reclamation should be significantly different from procedures adopted for mine site and spoil dump reclamation.

In mine site developments, the movement of a large volume of material is required so that the natural resources lying beneath the surfaee may be economically extracted. Thus, mine site reclamation necessarily involves the recontouring and revegetation of relatively large areas of disturbed surface materials. An exploration program usually does not involve much materials transport. Subsequent development of an exploration area for mining will only take place if and when the exploration studies have demonstrated that the proposed development is economically sound.

Since the implementation of an exploration program does not guarantee mine development, the principal emphasis during exploration must be placed on environmental protection, with reclamation techniques only being applied when land disturbance is found to be necessary; all reasonable efforts should be made to keep land surface disturbance during exploration to a minimum.

Minimal surface disturbance during exploration can only be achieved by detailed long range planning combined with stringent controls upon field personnel. This approach is being applied to exploration being carried out on the Saxon Coal Project.

THE SAXON COAL PROPERTY

Denison Coal Limited, in conjunction with its Ruhrkohle Group partners, is currently conducting exploration on the Saxon property with the intention of completing a final feasibility study toward the end of 1977. The aim of the feasibility study is to demonstrate that the Saxon property is capable of supporting a coal mining operation producing up to 4 million tonnes of metallurgical coal annually from both surface and underground mines.

The Saxon property consists of 33,585 acres of coal licences located in northeastern British Columbia adjacent to the Alberta Provincial Boundary. The coal licences are located to cover the principal coal bearing unit of the area, the Gates Member of the Commotion Formation. Four coal seams of economic importance with thicknesses in excess of three metres have been located within the Gates Member, and the present studies are intended to show that sufficient reserves are available for economical mining by both surface and underground methods.

Geographically the property is located in the eastern foothills of the Rocky Mountains about 170 km. south of Dawson Creek, British Columbia. The Narraway River cuts across the central portion of the property in a northeasterly direction and the Torrens River flows in a similar direction at the southern property boundary. The eastern and western margins of the property are defined by northwesterly trending ridges separated by a broad valley floor. The high ground on the property reaches an elevation of 2200 metres while the valley floor of the Narraway River is at an elevation of 1100 metres.

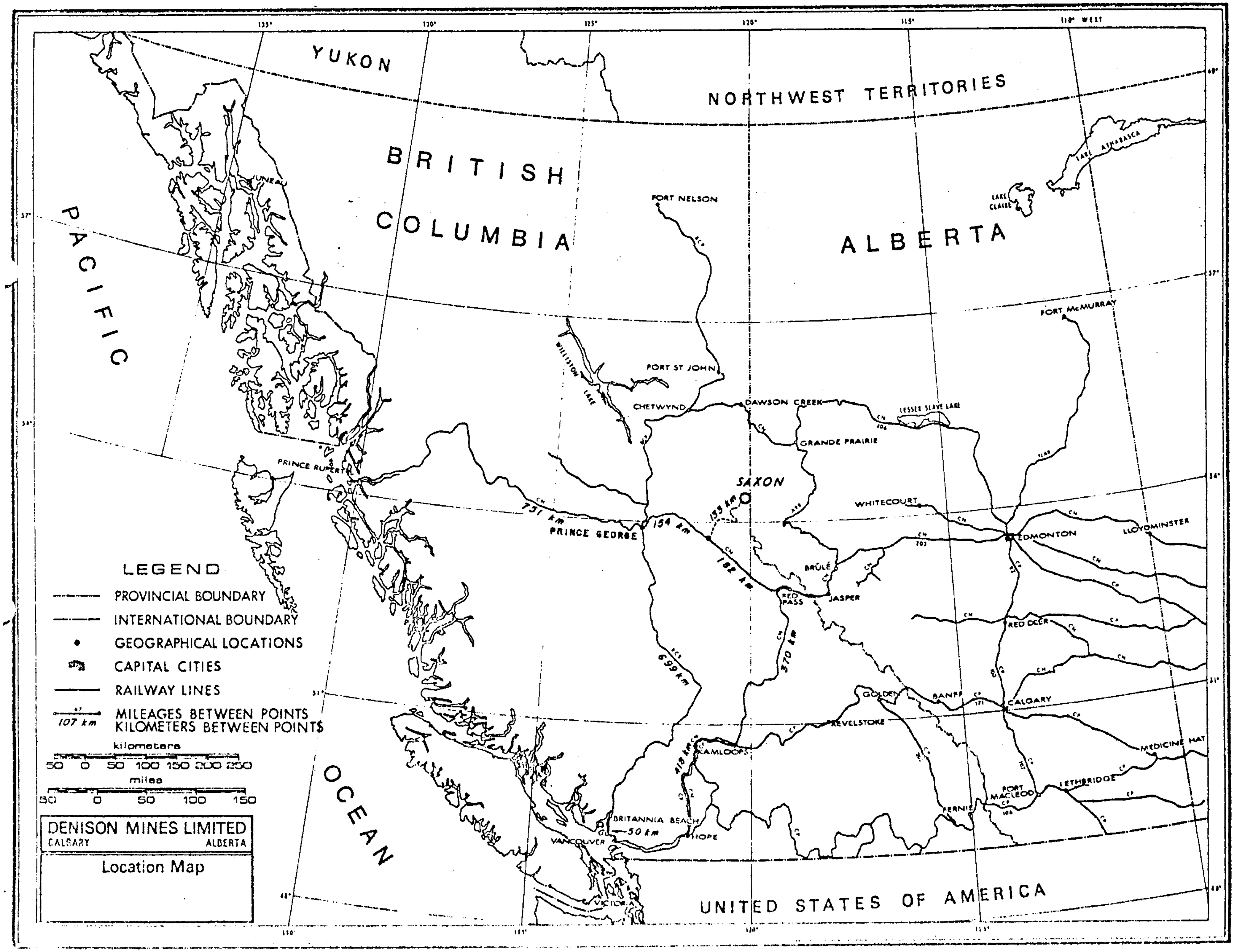
An initial environmental study of the Saxon project was recently completed by B.C. Research. This study has provided part of the basis for the discussion below by providing data on climate, and plant and animal communities.

The climate in the Saxon area is characterized by long cold winters and short growing seasons. The area is estimated to receive relatively low annual precipitation of about 35 to 40 cm., most of which occurs as snow. Strong winds blow from the west and northwest throughout the year.

At lower elevations the property falls within the Englemann spruce-subalpine fir zone, and is forested by spruce, lodgepole pine and poplar, with dense underbrush often consisting of willow species. Transition to the alpine tundra zone takes place at elevations in excess of about 1800 metres. The main valley floor, a sub-surface water discharge zone, is commonly marshy, and the surficial material in this area is a thin veneer of glacial till covering the Cretaceous strata.

In the alpine regions, a thick cover of grasses and small shrubs is present to an elevation approximately 300 metres above treeline. At higher elevations the vegetation cover, which consists of mosses and small mat-forming alpine plants, becomes more sparse, covering usually ten to fifteen percent of the land surface except in small well protected areas which are not directly exposed to the harsh weather conditions.

In high alpine areas an environment similar in appearance to arid desert plains, such as the "gibber plains" of Australia, is often found. These more barren regions have a dense surface cover of small stones which is formed by a combination of weathering processes and wind erosion. As weathering takes place, physical, chemical and biological processes break down the rock strata producing soil materials and sand and silt sized rock particles together with coarse rock fragments. In areas where vegetation cover is sparse, wind action winnows away the fine material, leading to an accumulation of the coarser fragments which protect the finer materials beneath. The prevailing wind direction in the Saxon area is from the west and northwest, and high alpine slopes facing those directions are found to be the most susceptible to the generation of the type of environment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FERNIE
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DENISON MINES LIMITED
CALGARY ALBERTA
Location Map

described above. This environment is particularly sensitive, and removal of the accumulated surfacial material can lead to increased wind erosion.

The variety of wildlife on the property is similar to that found in the eastern foothills farther towards the south. In the alpine region small herds of Rocky Mountain bighorn sheep consisting of 4 to 5 beasts have occasionally been seen and one herd of 30 sheep is known to inhabit the Mount Torrens area which lies beyond the property to the east. Moose have been observed in the swampy regions along the Narraway River and grizzly and black bears have been encountered in the alpine and forested regions. Goats, caribou, and deer are less common. Numerous smaller furbearing animals are found through the property. Baseline studies have shown that fish are only present in the Narraway River, apparently because numerous waterfalls have prevented their migration into the smaller streams of the area.

At the present time the only professional land use activities being conducted in the area are guiding by local outfitters and the operation of a trapline on the property. Small scale ranching and some logging is carried out in Alberta 10 miles downstream along the Torrens River. Occasional recreational visits by tourists, campers and hunters ocaur.

PROJECT PLANNING AND IMPLEMENTATION

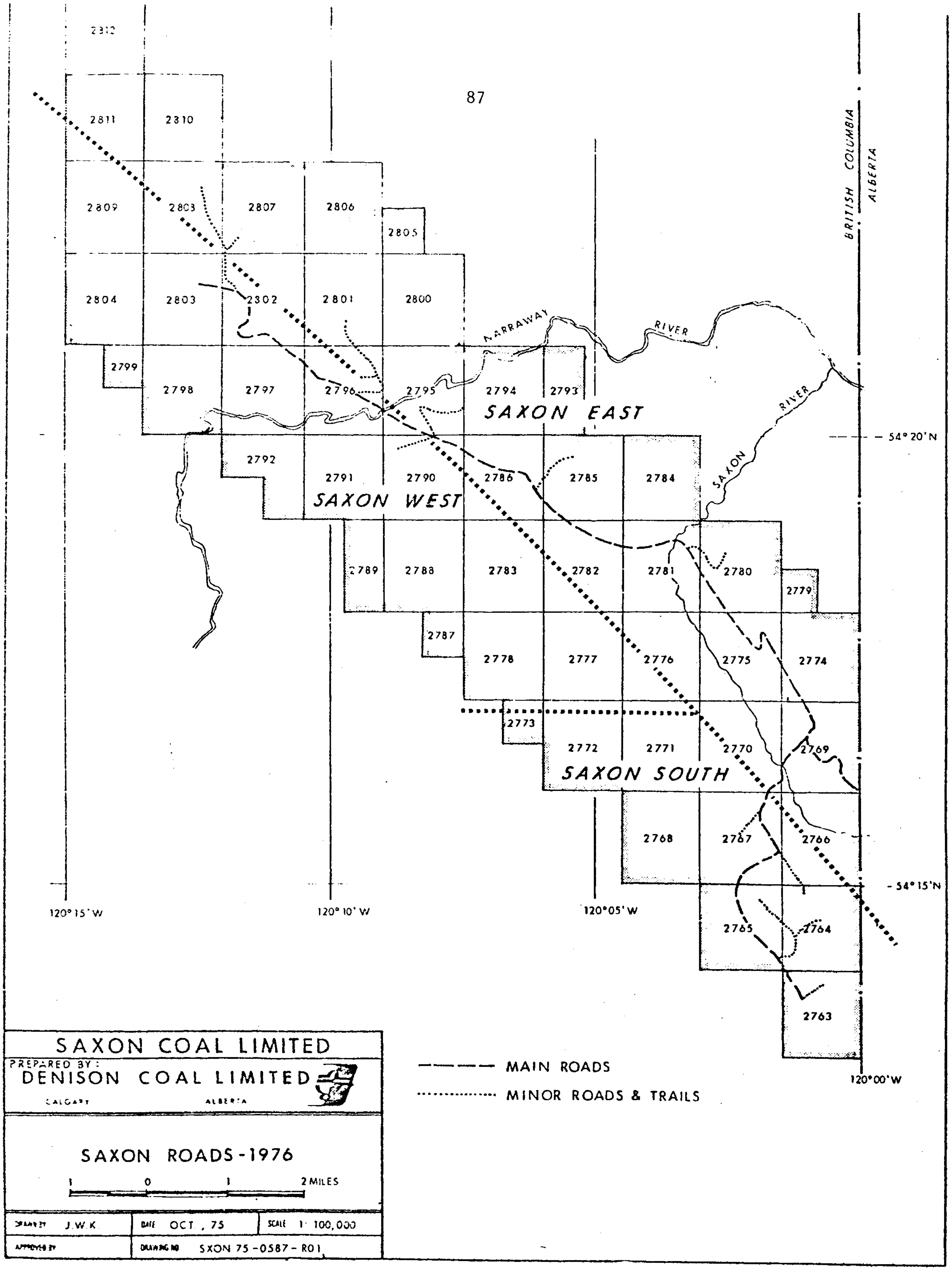
The initial period of exploration on the Saxon property took place in the period from 1970 to 1972 when a limited amount of drilling, aditing and mapping was carried out. The target for this program was the obvious Gates Member strata exposed on the northeastern ridge of the property, an area now called Saxon East, where coal was known to be present. The aim of this program was to determine whether the seams present contained sufficient tonnages of coal of a suitable quality to warrant further exploration as a mining project. Such was found to be the case, but most exploration activity began to focus, by all agencies, on projects being conducted farther north.

In 1974 exploration of Saxon was again considered, and a long range plan for exploration was formulated. A decision was made to carry out exploration using a three-stage approach: detailed geological surface mapping of the entire property in the first year, to be followed by two years of intensive exploration to conclude the study. Targets for the intensive exploration would be selected on the basis of the geological mapping, and areas of environmental sensitivity could be identified prior to the commencement of land disturbance.

The program of helicopter-supported geological mapping began in 1975 and was intended to determine whether additional mining possibilities could be located besides those known to be present in Saxon East, and to assess their importance before proceeding to a program involving significant land disturbance. The 1975 mapping program showed that an area of surface mining potential existed in the area called Saxon South, and that some possibilities for underground mining may be located in the densely vegetated and poorly exposed valley region called Saxon West.

Using the results of the geological mapping program and advice from various British Columbia government agencies, it was possible to plan the layout of access roads in the area to service all of the planned exploration to the completion of the feasibility study at the end of this year, as well as to be sufficient to allow further detailed study to be carried out in the future. In general, only short trails are required from this access for drilling purposes. The access road to Saxon South was also located along an area of previous land disturbance, and according to a route which will be suitable for mining purposes. Of the 33,585 acres that lie within the Saxon property boundaries, it is estimated that less than one percent will have been affected by exploration activities by the end of the program this year.

Although Saxon East was expected to be the area of best potential for underground mining, a limited amount of drilling was planned for Saxon West at the start of the 1976 field program to determine whether that area should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DENISON COAL LIMITED
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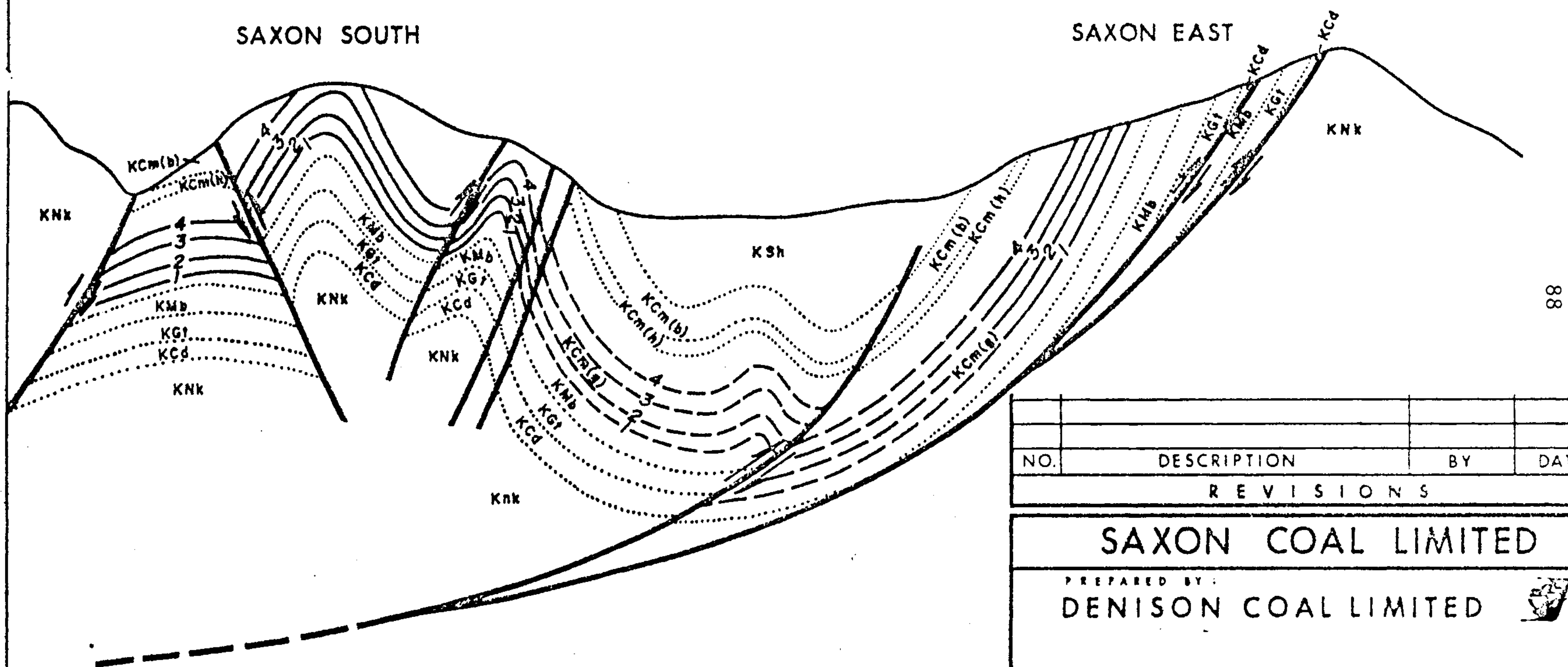

NO.	DESCRIPTION	BY	DATE

REVISIONS

SAXON COAL LIMITED

PREPARED BY:
DENISON COAL LIMITED

SCHEMATIC CROSS SECTION THROUGH SAXON PROPERTY VIEWED TOWARDS THE NORTH

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become the principal exploration target. Most of the exploration activities were planned for the two potential underground mines planned in Saxon East and the surface mining district in Saxon South. The 1976 exploration subsequently confirmed the results of the geological mapping program and showed that coal of suitable quality and in sufficient tonnages existed in these three principal mining areas.

ENVIRONMENTAL PROTECTION TECHNIQUES

To minimize the amount of land disturbance and thus reduce the cost of reclamation, a strong emphasis has been placed upon devising exploration techniques which are related to environmental protection.

Perhaps the most significant results have been gained by the use of hand trenching, as opposed to bulldozer tranching, to obtain detailed data from surface exposures of coal seams. In most exploration programs, use of surface seam data is depended upon to link surface mapping to the detailed but widely scattered data points available from drill cores. As a result, numerous seam surface data points are considered necessary to classify seam reserves in a proven category.

The intensive exploration of surface outcrops, when conducted by bulldozers, necessarily introduces comparatively large areas of surface disturbance, not only for the trenches themselves, but also to provide access for the bulldozer to the trench sites. Hand trenching, where field crew support is provided by helicopter, dramatically reduces the amount of surface disturbance.

It has been found that the hand trenches must be at least in excess of 1 metre deep to penetrate beyond the zone of surface creep to give consistent and reliable measurements of seam thicknesses and characteristics. Since the maximum practical dcpth of a hand trench is limited by the height of the trenchers, this technique cannot be used successfully in areas characterized by deep surface creep. At the present time it has been found that the construction of hand trenches is only practical in areas above treeline, since the dense vegetation and thick soil and colluvium cover below treeline makes the location of the seam and construction of the trench both extremely time consuming and physically exhausting work.

During 1976 some 60 hand trenches were constructed in the alpine area of Saxon South and yielded information that has greatly increased knowledge of the seams and confidence in the reserves calculated for that area. It was also necessary to construct three bulldozer trenches in the forested area of Saxon East at critical data points. One of these sites was then used as an adit site, while a second was constructed along the edge of the existing access road.

Through experience, it has been found that the cost of hand trenching is very low by comparison with bulldozer trenching, and consequently this method of data collection is intended to be used wherever possible in future operations. Similarly, it is anticipated that the cost of reclamation of the hand trenches will be minimal.

The use of helicopters to move and service drills as a technique for environmental protection has also been extensively used on the Saxon project. In 1976 one-quarter of the program was conducted using this exploration method. Initially this technique was employed in the Saxon South area to clearly demonstrate that sufficient coal reserves would be encountered to justify the construction of an access road and the resultant environmental damage, as well as to justify further expenditure for road-accessible drilling and the construction of adits. Further helicopter-borne drilling was carried out towards the end of that program in an isolated area where a single drill hole was required. At that time it was decided that the time delay and land disturbance for road construction could not be justified to establish a single drill site. In addition, previous experience with helicopter-borne drills indicated that the total cost of that hole would be similar if conducted by either method.

Helicopter drilling is a very expensive and particularly dangerous technique for exploration. Its use should be employed with discretion since the operation of any aircraft at close proximity to the ground, particularly in mountainous terrain, is a situation in which serious accidents can and do happen. Worker safety must be the foremost consideration when planning and conducting an exploration program. In some circumstances, such as those outlined above, the use of this exploration technique can be justified. In the 1977 exploration program some helicopter drilling is planned. In other circumstances, however, it is not intended, nor is it justified, to completely replace conventional drilling techniques by this exploration method.

During the program for 1976 several bridges were constructed over creek crossings. In all cases fording could have been carried out as occurs in many exploration programs. The bridges were constructed in an attempt to avoid stream siltation and the possibility of destruction of fish populations. Subsequent baseline studies carried out at the bridges and other locations showed that no fish were present in the streams, apparently due to the presence of waterfalls downstream. However, the bridge construction was still considered to be worthwhile so that stream siltation could be minimized and fish habitats farther downstream beyond the project area would be protected from activities carried out on the property.

Bulldozers and similar earth-moving equipment generate the greatest amount of surface disturbance on any exploration program. As a result, a very strong emphasis has been placed on operator education towards the requirement for creating minimum surface disturbance while maintaining good construction techniques. Initially the requirements were demanded and achieved by approaching the individual operator, and this was emphasized by applying pressure to his employer, the contractor. Once the early results could be seen by the operators themselves, their own pride in a job well done guaranteed that the job would be carried out in the prescribed manner. The general principles emphasized were:-

1. to make only the minimum amount of disturbance necessary;
2. to use existing areas of disturbance wherever possible;
3. to carry out construction along routes which it is anticipated will ultimately be used during mining operations;

and, most significantly,

4. to do no earth moving at all in areas where it is possible to simply walk the equipment over the land surface.

The latter method has been used wherever possible in the alpine areas and results in greatly reduced surface disturbance in this sensitive environment. It has been found practical for bulldozers to simply tow drills across sparsely vegetated high alpine plains, with earth moving being unnecessary.

RECLAMATION TECHNIQUES

Exploration reclamation on the Saxon property is being carriod out in accordance with the current reclamation guidelines. A relatively small amount of surface disturbance has been generated to date and, with the field program for 1976 being completed in December of that year, it was decided to defer seeding until the spring to allow plant growth to become firmly established before the onset of fall. A considerable amount of surface preparation is now being undertaken in conjunction with the 1977 program so that seeding and fertilizing of disturbed areas can be rapidly carried out during the spring.

All roads, either main access or drill trails, are being properly slashed to remove the possibility of fire hazards, and extensive culverting on the access roads has been carried out to allow the current flow of surface water. Further culverting and extensive ditching of the access roads is being undertaken, not only for reclamation purposes but also to provide permanent access for operations in the area. On the Saxon South access road, partially constructed during 1976, a Caterpillar D4 with back hoe is being used to dig substantial ditches to control drainage. When this is completed, the surface stripping will be buried in the road bed after final culverting is complete and prior to gravel surfacing material being placed on the road bed. Seeding of the road shoulders will follow in the spring.

Erosion bars will be constructed on the abandoned drill trails, and it is hoped that this aspect of the work will be complete before break-up to effectively control spring run-off.

Particular care has been taken to dispose of adit waste materials. The weathered coal and rock is hauled by truck to a carefully selected central area for burial. In Saxon South the original recommended site lay in a hollow which was later found to be a substantial water course. A nearby alternate site was selected at the crest of a small but pronounced rise. The crest of the rise was dug out, the adit waste dumped inside and the surface material replaced and recontoured to prevent any possibility of erosion of the coal spoil.

NEW TECHNIQUES

At the present time Denison is attempting to devise new techniques that may remove the necessity for bulldozer trenching below treeline. The low cost of hand trenching and the versatility of the technique above treeline would be desirable. In 1977 motorized hand augers will be used to break up the soil and vegetations along the line of trench prior to trench construction.

The company has ordered a climbing backhoe on a rental-purchase basis and will be experimenting with its use on all projects during this summer in an attempt to devise better trenching techniques involving minimal surface disturbance for this phase of exploration.

Efforts are being made to reduce surface disturbance to a minimum for this phase of exploration because it has been clearly established that it is not only an expensive procedure to reclaim disturbed areas, but it is also expensive to generate areas of surface disturbance in the first place.

RECLAMATION AND DISTRICT INSPECTION

A. D. Tidsbury

District Inspector, Ministry of Mines and Petroleum Resources

Area 10

For presentation to a gathering such as this, I found the subject - "Reclamation and District Inspection" a difficult one for establishment of a coherent theme. Accordingly, I have resorted to the time honored dodge of incorporating slides to illustrate specific points in a concise manner.

I presently administer inspection Area 10, but have some input and considerable experience with Area 9, which contains most of the coal measures referred to as the Northeast Coal Block. This fact, plus many years in mining, mineral exploration, petroleum and natural gas exploration and production, presumably account for my being here at this time. It should also be pointed out that opinion is my own - my confreres have not been consulted on this paper.

As we are all well aware, and for many reasons, the past decade has witnessed a considerable impetus in thought and effort devoted to ecological and environmental planning, evaluation and protection. Some seven years past the Ministry of Mines elected to create a Reclamation Section within the Engineering and Inspection Division.

Most of us presently employed as District Inspectors have had the unique opportunity to observe and participate in the evolution of the Reclamation Section, Reclamation Guidelines and covering Regulations. We have observed the struggle with terminology, reconciliation of differing standards and objectives, retroactivity and responsibility for reclamation, participation and cost in planning, practicality of proposals, bonding, enforcement, covering legislation, and many other aspects including Nature's lack of co-operation on frequent occasions. There has also been ample opportunity to observe both historic and current operational sites with respect to environmental rehabilitation, both assisted and otherwise.

Where then, does a District Inspector stand with respect to reclamation, rehabilitation and current environmental thinking?

It is suggested that he occupies a median position, neither directly involved in the environmentally damaging processes, nor personally participating in the planned healing endeavor. Not a reclamation expert, but having sure knowledge of why the disturbance was initiated. In many ways then, an informed observer having certain powers for control and direction of effort. There is also a more on-going and closer relationship with the Operator in the field than others have occasion for. The Inspector is familiar with the limitations imposed by locale and season, access and potential, budget and factual expenditure. He must also work within rather fixed rules and guidelines, maintaining integrity and fair play.

Due to understandable limitations in staff, and to avoid costly harrassment of the Operator, the Ministry quite logically feels that the Inspector, while perhaps not an expert, is certainly capable of guidance and direction in field progress of such things as reclamation in conjunction with other duties. He works closely with the Reclamation Section, and those specialists in the Section who cover wider fields at less frequent intervals, or who are available for consultation or advice on specific issues as required. To date, this practice has worked quite well, in so far as I am aware, as it pertains to Inspection and Reclamation.

As a result of such travel, observation, and experience, there are aspects of the industry-reclamation relationship on which an Inspector might comment in the interests of progress. Prior to doing so however, I would like to non-prejudiciously refer to a factual case of record in the North-east Coal Block, for which I was then Area Inspector.

***** (PHOTOS, GROUP 1)

In the fall of 1969 I called at an operation of considerable magnitude, encompassing stripping, a test adit of 100 feet plus, and a few thousand feet of NQ coring, which had been active on my previous visit. Activity had ceased, camp and equipment being moved out.

On the next monthly trip, enquiry disclosed that operations had been transferred to a nearby river valley where coal had been found. Since neither operation was authorized, to my knowledge, I proceeded post haste for information.

You can imagine my reaction upon finding a large winter camp, a number of access roads and exploration trenches approximating 100 miles in length, and every one on the camp with happy smiles, too busy to stop and talk.

All this in a restricted area, with no legal title and no notice of intent submitted to the District Inspector, and in a 3 month interval.

I am happy to relate that all is now legalized, funded, projected for production, and up to date in reclamation - rehabilitation.

With change in the intervening years, it is doubtful that such a situation could occur again. Legislation, regulations, and common interest would not permit such an undisclosed amount of activity without authorization.

***** (PHOTOS, GROUP 2)

However, on smaller scale, similar uncontrolled and poorly planned activity still surfaces from time to time in the mineral exploration field. Our first notice may be a complaint as to unpaid bills by a disgruntled employee or contractor, advice from the Forest Service, or other means. Coupled with individual effort on mineral claims and placer leases, the sum total of such poorly planned and often under-financed disturbance is significant, current, and growing.

In order to restrain such uncontrolled activity, usually initiated in "ignorance", and very difficult to differentiate at the onset from well planned, well financed, and more responsible effort, it would appear that a re-assessment of what is implied by "historic rights" and what constitutes a "privilege" is required. It is suggested that reclamation must be accepted as an operating cost from the outset. Industry must also assist regulatory bodies in a balanced and acceptable judgment on aspects of pre-production activities and development such as:

(1) Has the prospector turned up an occurrence, or does potential exist?

(2) Does the mineral have economic potential, in its locale, at this time?

(3) What type of evaluation best suits the prospect?

(4) How may evaluation be undertaken, with least disturbance, consistent with site and economic factors prevailing?

(5) Some means of limiting further major disturbance at a given site, should a concensus of qualified opinion deem it impractical at that time, is desirable.

(6) Revision of the Mineral and Placer Acts with respect to assessment work. Presently, useless physical work is often used as a means of retaining Title.

(7) Evaluation and factual recording of seasonal work, both to ensure justification for continuance, and to have findings available in the event of future un-related effort on the prospect.

(8) Review of funding and qualification reporting standards, to ensure adherence to the recommended work program, and to permit follow-up by the qualified report author for qualified evaluation.

(9) Inclusion of seasonally practical reclamation as a mandatory portion of the program, and/or total reclamation as a requirement to claim release or forfeiture.

In reality, none of these nine items is new or original. All, I am sure, have been discussed by most of us here on numerous occasions. In any event, such change is visualized as a means of limiting unnecessary environmental disturbance, and of obtaining more correct reclamation status, rather than coming from behind and plugging holes as in our present situation.

A very real danger exists in that injustice and hardship might be worked on individuals and smaller groups or organizations. This would certainly have to be guarded against if changes developed.

Other risks and hazards are inherent with early mandatory reclamation, or seasonal reclamation. In northern areas, and areas at elevation, the working season is already so short as to be extremely dependent upon weather. Accordingly, unless adopting unusual procedure and inordinate expense, reclamation on seasonal and/or continuous basis might well incur more harm than good, obtaining only poor to mediocre preparation and germination for the dollar expended.

More advanced prospects, larger prospects, and potential pit operations particularly, face inequities with rigid reclamation requirements. Because of the sheer size of the operation, and its projected active life, short term remedial effort is often an expensive and wasted one. For example, at an open pit mine in my area, attempts to conserve soil and till cover over bed rock are not practical. The mine is on side-hill terrain, as are the dumps. The only way to retain the overburden in situ when the dump is at practical size limit, is to convert it to a rock waste dump, thus loading the toe and sides of the overburden. Practice requires rock surface cover to permit truck access.

***** (PHOTOS, GROUP 3)

In longer term view, this is not deleterious to the end result. It is a multi-staged, multi pit project. Accordingly overburden and till from the final stages of pit development will suffice to adequately prepare finished dumps and pit areas for re-vegetation or planting. End result will be extensive flat and gently sloping areas suitable for forage growth and amenable to irrigation, as well as sloping bowls which could contain small lakes tied into the pre-existing drainage system with beneficial results as to stability and continuity of the system during dry seasons.

Tailings ponds too, may present non-conformable situations. These are vitally necessary, active throughout the life of the operation and far from being standard. Generally, rehabilitation is not possible during project life, though various remedial measures such as seasonal dust control may be practical.

Thus, from the Inspector's viewpoint, reclamation, preservation and rehabilitation of ecology and environment by all means, but with flexibility, planning, and especially timing, to best fit individual situations and circumstances.

From the planning and tailoring point of view, some general considerations which might be considered in reclamation recommended for pre-production work at assured mine sites follow:

(a) Access to some drill sites and test adits perhaps need not require critical location or reclamation if they will be covered or removed in pit preparation in a relatively short period of time in any case.

(b) Conversely, more planning and critical research should go into dump sites. There are notorious for lack of stability, seldom withstanding critical hindsight.

(c) Tailings ponds are similar to dumps. Perched pond sites may have obvious weaknesses. Similarly, ponds located in depressions or bowls may not be amenable to final stability and water control, though otherwise desirable.

(d) Funds expended on planning and research in the very early days of exploration and development, even including extensive delay, are well spent, and worth many more at a later date.

To sum up then, as a District Inspector, I believe we have made great progress in the last decade, taking changes in mining technology in stride. Continued progress is certain. With on-going co-operation between all who have input, tenable guidelines and policies will evolve. This objective will require mutual appreciation with thorough <u>awareness</u> of the problem, <u>knowledge</u> of the scope of potential environmental damage, and <u>effort</u> within acceptable and practical parameters.

WORKSHOP SUMMARIES

EXPLORATION AND INSPECTION

CONCERNING EXPLORATION COSTS

- financial committment must be established by the management of the mining company to support reclamation activities.
- management must be aware of guidelines and rules beforehand and have funding to handle it to avoid restrictive legislation.
- co-operation between mining companies and government, now, is very important to prevent the development of a massive body of red tape (rules and regulations).
- industry should come together co-operatively to share the costs, the problems and the results of research and experience.

CONCERNING EXPLORATION GUIDELINES

- guidelines change too often and have in them conflicts i.e. where it is necessary to reclaim an area after exploration which will be mined in the future.
- it may be better to interpret guidelines on a site specific basis.
- government agencies should give more input to small companies on reclamation, especially in following the guidelines.
- inspectors should act as guides, advisors and teachers, particularly to small operators. This should be combined with common sense site specific advice.
- may be difficulties for inspectors to convince small operators that guidelines should be followed because other resource users (e.g. hydro) have no guidelines.

CONCERNING COMMUNICATION

- need to facilitate communication especially in inter-governmental agencies.
- there is an inadequate sharing of information between mines and other agencies (e.g. agriculture, forestry, fish and wildlife, etc.).

- need communication on a regional level.
- the reclamation process should be regionalized as decisions are made at too high a level.
- there are inconsistencies between regions and Victoria, possibly due to a lack of communication.

CONCERNING INSPECTION

- more manpower needed at inspection level possibly with teams of inspectors with representatives from different disciplines and agencies.
- inspection is generally good but lacks expertise in some areas.
- need availability of resource people from the mines reclamation branch to assist reclamation programs in the field.
- unnecessary work could be alleviated by closer inspection.
- heavy work load of mining inspectors could possibly be supplemented by assistance and advice from other agencies such as Forestry Service personnel.

CONCERNING EXPLORATION PLANNING

- companies should notify different government agencies earlier about exploration work so that these agencies can produce area specific guidelines.
- industry should preplan protection of exploration areas.
- there are not enough baseline studies of areas to be explored.
- regional planning could be important in exploration, e.g. prevent duplication of access roads.
- preplanning of exploration access in conjunction with mining inspectors is essential.
- integration with other resource users in the planning is desirable as well.
- need to recognize the difficulty in restricting access to exploration roads, especially for recreational purposes.

CONCERNING THE PUBLIC

- public information programs to advise communities in the area of plans for exploration would be essential.
- public involvement has advantages as well as disadvantages.

CONCERNING DOUBLE STANDARDS

- double standards for mining exploration should not exist.
- should be standardization of regulations regarding reclamation for all resource users in both government and industry.
- disparity between requirements for the mining industry versus the logging industry on road construction and reclamation requirements may have to be resolved for multiple industry road useage to become a reality--although the economics of the road building and reclaiming would seem to favour this multiple useage.

CONCERNING EDUCATION

- education of exploration crews to minimize need for access roads is cost effective.
- need more education in the industry through the licensing process by the Ministry of Mines.
- B.C. and Yukon Chamber of Mines could sponsor and stress the reclamation necessity in all courses given to prospectors and other people exploring for minerals.

RESEARCH

Chairman - M.A.M. Bell, Biology Department, University of Victoria

Thursday, March 17, 1977

Afternoon Session

RESEARCH ON TAILINGS IN BRITISH COLUMBIA

U.B.C. EXPERIENCE

Presented at the Mine Reclamation Symposium,
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by

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RESEARCH ON TAILINGS IN BRITISH COLUMBIA
U.B.C. EXPERIENCE

ABSTRACT

For the past several years the Department of Soil Science at the University of British Columbia has been involved in research related to vegetation of mine wastes. The general objective of the research program has been to characterize mine wastes, especially tailings, by physical, chemical, mineralogical and biological properties. In this manner, the research has been oriented towards understanding the inherent properties of mine wastes so that the materials may be transformed to a "soil" that will not only maintain vegetation but also sustain it, without the necessity of continuous management. During 1976-77 the Department of Soil Science, under the auspices of the British Columbia Department of Mines and Petroleum Resources has intensified its research on tailings. This research activity has been oriented towards a better understanding of the various types of tailings, their elemental composition, the elements they release upon weathering, growth limiting factors and vegetative success. The ultimate aim is to develop guidelines for the establishment of vegetation in the various biophysical regions of the province. It was also hoped that the mining industry would become involved in collecting the data, both environmental and laboratory, in order for them to develop their own expertise as well as help plan future reclamation programs. This integration of government, university and private sector has much to offer in terms of efficiency of utilization of resources, training and obtaining a base-line upon which British Columbia reclamation programs can be patterned.

INTRODUCTION

The establishment of a vegetative cover that will sustain itself is one of the major concerns in reclamation of mine spoil. For many years vegetation establishment was carried out by what may be termed agronomic techniques, namely seeding, fertilizing and irrigating mine wastes. This process has been of some success, especially when applied to overburden and rock dumps and in some instances mine tailings. However, too frequently what appeared as a success in establishing a vegetative cover was a failure a few years later, unless management - fertilizers, irrigation and sometimes re-seeding - was continued. In the short run, this type of reclamation appeared sound. In the long run, however, the industry and government began to seriously question such things as: How long must management be applied to a mine waste area before it is reclaimed? In what state of vegetative cover should an area be left before it can be said to be reclaimed? What about the other values of a region in relation to the reclamation program?

To answer some of these questions it was believed that some research was necessary. Like other reclamation projects, mine spoil, especially tailings, offers a real challenge. Tailings and, to a lesser extent rock dumps, are not at equilibrium with their surroundings. Tailings materials were formed geologically at high temperatures and pressures within the earth. Tailings materials have been affected by man's activities of blasting, grinding, chemical extraction and deposition into a new environment of low temperature and pressure. The minerals composing the tailings are no longer stable and they begin to change, or weather, to form new compounds that are more in equilibrium in this new environment. During this weathering process, tailings, and other mine wastes, are changed chemically, physically, mineralogically and biologically. This changing process is usually slow to start, gains momentum for several years and then begins to slow down, just like natural soil forming processes.

Our goal in the Department of Soil Science at the University of British Columbia has been to study mine wastes in a manner that will allow an understanding of the soil forming processes. It is only through an understanding of the soil forming processes that one will be able to predict what the material will be like in the future, what chemical, physical, mineralogical and biological changes will take place and what the effects of these changes will be on the material. If the establishment of a self-sustaining vegetative cover is the object of reclamation, then it is obvious the kind of vegetative species used, the management practices employed and the chemical quality of the vegetative cover must be tied to the soil material that is forming. Tied to this overall objective, the Department of Soil Science has also been conducting more immediately applicable research programs to bridge the time gap before soil forming processes in mine spoil are better understood. For example, evaluation of chemical analysis to assess fertilizer requirements. Many methods developed by agronomists for agricultural crops are not directly applicable to mine wastes, because the mine wastes are not really soil. Other studies have resolved around assessments of limiting nutrients for vegetative establishment, namely growth chamber and greenhouse studies and evaluation of moisture retention and release from tailings and rock dump materials.

For two years, the Department of Soil Science, co-operated with the Government of Canada, Department of Energy, Mines and Resources, in studies of mine wastes in British Columbia. The aim of the program was to characterize mine wastes in Canada in the context of developing some guidelines for reclamation by vegetation. Under this program nine mines were visited and characterized by physical, chemical and mineralogical analyses. The mines studied were all grouped as sulfide mines. The results of the Canadian program are in draft and should be available to us by the end of March 1977 for review. The program outlined above was a broad general over-view of the situation in Canada. Although, hopefully of benefit, it will not meet all the needs of the mining industry in a complex biophysical province as British Columbia.

RESEARCH PROGRAM 1976-77

The research program initiated in 1976-77 with funding from the British Columbia Ministry of Mines, was an extension and intensification of our previous two years of work. In consultation with the Technical and Research Committee, a program was begun to look more specifically at mine tailings in British Columbia from a wide variety of biophysical environments. Ten mining sites were chosen, namely Bethlehem, Lornex, Sullivan, Endako, Kaiser, Similkameen, H.B., Emerald, Gibraltar and Brenda. It was hoped that the respective mines would co-operate in the research program. One of the goals was to help the mining industry to develop their own data base and expertise in relation to reclamation. To be candid, co-operation ranged from bare acceptance to enthusiastic support. One of the main problems faced was that most of the tailings disposal areas were still active. It was difficult to convince some that, although the disposal area was active, sometime in the future a similar surface would have to be reclaimed. Thus the sooner one obtained data on the tailings material the better the understanding would be when reclamation was attempted. We were interested in providing some coordination in relation to tailings reclamation and to carry out our objective of understanding soil formation as it is the resultant soil which will have to sustain the vegetative cover.

METHODS

The team from the University visited each mine site and examined the tailings disposal system. Transects were established whenever possible and tailings were examined for their vertical and horizontal variation. Contrary to common belief, tailings ponds are not uniform in their properties. Samples of tailings were collected and returned to the laboratory for analyses. Vegetation surrounding the tailings ponds on tailings materials were documented and in some cases sampled for chemical analysis. In the laboratory chemical, physical, mineralogical and biological studies were conducted. Each mine was asked to conduct some routine data collection on climate, water quality and tailings characteristics. It is hoped that once this data is collected guidelines for vegetation establishment may be developed that would better suit the particular biophysical environment in which the mine is located.

RESULTS AND DISCUSSION

In the field, tailings were characterized as to their particle size (texture), layering and colour to a depth of about one metre. Texture is important as it is one of the most significant parameters that affects erodability of the material by both wind and water, as well as controlling the available water storage capacity of the tailings material. Layering in a tailings pond of different particle size class materials is important in understanding water and air movement. The movement of water and air in materials is critical to vegetative growth. Every time there is a layer of contrasting particle size, there is a reduction in the rate of water and air movement in the material. This in turn affects the oxidation-reduction potential of the media with concomitant effects on the solubility of some of the elements and changes in mineralogy. The aspect of layering and the position of the water table are both critical parameters to measure in order to understand, and possibly control, this oxidative weathering. As stated earlier, mine tailings originally were formed under high temperature and pressure and under reducing conditions. When exposed to the earth's atmosphere the minerals change due to the oxidizing conditions and the lower temperatures and pressures. A notable example of this phenomenon is the oxidation of mine spoil containing pyrites to sulfates with changes in pH values of 6 to as low as 1.5. High water tables tend to keep the media in a reduced state and thus pH changes may not be so drastic. However, many elements are more soluble under reducing conditions and may, therefore, go into solution and be taken up by plants in excess amounts, (e.g. Mo) or move from the tailings pond into the surrounding water bodies with potential deleterious environmental effects. Colour of the tailings material is important as colour affects heat absorption which controls the rates of chemical reactions. In general, colour has not by itself been found, in our studies, to be a limiting factor with the exception of very black colours associated with coal mining. Most tailings materials are sand sized and thus prone to wind and water erosion, this is because of the low surface area sand sized particles possess.

In the laboratory, tailings samples were subjected to chemical, physical, mineralogical and biological analyses. The chemical analyses included pH, cation exchange capacity, exchangeable cations, total elemental analysis and available nutrients. These procedures were conducted to assess the "fertility" of the tailings materials. For example most plant nutrients are in the available form in the pH range 5.5 to 6.5. Cation exchange capacity is a measure of the holding ability of materials for positively charged chemical elements and exchangeable cations gives a measure of the positively charged elements that are actually being retained by the material. As an example in our studies in 1976-77 pH ranged from 8 or 8.5 to a low of pH. Cation exchange capacity ranged from less than one me/100 g to about 18 me/100 g. Cation exchange capacity tended to increase as pH increased. Exchangeable cations are generally low, with calcium being dominant.

Total elemental analysis is an essential parameter to determine as this gives an idea about the elements that are present in the tailings materials and thus aids in making predictions, about ammendments and potential toxicities that may exist. These were related to the weathering and fertility studies that were conducted. The measurement of availabla plant nutrients was carried out to assess the inherent nutrient content of the tailings that plants may be able to extract. This included total nitrogen; available phosphorus, calcium, magnesium and potassium. In general, nitrogen is limiting in tailings materials as is phosphorus. The main reason is the general lack of organic matter. Any method that would increase the organic matter content of tailings would be beneficial as it not only improves absorption of nutrients but also increases water retention and decreases the susceptibility to erosion.

Physical analyses included particle size distribution, bulk density, particle density and available water storage capacity. These parameters are important in order to assess porosity, erosion susceptibility and water supplying power. Obviously if plants are to be established it is essential to know the kind of support medium that is present. In general, the most severe factors in relation to plant growth were found to be the coarse texture of the tailings and their very low water storage capacity. Only in a few cases was bulk density (low porosity) found to be a problem.

Mineralogical analyses was conducted by means of a X-ray diffractometer. The kinds of minerals present, along with their chemical composition allows prediction of what changes will occur over time, as well as, gives indications of immediate problems. In an attempt to estimate what changes would take place artificial weathering studies were conducted. These included shaking the tailings with various solutions and using the soxhlet apparatus. It was surprising to learn that some tailings materials were not affected adversely by weathering and will probably not cause severe problems as they naturally weather. On the other hand, some tailings materials liberated high amounts of heavy metals and changed their pH dramatically. This, of course, is important to know when considering long term reclamation programs. Once again the studies have shown that tailings materials are quite different in their properties.

Another aspect of our program has been greenhouse work. This work has as its objective the determination of chemical growth limiting factors. As stated earlier, most tailings are deficient in nitrogen and phosphorus, in some cases other nutrients. In all treatments employing the use of organic ammendments the success of plant establishment was enhanced. Organic ammendments included sawdust, manure and peat moss. We are convinced that organic matter ammendments, at least initially, are necessary for good success in vegetation establishment. One problem faced in our greenhouse operations is the short time our studies have been on-going. It is planned to continue these studies, growing more than one crop on the same tailings material in an attempt to obtain information on long term effects of ammendments. This is felt necessary to continue before test plots are established in the field.

It is admirable to establish a vegetative cover that will sustain itself. However, one must know something about the chemical quality of the produced vegetation. To this end, we have been looking into one nutritional problem that may arise if ruminants feed for a substantial portion of their diet on vegetation grown on tailings. The condition we have looked into, in a preliminary way, is called molybdenosis. This condition is caused by high molybdenum in plants or a low copper to molybdenum ratio. Analyses have been conducted on vegetation growing on tailings as well as natural vegetation in the region, in an attempt to avoid bias and over generalization. In some cases it appears molybdenosis may be a problem. It is rather easily ammended if it is known. More work is planned in this area.

The last aspect of the 1976-77 research program to be mentioned is the importance of biological oxidation processes in mine tailings. There is evidence in the literature that microorganisms may play an important role in affecting the properties of tailings. Also, the kinds of organisms change with time as the tailings material ages. The present thrust has been to assess the effects of bacteria on sulfur and iron oxidation. These studies have shown, for example, that tailings of initially low sulfur content have sulfur oxidizing bacteria present. The study is too preliminary to attempt any further interpretation.

SUMMARY

The above has attempted to give some insight into the research program on-going in the Department of Soil Science at the University of British Columbia. Everything that has been done was not discussed in this address. Our philosophy has been to co-operate in activities in reclamation with government and industry. This is mainly to, train and educate personnel to conduct reclamation programs, to devise techniques that are suitable for mine wastes and to understand the basic processes that take place in these 'unnatural' materials; with the aim that eventual realistic guidelines may be established. I believe that one of the most efficient methods by which our knowledge and the practice of reclamation can be enhanced is by a co-operative approach. We, at the University, can offer some elaborate equipment for research, some evaluation of which parameters to study and why, some modification of methods of analytical work to better suit mine wastes and, most importantly, people who can work and advise on reclamation procedures. This 'people product' is not only graduates but also personnel to share ideas and discuss problems.

Industry can play a more important role by carrying on some of their own studies, both environmental and analytical, so that a solid base of information is generated, one which will serve in good standing and be predictive of conditions in the future. Also, industry has a responsibility to train its own in-house-personnel. Government, in my opinion, should continue to co-ordinate, co-operate, and fund research in all aspects of reclamation. In addition, they should play a dominant role in ensuring that well designed and pragmatic guidelines are established for reclamation for the various biophysical environments that are encountered.

In my opinion, the "sock it and see" approach to reclamation is a thing of the past! It is overdue not to work together, so that scientifically and technically sound reclamation programs become real.

A COMPREHENSIVE RECLAMATION RESEARCH PROGRAM ON COAL MINING DISTURBED LANDS

KAISER RESOURCES LTD.
SPARWOOD, B.C.

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February 24, 1977.

A COMPREHENSIVE RECLAMATION RESEARCH PROGRAM ON COAL MINING DISTURBED LANDS

ABSTRACT

Kaiser Resources Ltd. has been conducting an intensive reclamation research program since 1975. Although many of its component projects are long-term, some experiments have already been completed. As a result, methods are now available for predicting the success of thirteen commonly-used revegetation species on Kaiser's disturbed areas. We also know at what elevations and aspects to expect the greatest success with current reclamation practices. This may be helpful input in designing dumps and re-sloping efforts in the future.

Kaiser's reclamation research group also conducts annual assessments of its former reclamation efforts in an attempt to monitor the development of the new plant communities.

Extensive native and agronomic species test plots have been established in the subalpine zone. These will be augmented in the upcoming season by new treatments, including woody species cuttings, root plantings and grass-plug trials.

A year-long study of the distribution, cycling and retention of plant nutrients has been initiated. This study should yield valuable information concerning future fertilization management as well as the stability of the reclamation plant communities.

INTRODUCTION

Thus far little is known about the reclamation of disturbed lands in the mountains of western Canada (Thirgood and Ziemkiewicz, 1976). This lack of information is evident throughout western North America's mountainous regions, particularly in alpine areas (Brown and Johnston, 1976). To remedy this situation and make reclamation efforts more effective, coal mining companies in British Columbia are required by law to conduct reclamation research programs.

Kaiser Resources Ltd., one of the province's major coal mines, has an active reclamation research program. Since it is in the very earliest stages of progress the research is conducted with immediate field application in mind. Consequently it's trying to answer the most basic questions concerning species selection, fertilization and re-sloping.

The dynamic nature of Kaiser's reclamation research program is the result of a strong commitment on the company's part to produce high-quality reclamation work. In fact, field-scale reclamation work has been practiced since 1969. Therefore, Kaiser's staff has a more than academic acquaintance with field reclamation problems. This kind of experience has served to organize and direct my research. Thus the problems highlighted in practice can be dealt with using techniques familiar to the agronomist and the plant ecologist.

The following studies at Kaiser's property are presented as examples of the kind of research that can result from industry and university cooperation.

DISCUSSION

In 1975 and 1976 a program of vegetation assessment by aerial biomass clipping has been carried out on nine representative reclaimed areas on

Table 1. Yearly production by species (kg/ha) on nine reclamation areas on Kaiser Resources property

Species	Year	'A' Lagoon	Michel Pile	Baldy Face	Erick-son	McGil vray	lower 'C'	'C" seam	'D' seam	Assembly pad
crested	1975	1	348	21	133	106	36	16	26	
wheatgrass	1976	11	208	18	120	168	133	31	112	
intermediate	1975		1	30	137	95	9	3	14	
wheatgrass	1976		1	24	210	134	7	1	24	
redtop	1975		14	21	4	3	9	2	13	
	1976		50		92		18	118	35	2
meadow	1975									
foxtail	1976									56
smooth	1975	30	19	119	30	36	39	34	61	4
brome	1976	300	146	122	32	48	165	16	206	30
orchardgrass	1975			5			229	128	164	20
	1976			2			372	374	659	588
red	1975	10	5	55	19	90	7	19	38	1
fescue	1976	57	8	55	14	193	44	71	284	198
perennial	1975			2	124	469	403	231	501	89
ryegrass	1976				6	4	24	87	470	118
timothy	1975	48	41	30	49	301				15
	1976		1	10	15	202	14	18	4	334
canada	1975	19	146	4	28	206				
bluegrass	1976		226	4	89	71				
kentucky	1975									
bluegrass	1976		110	2	38	1	2			3
alfalfa	1975	4		8	603	1090	1189	738	343	6
	1976	48	1	258	511	1202	1001	1456	1433	67
sweetclover	1975	10		19	41	4	5	16	7	2
	1976	72	341		311	149				
red	1975					1	504	209	113	
clover	1976						589	134	458	
white	1975			7	6		226	100	120	
clover	1976						41	56	517	10
total	1975	123	574	322	1172	2300	2657	1498	1401	136
total	1976	488	1102	524	1455	2160	2422	2358	4202	1406

Kaiser properties. The areas range from 1,158 m to 2,100 m elevation. Their areas range from 27 to 90 ha.

Sampling is conducted by clipping 1 m^2 plots along a permanent sampling grid on each site. The clipping is done by species, the samples air-dried and weighed. The sampling is done in August of each year.

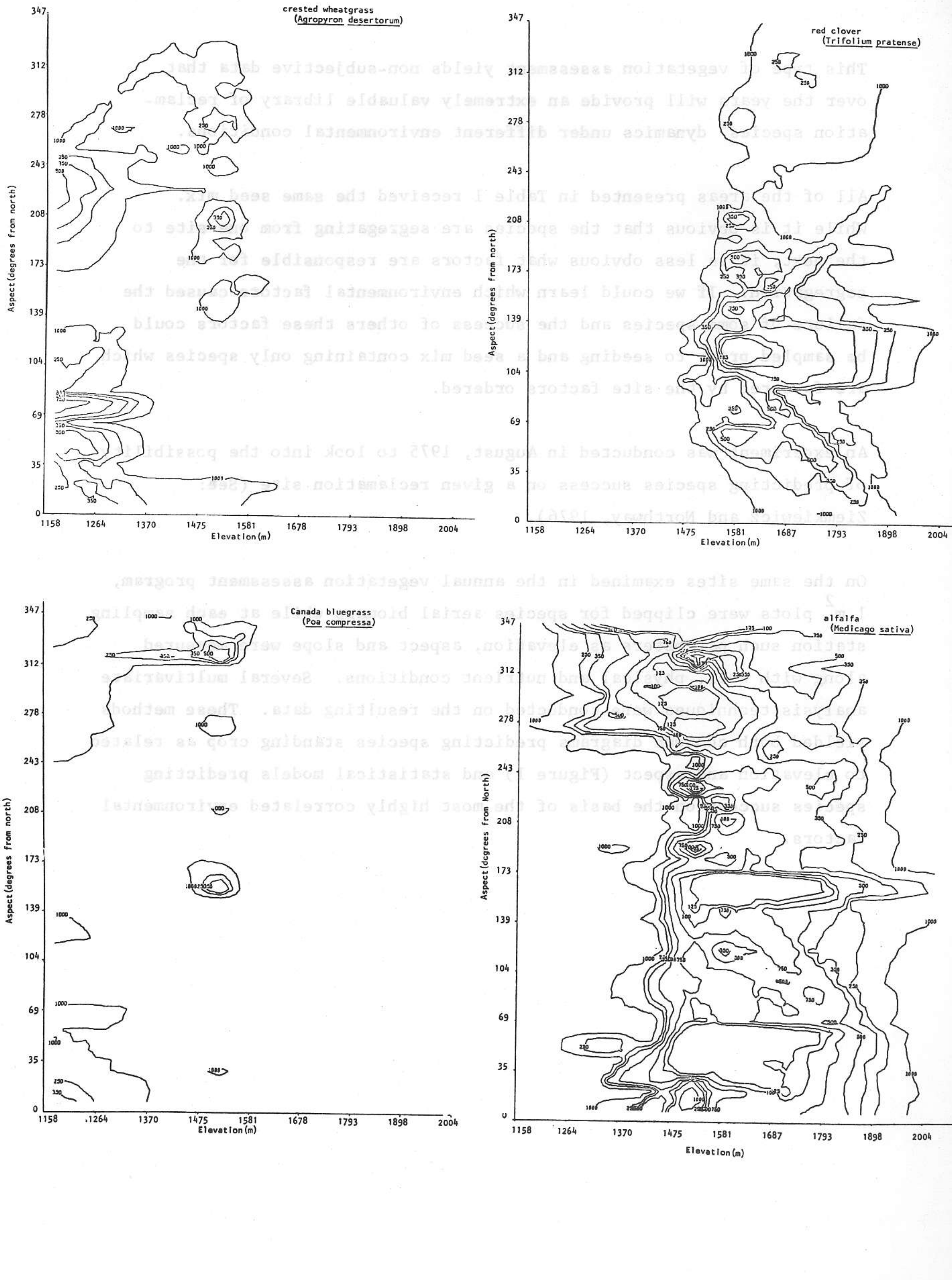
Table 1 represents the productivity of fifteen revegetation species on nine reclamation areas. The sites are ranked by elevation from 'A' Lagoon in the valley bottom at 1,150 m to the Assembly Pad at 2,100 m elevation. Perhaps the largest areas to be reclaimed in the future are above 2,000 m elevation, therefore the Assembly Pad is of particular interest for future seed mix selections. The table indicates that while many species are unsuccessful at the high elevations others merely develop slowly. For example, red fescue production increased by 200% from 1975 to 1976. Timothy, orchard grass, smooth brome and alfalfa also showed large increases over the year, while perennial ryegrass showed little change and dropped from first to fourth in production ranking. In the mid-elevation areas perennial ryegrass generally showed severe declines from 1975 levels. However, most other species remained steady or increased. Alfalfa, smooth brome and red fescue appeared to be the most consistent performers over the range of conditions represented by the sites.

Total site production levels were up in 1976 over the previous year. The most spectacular improvement was at the Assembly Pad where aerial biomass increased from 136 to 1,400 kg ha^{-1}. The vegetation on 'A' Lagoon seems to be improving while Baldy Face's development is hindered by steep slopes and dry ravelling. The other sites appear to be quite healthy and are producing large amounts of high-quality forage for the deer and elk herds of the area. On Lower 'C' and 'D' Seams evidence of heavy grazing of the newly-established plant communities was observed in 1975 and 1976. There were also many signs of deer bedding on Lower 'C" Seam.

Figure 1 Aerial production of four reclamation species as functions of aspect and elevation. Aerial production is represented on the 'Z' axis as a series of contours.

Contour interval legend:

1000=100 kg ha^{-1}
250=250 kg ha^{-1}
350=350 kg ha^{-1}
.
.
100=1000 kg ha^{-1}
125=1250 kg ha^{-1}


crested wheatgrass
(Agropyron desertorum)
red clover
(Trifolium pratense)
Canada bluegrass
(Poa compressa)
alfalfa
(Medicago sativa)
Aspect(degrees from north)
Elevation(m)
347
312
278
243
208
173
139
104
69
35
0
1158
1264
1370
1475
1581
1678
1687
1793
1898
2004

This type of vegetation assessment yields non-subjective data that over the years will provide an extremely valuable library of reclamation species' dynamics under different environmental conditions.

All of the areas presented in Table 1 received the same seed mix. While it is obvious that the species are segregating from one site to the next, it is less obvious what factors are responsible for the segregation. If we could learn which environmental factors caused the failure of some species and the success of others these factors could be sampled prior to seeding and a seed mix containing only species which are favoured by the site factors ordered.

An experiment was conducted in August, 1975 to look into the possibility of predicting species success on a given reclamation site (See: Ziemkiewicz and Northway, 1976).

On the same sites examined in the annual vegetation assessment program, 1 m^2 plots were clipped for species aerial biomass while at each sampling station such parameters as elevation, aspect and slope were measured along with soil, physical and nutrient conditions. Several multivariate analysis techniques were conducted on the resulting data. These methods yielded both contour diagrams predicting species standing crop as related to elevation and aspect (Figure 1) and statistical models predicting species success on the basis of the most highly correlated environmental factors.

The elevation/aspect contour diagrams can be used to help design dumps and other disturbances to coincide with those elevations and aspects most likely to support lush revegetation plant communities. For example, if all other factors were equal, it would be foolish to design a dump with a long south-facing slope at 1,300 m elevation, rather than a north-west facing slope at the same elevation.

Since it would be impractical to order a different seed mix for each specific site, some generalizing must be done. Perhaps the most significant parameter in species success is elevation (Figures 1-4). It seems that the species sort out into two associations; one from 1,150 m to 1,650 m elevation and another above 1,650 m. The lower elevation seed mix then should be chosen from the following: crested wheatgrass, intermediate wheatgrass, smooth brome, Canada bluegrass and alfalfa. Those species showing the best performances at the upper levels are: alfalfa, smooth brome, orchardgrass, perennial ryegrass, white clover, red clover, timothy, meadow foxtail, red fescue, Kentucky bluegrass and redtop. These selections can be further refined by use of the statistical models in conjunction with the contour diagrams.

In 1972 and again in 1973 species test plots were established on Harmer Knob at an elevation of 2,200 m. These plots have been monitored annually as part of the research program. Although many species were initially sown in these sites, many have by now been virtually eliminated by the harsh environment. Those which have proved most successful thus far have been: red fescue, redtop, smooth brome, meadow foxtail, orchardgrass, timothy, Kentuch bluegrass and Canada bluegrass. Four native species have invaded the plot areas: spike tristetum, slender wheatgrass, fireweed and rough hairgrass.

There has been much discussion among reclamation workers concerning the relative merits of native and agronomic (or introduced) species. The complexity of the problem defies simple generaliztions. Agronomic species have been used for decades in range rehabilitation work in the western U.S. These species have frequently produced stable plant communities capable of supporting large livestock herds. However, agronomic species have often proved unsuccessful in subalpine or alpine areas (Berg, 1974).

Experience at Kaiser's property indicates that some agronomic species perform well at least in the short term, in subalpine conditions. We also know which native species are capable of colonizing the raw, untreated spoils of Harmer Knob.

Entry into native seed production would require considerable capital outlays either in large-scale seed collection or in a seed increase program. At best one could contract with an established seed grower and expect to pay four to five times the price of agronomic seed. However, if the vigor of the native species is such that maintenance expenses such as repeated fertilizings, and reseeding are unnecessary, then the initial added expenses may be more than justified.

However, the available data on high-level reclamation allows us to make only hypotheses, not decisions that if incorrect could cost hundreds of thousands of dollars needlessly spent. So, to test the hypothesis that native species are more vigorous than agronomics at high elevations on Kaiser property, we first had to collect and clean sufficient seed for testing purposes. This involved locating large populations of the desired species, harvesting, threshing and storing the seed.

Consequently another set of test plots was established at the Harmer II dump area (elevation 2,050 m) in September, 1976. These plots will compare the performance of 17 agronomic species and varieties with 10 native species. Both native and agronomic treatments include grasses and legumes. Each species is duplicated within plots and the plots are duplicated over both south-west and west facing slopes. This was done to see if the southerly slopes are in fact a harsher environment, and if the different environment affects species performance.

These plots will be expanded next season by the addition of a spring planting and with various vegetative and plug planting trials.

It is important to remember that while many of the agronomic species seem to peform well now, four years after seeding, the same may not be true in ten or twenty years.

This finally brings us to the question of stability. For a plant community to be stable it must be able to reproduce itself indefinitely or allow for beneficial community compositional changes. At any rate, biomass production rates should remain at reasonable levels. For this to occur the plant community must be able to capture and recycle enough energy and nutrients to maintain produation without artificial inputs.

Currently, Kaiser's reclamation areas receive annual fertilization treatments. This is a costly procedure, however, since there is no hard evidence as to the conseqeuences of discontinuance; the program is maintained as a precaution.

If fertilization was stopped on a test area and aerial growth compared on both fertilized and unfertilized plots it might take years to notice a difference and this approach would tell us little about the fate of plant nutrients in each community. In a plant community, nutrients are stored in the roots, litter and soil as well as in the shoot. In fact, for some nutrients, the shoots contain only a small proportion of the system's total. Also, nutrients can be tied up in unavailable form in the litter and soil, so exchange rates are also critical.

In order to find out where these nutrients reside in the reclaimed areas, a project was initiated in August, 1976 that, over a year, will examine the amounts and rates of transfer for the major nutrients. This study was replicated over both montane (1,650 m elevation) and subalpine (2,100 m elevation) sites representing Krajina's interior Douglas fir and subalpine fir, Engleman spruce zones respectively. This project, which will look at the effects of fertilization vs. non-fertilization on shoot, root, litter and soil nutrient levels, involves an intensive sampling and chemical analysis program and will be completed in October, 1977.

Projects to begin in 1977 will be a study suggested by Robert Gardner, looking at relative rates of nitrogen and phosphorus fertilization and amended to examine the relative value of one heavy application vs.small annual additions of fertilizer. The research group should be able to initiate an experiment using municipal sewage sludge as a slow-release fertilizer and soil-building material. Also, we'll try to initiate a slope angle/mulch hydroseeding study in which slope angles of 22° through 36° will receive various mulch and no mulch treatments applied via hydroseeder. This will give us some idea of the effectiveness of mulch at high elevations and allow some statement on what slope angles can support the revegetation plant communities.

CONCLUSIONS

Reclamation workers in British Columbia are often in the uncomfortable position of trying to decide 1) if an area is reclaimable; 2) if not, what must be done to make it so; and 3) in terms of cost/benefit what is the most efficient method of reclamation. The questions are complicated by the variety of sites that must be dealt with. The individual charged with making these decisions often has no organization or body of literature to turn to that can help in answering the questions pertaining to his particular site.

Reclamation researchers in British Columbia are just beginning the process of assembling such literature. Perhaps more importantly, a series of techniques is being developed which can provide the kind of data that will enable the reclamationist to make his decisions with greater confidence and, hopefully, avoid costly trial and error.

Mindful of the benefits, Kaiser Resources Ltd. has been conducting an intensive reclamation research program since 1975. Although many of its component projects are long term, some experiments have already been completed. As a result, methods are now available for predicting the success of thirteen commonly-used revegetation species on Kaiser's disturbed areas. We also know at what elevations and aspects to expect the greatest success with current reclamation practices. This may be a helpful input in designing dumps and resloping efforts in the future.

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THE RECLAMATION PROGRAMME

AT THE

FACULTY OF FORESTRY

UNIVERSITY OF BRITISH COLUMBIA

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THE RECLAMATION PROGRAMME AT THE FACULTY OF FORESTRY UNIVERSITY OF BRITISH COLUMBIA

by
J.V. Thirgood

This paper presents a brief overview of reclamation activities in the Faculty of Forestry. It provides an example of what can be done by a small group with a continuing programme and limited financing.

Paul Ziemkiewicz has already reported on one study that provides an example of the kind of thing that can be done at the University with the co-operation of industry. I now want to discuss our programme in broader terms, also to give some indication of the viewpoint.

Our Reclamation Programme in Forestry started in 1968. It was the first such programme in Western Canada and, probably, in Western North America. Since that time we have produced almost 40 publications in the form of Ph.D., Master's and Bachelor theses, journal articles and conference papers and have provided a means of international communication and exchange of information through a widely distributed newsletter. In co-operation with the University Centre for Continuing Education three short courses have been held. Most important, we have provided educational opportunities - training - for a number of men who are now working professionally in the field.

Our Faculty interest in land reclamation was stimulated initially by a request from the then general manager of Kaiser Coal Ltd. for advice as to how the company might tackle its reclamation problems.

In subsequent years our interests have become considerably broader than

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B.C.Ministry of Mines and Petroleum Resources.

the surface mining situation in the East Kootenays but I would like to pay tribute to the continuing support that Kaiser Resources has given since that time. The Kaiser Resource Fellowship in Land Reclamation and a senior class prize in conservation, also provided by Kaiser, have provided the essential seed money for continuity of student support upon which we can build, without, I would stress, any limitations or restrictions whatsoever on the areas of study. No less important has been the continuing informal co-operation that is demonstrated by the paper you have just heard, the opportunities for summer employment that have provided valuable experience for our students, and, not least, the continuing contacts with Kaiser's reclamation staff.

But it would be wrong to suggest that Kaiser Resources alone has provided facilities for student research. Other companies have provided support and facilities and I cannot recall one request that has been refused. Theses have resulted out of work on the copper deposits in the Highland Valley, vegetational recovery in the Columbia Valley at Trail, and at Kitsault where co-operation with Climax Molybdenum and its predecessor, B.C. Molybdenum, has permitted us over the past 8 years to make continuing observations under north coast conditions, ranging from a Ph.D. study of the recovery of vegetation at the Anyox smelter and along Observatory Inlet, to the establishment of long term species and site amelioration trials on the Kitsault mine dumps and, incidentally, to provide a valuable educational experience for several reclamation students. There are several people in this room who have accompanied me on our annual pilgrimage up Alice Arm.

I was but newly returned to the Province in 1969 and just into our programme when the public controversy on surface mining erupted and I found myself quite unwittingly in the eye of the hurricane for merely stating that mine waste was not the hopelessly sterile or even toxic material that was the common view at that time, that reclamation of mined land had been successfully undertaken in other parts of the world and that I believed that Kaiser meant it when it said that it intended to undertake a significant reclamation programme.

For a time I thought I was going to be carried out of the Province on a rail, but 8 years later I feel vindicated. As the papers presented at this meeting attest, there is a serious reclamation programme underway in the Crows Nest Pass which shows encouraging successes. Throughout the Province we can see that it has been found possible to grow vegetation on almost every spoil type. Increasingly it has become apparent that technical solutions are available or can be developed through application of well established methods. The major reclamation difficulties are not primarily of a biological nature -- with the notable exception of the treatment of tailings. Most of the difficult biological situations are a matter of engineering technique; the need is that the wastes be so arranged as to permit them to sustain vegetation.

This, of course, is not to say we have solved our reclamation problems or even, as a Province, have met our responsibilities. Our problems are not confined to science and technology. Having said that, I must go on to say that from my vantage point it appears that we have made very significant advances in these regards in the last year or eighteen months.

Nevertheless, I was glad to hear Marc Bell's comments on the need for research into the institutional problems, for, from the outset, in forestry, we have recognized that although the site/plant relationships are important and these have featured largely in our programme, our areas of concern extend beyond these. Much of our earliest efforts were directed towards identifying the essential institutional and organizational requirements for effective reclamation and in establishing the inter-relationship between the extraction and reclamation phases of mining. Indeed, one of the earliest studies completed was a master's thesis by J.L.F. Hogg on "Natural Resources Policy, Law and Administration with respect to Mineral Exploration in British Columbia". The need to integrate reclamation and extraction through planning and the modification of mining techniques, rather than to look on reclamation as something to be done when the real business of mining is completed, is commonplace today, even if perhaps it is still more often honoured in theory than in practice, but a few years ago this was a radical suggestion.

Nevertheless, I believe the institutional and planning aspects are still today the areas of greatest constraint on effective implementation of provincial reclamation policy.

There is also the question of off-site or downstream effects. Often we tend to be preoccupied with the mine site. I recall that it was several years before there was any awareness of the significant adverse effects of poorly planned and ill-considered exploration activities. The overall regional impact of mining must be of major concern.

Another early concern was the lack of provision for information exchange, arising out of the professional and geographical isolation of the relatively small number of people active in reclamation practice and research. There was a clear need to provide for information exchange and intercommunication. Furthermore, we soon found that this was not a problem confined to British Columbia or even Canada, but was world-wide. To assist information flow we started the Reclamation Research Newsletter and Bibliography under the auspices of the International Union of Forest Research Organizations. In six years the mailing list for this newsletter increased from 18 to some 400 workers in 30 countries, until in 1975, our coming together with the Ontario Cover Crop Committee based at the University of Guelph resulted in the founding of the Canadian Land Reclamation Association to provide an interdisciplinary meeting-ground for all concerned with land reclamation. This is a pioneering effort and is the first such society in the world. One of its major purposes is the publication of the Reclamation Review, an international interdisciplinary journal, to continue and extend the role of the U.B.C. Reclamation Newsletter. Unfortunately, because of inflation, major difficulties are being encountered by the Editorial Board with the publishing arrangements. Incidentally, the annual meeting of the Canadian Land Reclamation Association this year is being held in Edmonton.

To summarize, in Forestry, we have tended to look at Reclamation from the viewpoint of the biologically-oriented land or natural resource manager. We have seen mining, not as a final land use, but as a temporary or intermediate use, and our concern has been with the bringing back of the site to productive uses compatable with regional patterns.

Foresters may perhaps be characterized by their primary concern with the management and manipulation of vegetation and land-based resources. Roger Berdusco's paper well shows the contribution that Forestry can make to Reclamation. We are concerned with practical application and the maintenance of productivity; with husbandry rather than cosmetic reclamation - the green lie. We are conditioned to approach the matter from the standpoint of classical land management planning, the elements of which have been defined in a forestry context as follows:

1. A specified management period.
2. Initial collection of facts and a description of the area to be managed.
3. Analysis of the facts and an assessment of management options.
4. Designation of management options.
5. Design of a programme to accomplish the objectives.
6. Record of results, collection of facts by inventory and research to be used in formulating the plan for the next management period. (Osmaston 1968).

Consequently we have been predisposed to support the approach advocated by Tony Milligan yesterday, that of advance through the conduct of field scale reclamation allied with on-going research to resolve problems as they become apparent. Perhaps this is a pragmatic approach and one that, in purest terms, is not particularly elegant, but it has been proven effective throughout the history of the evolution of land management, provided always that the practice is intelligently conceived and applied and that due attention is given to the all important maintenance of records of work done and results obtained. This is not to say, of course, that more basic approaches are not highly important. The current work on tailings by Bob Gardiner and Les Lavkulich provides an example of the kind of situation where this is vital if advances are to be made. Paul Ziemkiewicz is currently undertaking a study of nutrient cycling in high elevation reclamation ecosystems that will provide important information regarding the stability of the vegetation we are establishing.

Reflecting the approaches of our profession we are interested in resource policy; the resolution of resource and landuse conflicts; regional or area planning and impacts; the development of clear management objectives; long term and operational planning to achieve these objectives in a rational manner; economic evaluation; site categorization; the development of working techniques; problems of species selection and evaluation; the trial of introduced and native species; the establishment of vegetation, its maintenance and final use; natural succession; questions of watershed management and silt control; provision of wildlife habitat; the amelioration of visual impact - in a word, all the landuse problems that result from the physical impact of mining.

To the solution of these problems we can bring to bear the knowledge, methodologies and experience that has been gained in forestry over the past two hundred years in the treatment of steep unstable soils in rugged landscapes. Although in British Columbia most forestry activities have been directed to timber production it is important to remember that there is a long tradition of protection or rehabilitative forestry with emphasis on the stabilization and restoration of degraded sites, often in severe environment under mountainous conditions. This expertise in soil and water conservation and environmental rehabilitation, when coupled with the broadened concepts of wild land resource management of the latter part of this century, are directly applicable to mined land reclamation.

A final, but general, value of university involvement is that, to a greater extent than government or industry, we can, and should, take an independent stance.

I have only reported in very general terms on our programme but I believe that the successes achieved have indicated what can be done by a small group, and the potential that exists for close co-operation between government, industry and university and the mutual benefits that can result to all parties. There are only a few people involved in this important task of mined land reclamation and it behooves us all to develop mechanisms to maximize our joint contributions.

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March 29/77

NATIVE SPECIES IN RECLAMATION OF DISTURBED LANDS

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NATIVE SPECIES IN RECLAMATION OF DISTURBED LANDS

ABSTRACT

When reclamation seeks to reintegrate disturbed lands into the natural landscape, use of native species could have decided ecological, economic and aesthetic advantages. As products of millions of years of adaption to varied environments, native species generally require no maintenance, are self perpetuating, and are visually integrated with surrounding landscapes. In the practical sense, native seed is presently unavailable commercially. Therefore, research is necessary on the collection of native seed and cuttings, the storage and treatment of seed for dormancy breaking and germination, the time of seeding and methods of propagation for maximum seedling establishment, the growth on different materials and sites, the selection of proper species combinations (including agronomics), and on the practical and cost aspects of commercial production. By observation in nature, and by lab experiments, native species should be evaluated for their role in succession, erosion control capability, contribution to soil humus, palatability for wildlife and visual integrating capabilities.

Initially, research priority should be given to species suitable for difficult sites where agronomic species are relatively unsuccessful or costly to maintain (e.g.high elevations, steep slopes, dry areas).

The immediate goal of this research would be the production of a catalogue of native species suitable for reclamation of disturbed lands in British Columbia. This catalogue would contain all available information on areas, sites, conditions, etc. for which species would be suitable as well as information on species germination, propagation, and early maintenance requirements.

Establishment of an independent Reclamation Research Institute is proposed to fund and coordinate this research in connection with other aspects of reclamation in the province.

NATIVE SPECIES IN RECLAMATION OF DISTURBED LANDS

In this paper we set forth arguments favoring the use of native species in reclamation of mined lands in British Columbia, mention problems this might entail, research which should be done, and where, how it might best be coordinated and suggest how this information might most readily be made available to reclaimers.

Before going further, some distinction should be made between native and agronomic species. An agronomic species is a plant selected and bred for specific agricultural purposes such as forage, hay, or cover crops. These species are genetically uniform and require intensive management for vigorous growth and reproduction. Native species occur naturally within a region and have adapted through millenia to local climates and habitats. They are genetically diverse self-perpetuating species requiring no maintenance to grow vigourously in their native habitats.

To date, most reclamation has relied on agronomic species because seed is readily available in bulk from commercial producers at low cost. Where the reclamation objective is to return the land to agricultural production, agronomic species are the logical choice. However, when fertilization and/or irrigation are cut off, "instant green" agronomics often do very poorly. Two such sites are the Similkameen Mining operation at Princeton and Placid Oil's Bull River Copper site.

When the reclamation objective is to re-integrate the site into the natural landscape, a durable, self-maintaining plant cover of native species has obvious benefits. Nature has been reclaiming drastically devastated areas with native species since time began. Learning how she does this might save a few dollars.

Unlike Europe (e.g. Schiechtl, 1973) and apart from the traditional efforts of forestry and horticulture, relatively little thought has been given to using native species for reclaiming disturbed lands. In Alberta and British Columbia seed of a number of native grasses and forbs has been collected and germination and field tests made by mining companies or their consultants. These tests are basically in an early stage of development, so relatively little information has been accumulated. For example, Kaiser Resources, a leader in the reclamation of coal mined lands in British Columbia, set up test plots of native grasses and forbs only last summer and started germination tests this winter, although they have done work with native shrubs for a number of years. Their research in native shrubs has included propogation by seeds and cuttings and field trials of certain species. Native shrubs have been used on a limited scale for reclamation attempts and erosion control by British Columbia's Fish and Wildlife Branch, Parks Branch, and Department of Highways. Horticulturalists use some native shrubs for landscaping, but ridiculous as it sounds, the available commercial stock of B.C. natives apparently comes only from European growers.

Some reclamation trials with native grasses and forbs have been done in the arctic regions of the Northwest Territories, and in the Rocky Mountains of Colorado, Idaho, and Montana (Nishimura, 1974; Farmer et al, 1976; Harrington, 1946). Arctagrostis latifolia (Polar Grass) was used in trials in the Northwest Territories and although after two years its performance was inferior to the agronomics used, after seven years it was many times more successful (Hernandez, 1973). Many native species have been tried or suggested in western North America (see Appendix) and a preliminary literature review shows that a fair amount of information is available on test triala and germination of native shrubs and herbs.

One of the reasons for the relative lack of both research and reclamation trials with native species is the lack of readily available seed or nursery stock. Also, in many situations, agronomic species either do well, or are preferred, depending on ultimate land use goals. Agronomic seed is readily available at low cost, so in such situations there is little incentive to consider use of native species. On the other hand, agronomic species generally do not do well in harsh environments such as the alpine tundra. In most lowland situations where intensive management such as fertilization and/or irrigation is eliminated, agronomics eventually die out. Native species can play an important role in these situations and have a number of ecological, economic and aesthetic advantages.

In harsh environments such as the alpine tundra native species have evolved and adapted to the normal alpine conditions as well as to the extremes. Thousands of years of evolution have resulted in diverse genetic populations of each species that are able to survive harsher than normal alpine conditions because of adaptations to cold and frost during the growing season. Native species in other environments have similarly evolved and adapted to both normal and extreme conditions of their particular habitats.

Conversely, agronomic species (originally selected from a native species stock somewhere) are propagated for specific agricultural purposes. Different varieties of these agronomics are available, but these are still basically selected for agricultural use, and continued maintenance is necessary to keep a good cover for any extended period of time. In alpine or other non-agricultural extreme areas they will generally not go to seed, or will rapidly die if fertilization is stopped. For these reasons agronomic species usually do not have the capacity for vigorous growth in all the varied environments in which they are used.

Certain native species are known as pioneers, because they will invade areas after natural disturbance such as fire, flooding, or mass wasting. Pioneer species are adapted to the environmental conditions in the area thereby enhancing their chance of successful establishment. They also initiate humus accumulation and nutrient cycling in the early stages of succession making the site suitable for other species. Eventually most pioneers are out-competed by other natives better adapted to the "improved" conditions. Stable self perpetuating plant communities requiring no maintenance develop in the long run. Use of these pioneer species, possibly with some fertilization, irrigation or other site preparation and in combination with agronomics in reclaiming sites could result in reduced management cost because natural plant succession to self-maintaining communities will be accelerated. Further, a diverse native plant cover such as this will encourage long term stability of the vegetation.

In order to minimize the management cost, selection of appropriate local races, or ecotypes, of native species has proven value. Foresters have known and applied this for years when selecting different provenances of trees to get the best wood production. The use of these ecotypes that are genetically suited to certain areas will likely result in increased revegetation success.

In addition to their ecological and economic advantages, native species generally integrate better visually into the surroundings than either agronomic or introduced species. Their growth form, color, and texture seem to blend into the natural landscape and as a result they are aesthetically more pleasing.

The disadvantages of using native species at present are largely practical ones: unavailability and/or high cost of stock or seed; little knowledge of what species to use, when, and under what conditions; the immediate requirement of plant materials for reclaiming specific sites now; and lack of certification of stock quality, to mention a few.

Bearing these points in mind a great deal of observational and experimental research and field testing on native species should be set in motion as soon as possible. Some areas where such studies are needed follow.

For example, determining local races appropriate for reclamation requires inventory of the vegetation for each general area (e.g. alpine of Northeast Coal Block) and evaluation of likely reclamation species on the basis of, among other things, their place in succession, role in nutrient cycling, nitrogen fixing capability, contribution to the buildup of humus, amelioration of the site conditions to encourage the buildup of the microflora and fauna palatability for wildlife, ease of propagation, and the range of habitats to which they are adapted. This information can play an important role in determining the suitability of different species - and local races of these species (i.e. ecotypes) - for different types of mine waste.

Collections of seed, cuttings, transplants, etc. should be made for each promising species, and seed storage and dormancy breaking requirements should be determined. Methods of propagation should be evaluated, along with the best timing and methods for seeding of each ecotype to ensure a high seedling establishment in a particular environment. In harsh environments, the time of seeding is critical to ensure a favorable microclimate for both germination and seedling establishment.

In nature, groups of species often interact in mutually advantageous ways. Therefore, different combinations of native and/or agronomic species should be evaluated. Also, staggering the time of seeding of different groups of species may be very important. The possible advantages of sowing agronomics immediately for erosion control and for the addition of organic matter to the soil, followed by the seeding of native species should be explored. Such organic/native mixes should be further researched because of the high shoot to root production in the agronomics as compared to the initial high root to shoot production in the native species (Ziemkiewicz, P.; pers.com.1977).

In some harsh alpine environments viable seed crops occur in only the best summers, therefore most species are well adapted to vegetative (non-seed) methods of reproduction. In such cases where seed collection is a problem, techniques such as using plugs of natural vegetation may be valuable in innoculating sterile soils with microorganisms, as well as accelerating invasion of the native flora. Coordinating this technique with seeding of agronomic species for erosion control and organic matter additions should also be examined.

In evaluating native species, reclamation objectives as well as site conditions will undoubtedly determine which species are appropriate. A reclamation objective of improved wildlife habitat would likely require a different combination of species than a goal of pulpwood forest. Microsite variations could also influence success and should be taken into consideration. In extreme cases, such as where toxic materials are to be revegetated, and conventional site ameliorating methods are unsuccessful, then native species showing mild tolerance of these conditions might be aelected and experimentally bred for increased tolerance to revegetate these sites.

These are a few of the areas where research in native species could lead to improved reclamation and reduced costs in British Columbia. Clearly the collection of such information through research and testing would take some time for all the Province. Some information exists already in the literature but needs to be retrieved and interpreted for reclamation purposes. This would provide the basis for more clearly defining research priorities and establishing research programming. However, because of the urgency of getting research underway now we feel that research priority should be given to difficult sites where agronomic species are relatively unsuccessful or costly to maintain such as steep slopes, dry areas, and alpine tundra.

A major goal of this research would be the production of an annotated catalogue of native species suitable for reclamation of disturbed lands in British Columbia. This manual could be started now with existing information and eventually would contain all available information on each species pertinent to reclamation as well as best methods for ensuring reclamation success (regional and site suitability; where-when-how to collect, store, propagate; role in succession; other species features.) Research to achieve this goal should be initiated now.

Who should do the research? Traditionally this is the universities' domain because of its close relation to professional training and education, staff with research interests, graduate students, research facilities, independent (usually insufficient) funding, and detachment from vested interests. However, university research is criticized because results are often slow in coming, difficult to comprehend, and of little practical value to land managers. But this is changing as more university research is geared to finding practical answers. Should government or industry foot the bill? And who should determine research priorities? Because of their immediate concern with actual reclamation problems should companies do the research or contract it out to consultants? Or, should it be a collaborative effort of universities, private consultants, government and industry with some central group controlling the direction of the research?

We feel a joint effort would be most fruitful, with research priorities and funding being administered under an independent British Columbia Reclamation Institute which would be concerned with lands disturbed by any means - mining, electric power generation, construction, forestry, highways, etc. - and whose membership would come from public and private land use agencies.

With such coordination, with the growing emphasis on not only revegetation but also long term maintenance of green cover, and with the ecological, economic and aesthetic benefits which native species clearly have to offer, the payoff to reclaimers from supporting more research in native species for reclamation in British Columbia should be obvious.

APPENDIX

This list summarizes a preliminary investigation of the literature by W.F. Hubbard (see Hubbard & Bell, 1977).

NATIVE SPECIES IN MONTANE RECLAMATION

1. Native species that been used for reclamation test plots and trials:

   Shrubs and Trees:

Amelanchier alnifolia	Saskatoon
Betula nana	Dwarf Birch
B. papyrifera	Paper Birch
Cornus stolonifera	Red Osier Dogwood
Juniperus communis	Mountain Juniper
J. horizontalis	Creeping Juniper
Picea engelmanii	Engelmann Spruce
P. glauca	White Spruce
Pinus contorta	Lodgepole Pine
Populus tremuloides	Trembling Aspen
Pseudotsuga menziesii	Douglas Fir
Rosa Woodsii	Woods's Rose
Rubus idaeus	Red Raspberry
Sambucus racemosa	Red Elderberry
Shepherdia canadensis	Buffaloberry
Symphoricarpos albus	Snowberry

   Forbs:

Achillea millefolium	Yarrow
Agastache urticifolia	Horsemint
Artemesia norvegica	Mountain Sagebrush
Aster alpinus	Boreal Aster
Balsamorhiza sagittata	Arrowleaf Balsamroot
Epilobium angustifolium	Fireweed
Heracleum lanatum	Cow Parsnip
Lupinus alpestris	Alpine Lupine
Osmorhiza occidentalis	Western Sweet-cicely

Penstemon nitidus	Shining Penstemon
P. whippleanus	Whipple's Penstemon
Phacelia heterophylla	Varileaf Phacelia
P. sericea	Silky Phacelia
Vicia americana	Common Vetch
V. cracca	Bird Vetch

Grasses and Sedges:

Agropyron dasytachyum	Thick-spiked Wheatgrass
A. smithii	Bluestem Wheatgrass
A. spicatum	Bluebunch Wheatgrass
Agrostis scabra	Winter Bentgrass
Arctagrostis latifolia	Polar Grass
Bromus carinatus	California Brome
B. ciliatus	Fringed Brome
B. tectorum	Cheatgrass
Calamagrostis canadensis	Canada Reedgrass
Carex bigelowii	Sedge
Danthonia parryi	Parry's Oatgrass
Deschampsia cespitosa	Tufted Hairgrass
Eriophorum vaginatum	Cotton Grass
Festuca ovina	Sheep Fescue
Koeleria cristata	Prairie Junegrass
Phleum alpinum	Alpine Timothy
Poa alpina	Alpine Bluegrass
Trisetum spicatum	Spiked trisetum

II. Native species that have been <u>proposed</u> for reclamation trials*:

Shrubs and Trees:

Abies lasiocarpa	Subalpine Fir
Acer glabrum var.douglasii	Douglas' Maple
Alnus sinuata	Sitka Alder
A. tenuifolia	Mountain Alder
Arctostaphylos uva-ursi	Bearberry
Betula occidentalis	River Birch
Ceanothus sanguineus	Redstem Snowbrush
C. velutinus	Sticky-laurel
Crataegus oxyacantha	Hawthorn
Pinus albicaulis	White Bark Pine
P. banksiana	Jack Pine
P. flexilis	Limber Pine
Populus balsamifera	Balsam Poplar
P. trichocarpa	Black Cottonwood
Potentilla fruticosa	Shrubby Cinquefoil
Rhododendron albiflorum	White Rhododendron
Salix alaxensis	Alaska Willow
S. arctica	Arctic Willow
S. polaris	Willow
S. reticulata	Willow
Spiraea lucida	Spiraea

Forbs proposed:

Artemesia caudata	Artemesia
A. frigida	Pasture Sagebrush
Corydalis aurea	Golden Corydalis
Dryas drummondii	Yellow Mountain-avens
D. octopetala	White Dryad
Epilobium latifolium	Red Willow-herb
E. watsonii	Watson's Willow-herb

Equisetum arvense	Field Horsetail
Hedysarum alpinum	Alpine Sweetvetch
Polygonum bistortoides	American Bistort
P. viviparum	Alpine Bistort
Saxifraga tricuspidata	Prickly Sazifrage
Sedum stenopetalum	Wormleaf Stonecrop
Veronica cusickii	Cusick's Speedwell

Grasses:

Agropyron scribneri	Spreading Wheatgrass
Calamagrostis montanensis	Plains Reedgrass
C. rubescens	Pinegrass
Carex spp.	Sedges
Festuca brachyphylla	Alpine Fescue
F. idahoensis	Idaho Fescue
Helictotrichon hookeri	Spike-Oat
Festuca scabrella	Buffalo Bunchgrass
Hordeum jubatum	Foxtail Barley
Poa cusickii	Cusick's Bluegrass
P. fendleriana	Mutton Grass
P. lanata	Woolly Bluegrass
P. sandbergii	Sandberg's Bluegrass

* This list is by no means complete.

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WORKSHOP SUMMARIES

RESEARCH

CONCERNING INFORMATION EXCHANGE

- communication and exchange system needed for information.
- information should be put in a data bank or clearing house and be disseminated more effectively in an intelligible form to all echelons (i.e. cat operator to mine manager).
- better information sharing facilities needed, possibly combined with above agency.
- university theses should be published in an intelligible form.
- results from research should be converted to a practical form usable for industry.
- much information (technology) already available. How do you get this out?
- develop a reclamation manual for field use.
- could be started through annual reports of Mines Ministry, showing successes and failures.
- suggest a central library controlled by the Secretariat or Mines Branch be set up.
- handbook produced showing successful results; up-dated every three years.
- annual abstracts of additions to central library.
- the necessity of sharing and co-operating in (mine) reclamation is not only on a provincial level but also on a national and world scale.

CONCERNING A RESEARCH ADVISORY GROUP

- need an advisory group for research.
- should combine provincial and federal government agencies as well as universities, industry and research centers.

- purpose of the group would be to establish priorities and objectives in the field of research.
- the group should have regional advisors.
- the group could act as an intermediary to filter information and to hire consultants to look at specific problems in various areas.
- some adversity to setting up another "bureaucratic agency" but it was recognized that smaller companies, not financially capable of carrying out their own research, need some group to draw upon.

CONCERNING RESEARCH CONFIDENTIALITY

- problem with confidentiality of research as those who pay for it have a right to it.
- an incentive to share company research results should be developed.

CONCERNING EDUCATION

- need education of company field personnel of what is known, e.g. a college course.

CONCERNING DIVISION OF RESEARCH

- duplication of research occurs.
- short term site specific research should be done by industry.
- long term regional research should be done by universities and research centers in conjunction with industry.
- the regional or general research should be carried out by those people best qualified to do specific work, which may not always be a university.
- consultants can be of value in conjunction with industry in applied research.
- common research, for a specific area, should be looked at jointly by companies and researchers, so that expense is reduced.

CONCERNING RESEARCH FUNDING

- there were differences as to how general problems should be funded:
  - a) funding by government and industry for general problems, possibly a research charge or royalty; proportional taxation of companies to develop fund to pay for research done on reclamation.
  - b) government should fund long term general research through normal revenue channels and not raise a separate levy tax as in Alberta.
- short term site specific research should be funded through industry's normal reclamation funding i.e. built into production budget.
- companies could form consortia to resolve common problems through research and spread costs.
- mining companies prefer to invest money in developing their own personnel's expertise.
- time lag in research is a key problem as costs for research are heavy and returns sometimes slow in coming.

CONCERNING NEW RESEARCH AREAS

- need identification of other types of research that may be necessary to evaluate reclamation impacts eg. fisheries or wildlife.
- need more socio-economic problems research. What does local community want?
- need more research into native species seed bank production.
- need development of applied field techniques.

PRESENTATION OF

FIRST ANNUAL RECLAMATION AWARD

Terms of Reference

MINE RECLAMATION AWARDS

Under the auspices of the British Columbia Ministry of Mines and Petroleum Resources, and the Mining Association of British Columbia, a Reclamation Award has been established to recognize outstanding achievement in mine reclamation in British Columbia. The guidelines for these awards are as follows:

1. Nomination will be solicited from Ministry of Mines Inspectors. In addition nominations may be made by companies with respect to their own work, or work done by individuals or organizations familiar with the goals of reclamation.

   Nominations should be submitted in writing to:

   Chairman, Awards Subcommittee
   c/o Technical and Research Committee
   Ministry of Mines and Petroleum Resources
   Mineral Resources Branch
   1835 Fort Street
   Victoria, B.C. V8R 1J6.

   In the nomination, documentation of the reclamation achievement must be outlined and reasons proposed why the project or program merits recognition.

2. The reclamation project may be major or minor in extent and may be the result of one person's activities.

3. The technical and Research Committee will decide the winner of the Reclamation Award and the two citations.

4. The Reclamation Award and Citations will be awarded each year at the annual Mine Reclamation Symposium.

5. The Reclamation Award cannot be won by a mining company two years in succession - Citations may.

6. Deadline for receipt of nominations for the awards is January 31 of the year the award will be given.

MINE RECLAMATION AWARD

The first Annual Reclamation Award is presented to Kaiser Resources Ltd.

Kaiser's Reclamation specialists have demonstrated that with effective application of current technology, alpine terrain disturbed by exploration and surface mining for coal can be stabilized and rehabilitated for wildlife habitat, an important resource in the Sparwood area. Government and industry continually use Kaiser's reclamation experience to educate both the mining industry and the public that surface mining for coal can proceed with minimal environmental impact. This is a critical issue for the Province of British Columbia at this point in time in light of proposed coal development in the north-east and south-east regions.

Kaiser also leads the mining industry in development of facilities and techniques for propagation of native woody plants for operational scale reclamation. Kaiser is contributing toward development of improved reclamation technology through financial contributions for graduate student research and a continuing in-house research program on topics of slope stability, plant species selection for high elevation reclamation, and plant nutrient cycling.

CITATION AWARD

In the opinion of the committee, it was felt that the Bull River Mine of Placid Oil Company should receive a citation for the reclamation work done.

The Bull River Mine was a small open pit copper mine, located in the East Kootenay approximately 30 miles east of Cranbrook. On completion of mining operations the company has resloped all their dumps, backfilled one small pit and allowed a lake to form in the other pit. All areas have been seeded and fertilized. The company co-operated fully with the Ministry of Mines and worked with the Fish and Wildlife Branch in the matter of restoring wildlife habitat.

First Annual Mine Reclamation Award
presented
to
Kaiser Resources Ltd.

Tony Milligan (left) reclamation officer and Roger Berdusco (right) assistant reclamation officer receiving the award from the Hon. James Chabot (centre) Minister of Mines and Petroleum Resources on behalf of Kaiser Resources Ltd.

IMPACT ON RESOURCES AND USES

Chairman - Jon O'Riordan, ELUC Secretariat

Friday, March 18, 1977

Morning Session

RECLAMATION FOR UNGULATES IN SOUTHEASTERN BRITISH COLUMBIA

M.G. Stanlake
D.S. Eastman
E.A. Stanlake

Ministry of Recreation
and Conservation

March 18, 1977

RECLAMATION FOR UNGULATES

-talk presented by Michael G. Stanlake
at the Mine Reclamation Symposium
in Vernon, B.C., March 16-18, 1977.

We have heard a lot about land use planning in reclamation - that reclamation should start before construction. However, there is another very important question that must be answered even before we start reclamation planning: why should we bother reclaiming this land at all?

Ideally, we want to return the land as quickly as possible to a productive state. If the land originally had no productivity, there is no need to reclaim it. Therefore, we have to find out what the capability of the land is before we decide WHY we are going to reclaim it. Then we decide HOW to reclaim it. It is not always possible to make the land look the same but we should strive to make it produce according to its best capability.

One important capability of land is the production of wildlife. Since some mines occur on valuable wildlife habitat, the Wildlife Research Section of the B.C. Fish and Wildlife Branch began a study in 1974 in southeastern B.C. on wildlife-mining interactions with respect to reclamation. In this talk, we give some general results and make some recommendations for reclamation based on our experience.

In the area we worked on, the land had several productivities, two of which were wildlife and aesthetics, i.e. visual appeal. Once the land surface is disturbed, the aesthetic value is lost. Most people do not consider a reclaimed pit aesthetically pleasing. Therefore, in our study areas, the productivity we wanted returned was the ability of the land to produce wildlife. The recommendations that we make are based on the idea of returning the land to a productive state for wildlife as quickly as possible.

I will now describe briefly the results of our study and then give our recommendations and why we made them. The study was done in two parts:

1. the use of reclaimed land by wild ungulates; and,
2. the effect of coal exploration activities on sub-alpine winter ranges.

In the reclamation study, we found that ungulates use the reclaimed areas and that this use is increasing. However, use is still lower than for some of the more important surrounding natural plant communities. Full details of this study are in the final report (Stanlake, Stanlake and Eastman, in press).

In the exploration study, we found that the main effect on ungulates was the loss of range. The roads themselves posed no serious hazard to animal movements in the areas we studied. However, we did not study the effects of the increased access on harvest of wild ungulates: this topic bears careful study. A final report for the exploration road study is now available (Stanlake, Stanlake and Eastman 1976).

With this information and bearing in mind what I said earlier, I will go through our recommendations, starting with the ones for reclaimed strip mine.

1. During the mining of an area, leave "islands" of natural vegetation wherever possible. These "islands" should be planned for in the initial stages of the mining operation.

The reason we make this recommendation is quite simple, the islands provide not only a seed source for plants, but also cover for wild ungulates. It has been shown that wild ungulates need "islands" of this type to utilize fully open areas such as a reclaimed strip mine.

The next three recommendations go together. I will go through them first and then give the rationale behind them.

2. Conduct more field trials on the suitability of native forbs and grasses for the reclaimed areas. In choosing native forbs and grasses, emphasize their palatability and nutritive value to wild ungulates.

3. To enhance the reclaimed area for wild ungulates, plant more trees and shrubs, preferably browse species such as saskatoon and willow. For this, nurseries are required as well as site requirements for each species, e.g. soil, elevation, aspect, slope, precipitation, and amount of sunlight.

4. To increase slope stability and also to increase wildlife use at the beginning of the reclamation process, transplant clumps of natural grasses, forbs and shrubs onto the disturbed areas.

We would like to see natural vegetation back on these areas, since wild ungulates are most adapted to this type of vegetation. We emphasize palatability of this vegetation since it is usually no good having an area covered with vegetation that wildlife cannot use. It is conceivable that an area could have 100% cover, but if the vegetation is not palatable then the area is not reclaimed for ungulates at all - it is only green.

5. To reduce the number and variety of species planted, a correlation between species and area should be done to determine the most suitable species (preferably native) for a particular area.

This recommendation is pretty well self-explanatory.

6. Define the influence of various application rates of different fertilizers on annual growth, seed production, nutrient content and utilization of reclamation plant species. This information could then determine the most effective way to hasten the reclamation process through fertilization.

(Slides were shown to illustrate the difference between an area fertilized only when seeded - Placid Oil Mine - and an area fertilized annually - McGillivray Pit.) Proper seeding followed by inadequate maintenance fertilization will waste time and money.

The next set of recommendations are from the exploration study. I will try to give you an idea of the kind of thinking that went on when we were looking at these areas and then show you how the recommendations came to be. Originally we thought that exploration roads were a hazard to wildlife movement in that they would block migration routes across ranges and also that they would cause loss of range through destruction. We set about looking at the problem of the roads being a hazard and really to our surprise, we found that, in our opinion, on the roads we investigated, there was no hazard.

We were then left with range destruction as the main problem created by exploration roads. Therefore, our recommendations for reclamation of exploration roads are geared towards alleviating the destruction and returning what you can to production as quickly as possible.

1.a. Roads should be constructed in such a way as to protect the stability of the sidecast. On climbing roads that are pushed through unstable materials or, where there is a large unstable sidecast, the road should be insloped, adequately ditched and the water removed where safe to do so. In other cases, roads should be off-sloped where, in the opinion of the reclamation section involved, the sidecast material is stable enough to handle any ground water that may seep into it.

1.b The sidecast and cut bank should be seeded as soon as possible after construction. In this way, vegetation can start immediately. From this time on, under no circumstances should any new material be pushed over the sidecast. In reopening the roads in the spring, any slump should be excavated and hauled away. If the road surface needs grading, the material should be graded from both sides towards the centre.

Bearing the above recommendations in mind and also remembering that we found these roads were not a hazard to wildlife movement, we make the following recommendation:

2. Exploration roads need not be resloped.

In many cases, refilling road cuts with sidecast material is infeasible because this sidecast is far out of reach of any conventional machinery. Any operation of this kind would only partially refill the cut and still leave a smaller sidecast and cutbank. More importantly, any resloping activity would destroy existing vegetation that has established, be it native or introduced.

When roads are resloped, you are getting back to exactly the same situation as when the road was first constructed - there will be new unstable material with no vegetation on it. No area is gained for wildlife and you are also going to lose the years of productivity that could have been gained if you had started work as soon as the roads were developed.

An example of the extent of the natural revegetation that can take place on these areas and that would be destroyed if the roads were resloped were illustrated by two slides, one showing an eight year old road and the other showing a road three years old. To bring machinery into these areas and destroy this vegetation just to attempt to return the land to its original shape would be a crime.

We offer a few more recommendations that could minimize damage to winter ranges.

3. The road should be kept open and the drainage maintained until the vegetation of the sidecast is complete. In this way, any slumps after the road is closed that may divert runoff into the sidecast will not be harmful. When the road is closed, the surface should be seeded and access to the road carefully regulated.

4. All adit refuse should be end-hauled and under no circumstances pushed down the hill.

   It is very difficult to revegetate coal on southwest-facing slopes.

5. On roads where the cutbank is very steep or overhanging for some distance, small runouts should be cut down the cutbank at major animal trails to minimize any interference to animal movements.

One final recommendation concerns the role of the reclamation section in a mining company's organization. It has an indirect effect on reclamation for wildlife.

6. The reclamation section of any company should have control over the placement (this means the avoidance of specific danger areas where possible since the general placement of the roads will be dictated by the needs of the geologist) and construction of all exploration roads.

Only someone who is on site at all times will have the necessary intimate knowledge of an area to decide on the best possible approach to any problem. As these people will be responsible for the eventual reclamation, it is only reasonable that they should make the ultimate decision and interpretation of any recommendations for exploration road construction and reclamation.

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UNIQUE ECOLOGICAL CONSIDERATIONS

ECOLOGICAL RESERVES PROGRAM

Bristol Foster
Ministry of the Environment

March 18, 1977

ECOLOGICAL RESERVES IN BRITISH COLUMBIA

HISTORY

In the mid 1960's scientists in all parts of Canada started projects to examine the ecological factors of biology as an outgrowth of the International Biological Programme, a worldwide endeavour involving dozens of nations. Among the many projects initiated by the I.B.P. was a programme for the conservation of carefully selected terrestrial ecosystems. In 1968 the Government of British Columbia agreed to form a B.C. Ecological Reserves Committee to advise on the selection of potential reserve sites. A year later, the government formally embarked on setting aside ecological reserves under the Land Act. Then in 1971 the Legislature gave approval to the Ecological Reserves Act. British Columbia became the first province in Canada to formalize and give permanent status to ecological reserves. Quebec, the second to do so, established its Act in 1974.

British Columbia now has 77 reserves varying from 1.5 to 82,000 acres, averaging 2,644 acres and totalling almost 200,000 acres.

KINDS OF ECOLOGICAL RESERVES

Basically the purpose of the Act is to reserve Crown land for ecological purposes, including:

(a) areas suitable for scientific research and educational purposes associated with studies in productivity and other aspects of the natural environment.

(b) areas which are representative of natural ecosystems.

(c) areas that serve as examples of ecosystems that have been modified by man, such as after mining, and offer an opportunity to study the recovery of the natural ecosystem from such modification.

(d) areas in which rare or endangered native plants or animals may be preserved in their natural habitat.

(e) areas that contain unique and rare examples of botanical, zoological or geological phenomena.

Areas having potential for one or more of these purposes are proposed by members of the Ecological Reserves Committee, Naturalist Clubs and the concerned public. The proposals are screened through the Committee and relevant Government Departments to resolve any resource conflicts. Areas proposed for their scenic or recreational values are transferred to the Parks Branch.

Areas agreed upon by the Lieutenant-Governor in Council are subsequently published in the British Columbia Gazette. Protection from any activity which would disturb the natural balance is provided for under the Ecological Reserves Act.

While the Act stipulates that only Crown land may be made into an ecological reserve, funds are available for the Crown to purchase private property thereby allowing private lands to become a reserve.

PURPOSE OF ECOLOGICAL RESERVES

1. Permanent outdoor research laboratories, available to scientists once a permit is granted. Ecological reserves must be permanent to allow the continuity of research over decades or even centuries which is needed to unravel some of the basic ecological processes. Intensive short termed research is no alternative. We cannot predict the sort of questions that will be asked of our ecological reserves in 10 or 100 years.

2. Genetic banks - a nature museum function. As man continues to modify the surface of the earth, species of plants and animals may become extinct before they are even known to science (mites and soil nematodes for example). Distinctive genepools are an irreplaceable resource. Samples of both rare species and locally adapted common forms must be preserved.

3. Benchmark areas, against which man's modification of most of the province can be measured. Without such natural "control" areas it would be much more difficult to determine man's impact on the environment and how to lessen it.

4. Outdoor classroom for groups of students under permit to learn natural processes.

ECOLOGICAL RESERVES AND PARKS

Parks are established so people can enjoy recreation in a natural setting.

Ecological reserves are established for scientific and outdoor classroom purposes. Casual non-consumptive, non-motorized uses such as hiking, photography, a wilderness experience, bird watching, etc., is allowed on all reserves without a permit at present. Some particularly delicate reserves might be closed to the public in future.

From the point of view of the scientist there are two main reasons why ecological reserves are valued over parks: their permanence and scientific use are more clearly established, and being a part of an international program they will attract researchers from afar.

While parks and ecological reserves serve different purposes, together they provide a full range of opportunities for man to experience and learn from the natural world.

BENEFITS FROM ECOLOGICAL RESERVES

Everybody benefits directly or indirectly. Undisturbed natural areas will yield a wealth of knowledge through their function as outdoor laboratories and classrooms. Among those who will benefit from the existence of ecological reserves are natural history societies, students and educators, foresters, limnologists, zoologists, botanists, soil scientists, biochemists, geologists, microclimatologists and many other resource experts.

Future generations will benefit from the preservation and protection of ecological reserves. While their value cannot be measured in economic terms, their wealth to future citizens will lie in their outstanding natural qualities and rarity. As time passes and human alteration of the environment continues, the very real scientific value of unaltered sites is certain to increase.

WATER QUALITY AND MINE PROCESS EFFLUENT

F. Hodgson
Pollution Control Branch
Ministry of the Environment

March 18, 1977

WATER QUALITY AND MINE PROCESS EFFLUENT

Paper Presented to the Mine Reclamation Symposium, 1977

Vernon, B.C., March 18, 1977

The speakers before me have covered the problems associated with reclamation and have outlined many of the techniques that have been used and are being used to solve them. One of the principle reasons for spending millions of reclamation dollars is to protect the lakes, rivers and streams that are so often located practically on the door-step of the mine.

There are many regulatory requirements that have to be satisfied and yet each is the result of public pressure exerted upon our legislators and their response to this pressure. These all have the effect of increasing the cost of bringing a property into production but many of them are necessary if we are to preserve our environment.

Now while the large mining complex as opposed to the small mine is usually on a more solid financial foundation and is better able to cope with such costs as reclamation and pollution control, it also brings with it a much larger potential for damage to the environment.

Previous speakers have dealt with the acreage involved in reclamation of waste dumps and tailing ponds. I have been asked to speak on water quality and mine process effluent.

From the point of view of protecting the receiving environment, mine process water must include tailing water, tailing pond seepage, mine drainage and runoff from the mine-mill area.

In British Columbia, we are fortunate that, notwithstanding the fact that our terrain is rugged, most of the mines have installed tailings impoundments with a recycle of supernatent back to the process. However, this does not completely eliminate concern. These plants are pumping up to 20 million gallons of water per day into the tailing pond. This water may be carrying up to 40,000 tons of solids or 30 tons per minute. The water surface behind the dam is a hundred acres or more. A break in the tailing line or a breach of the dam can be serious not only from a siltation point of view but also from the combined toxic effect of dissolved metal ions on the biota in downstream water.

I have reviewed the sampling results of some 30 odd mines listed in our computer files and with few exceptions most of these mines are meeting Pollution Control Branch Level A objectives or better (that is on an average value) in the tailing discharge when the principle dissolved metals are considered. There are some results that exceed P.C.B. requirements; however, there has not been sufficient data accumulated to determine, during this analysis, whether or not they are erratic values or are numbers that represent non-compliance with permit conditions.

Test results from one property, where we have been able to accumulate enough data to do a reasonable analysis, is summarized in Table 1. While the illustration may not be an ideal textbook case, it does indicate the wide variation that occurs when the maximum, minimum, 50 percentile and 90 percentile are compared (90 percentile means that 90 percent of the test results are equal to or less than the number listed). The determination of, say, the 90% percentile or the 95 percentile can be a useful tool especially at those properties when permit limits are being crowded.

COPPER MOLYBDENUM MINE IN BRITISH COLUMBIA

CONCENTRATION OF CONTAMINANTS IN TAILING

	MAX	MIN	50 PERCENTILE	90 PERCENTILE
PH	11.4	8.7	10.1-10.7	10.5-10.9
CYANIDE mg/1	.54	.003	.062	.263
CADMIUM mg/1	.006	L.0005	.0025	.0035
COPPER mg/1	.148	.001	.0013	.0305
IRON mg/1	.134	.001	.0309	.0724
LEAD mg/1	.035	.001	.0096	.0182
MOLY mg/1	.300	.002	.168	.2163
ZINC mg/1	.036	.001	.004	.008
MERCURY ug/1	.29	.1	.07	.143

TABLE 1

One of the toughest problems that faces the environmentally conscious operator is to be blessed with a massive sulphide ore body. This presents problems in both the short term and the long term. Almost invariably drainage from the mine becomes acid carrying a load of dissolved metals and in a very few years the tailing pond becomes acidic also. Table 2 indicated the degree to which metal ions can build up in massive sulphide tailings supernatant. It should be noted that the values shown here are not high when compared to similar tailings ponds in other parts of Canada or the world.

So far, we have looked only at the short term. Acid drainage from sulphide tailings can continue for literally hundreds of years unless the acid consuming capacity exceeds the acid producing capacity of the whole tailing mass. If this balance is not present when the tailings are deposited, there are few options left. Reclamation of the surface to prevent the entry of water and oxygen is one alternative. Another is to treat the seepage until acid generation is completed.

One problem that faces the environmental regulatory agency is the small operator. The small mine has in the past, kept many people employed and out of the soup line. At the same time, he has created his share of pollution as we understand it today. In some cases, the destroyed areas have healed; however, with the increased encroachment of remote areas by our ever-growing population, and the mobility of our people, even temporary destruction of the environment can not be approved. On the one hand, the agency has no desire to exclude the small mine from going into production. On the other hand, we must insist that the environment is not damaged.

DISCHARGES FROM A LEAD - ZINC

MINE MILL COMPLEX IN B. C.

	ACID MINE DRAINAGE *	ACTIVE TAILING POND SUPERNATENT	OLD TAILING POND SUPERNATENT	LEVEL A OBJECTIVES
PH	3.0	7.3	5.48	6.5-8.5
SULPHATE mg/1	1400.	1943.	3911.	50.
CYANIDE mg/1	-	1.0	0.05	0.10
CADMIUM mg/1	0.14	0.02	0.97	0.0005
COPPER mg/1	0.25	0.07	.78	0.05
IRON mg/1	415.	45.15	1102.5	0.30
LEAD mg/1	4.3	.2	3.49	0.50
MANGANESE mg/1	31.60	14.76	28.9	0.05
ZINC mg/1	120.	1.2	36.9	0.50
TOTAL MERCURY ug/1	.07	.135	.356	1.0

* TYPICAL VALUES

TABLE 2

Table 3 shows the type of monitoring that we are getting from a typical 50 tpd operation. This may be a good plant from the production standpoint; however continued operation at the levels indicated will soon have a deleterious effect upon aquatic life.

The Pollution Control Branch with the help of its computer system is attempting to follow trends in the quality of the tailing pond water systems which might develop into problems in the future. By way of illustration, dissolved molybdenum in the tailing pond supernatent at a large copper molybdenum mine (Table 4)has progressively risen in the last few years. It is interesting to note how this increase has also been reflected in the monitoring well downstream of the tailing dam and in the creek downstream of the well. Monitoring of the second creek upstream of the tailing dam serves as a control point. The level of the molybdenum in this creek has not risen.

Should a trend such as is illustrated here continue, whether we are tracing moly, copper, lead or some other ion, from a mill discharging 30 to 40 thousand tons of tailings per day for 20 to 25 years, the problem becomes enormous.

One of the concerns at this plant is that the levels of dissolved molybdenum will continue to rise in the downstream creek, even if a large portion of the seepage water is returned back to the impoundment, since it is practically impossible to collect and return all of it.

SMALL LEAD ZINC MINE
IN BRITISH COLUMBIA

CONCENTRATION OF CONTAMINANTS IN TAILINGS SUPERNATENT

		MAX	MIN	MEAN
PH		9.6	8.9	-
CYANIDE	mg/1	9.6	.02	5.7
COPPER	mg/1	11.2	.13	6.2
LEAD	mg/1	.056	.003	.024
ZINC	mg/1	.07	.005	.027

TABLE 3

OPEN PIT COPPER - MOLYBDENUM MINE-MILL

VARIATIONS IN THE AVERAGE LEVELS

OF DISSOLVED MOLYBDENUM (IN mg/1)

YEAR	TAILINGS POND SUPERNATANT	MONITORING WELL DOWNSTREAM OF DAM	CREEK DOWNSTREAM	CREEK (UPSTREAM CONTROL POINT)
1971/72 (PRE-PRODUCTION)	--	--	N.D.	0.09
1972/73	0.05	0.03	N.D.	N.D.
1973/74	0.03	N.D.	N.D.	N.D.
1974/75	0.08	N.D.	0.08	N.D.
1975/76	0.25	0.32	0.11	N.D.
1976/77	1.09	0.39	0.12	0.02

N.D. = NON DETECTABLE

TABLE 4

Table 5 shows the increase in the levels of dissolved sulphate in the same monitoring well discussed in the previous table. As shown on the graph, the levels of dissolved sulphate has increased in the last few years. The numbers shown here are not cause for alarm but if the trend continues, another very serious problem may arise.

One possible explanation for part of the increase could be due to the fact that sodium hydrosulphite is used as a milling reagent. However, we are finding that the sulphate levels are rising in a number of other mines where the same reagent is not used.

A few years ago, many of us were of the opinion that at a well-run mill, reagents with few exception, reported with the concentrates and thereby became someone else's problem. In addition, those that were discharged into the pond rapidly degraded. Within the last few years, we have found that some of these reagents, or their daughters, are quite persistent and are detectable in seepage water for at least two years after their use has been discontinued. There is no sound data at this time to indicate that they pose any threat; however, more research is required in monitoring for reagents to determine their effect on the receiving environment.

I would now like to turn to the problems associated with what is commonly referred to as suspended solids.

OPEN PIT COPPER-MOLYBDENUM MINE-MILL
VARIATIONS IN THE AVERAGE LEVELS OF
DISSOLVED SULPHATE (IN mg/1)

MONITORING WELL DOWNSTREAM OF THE TAILINGS DAM

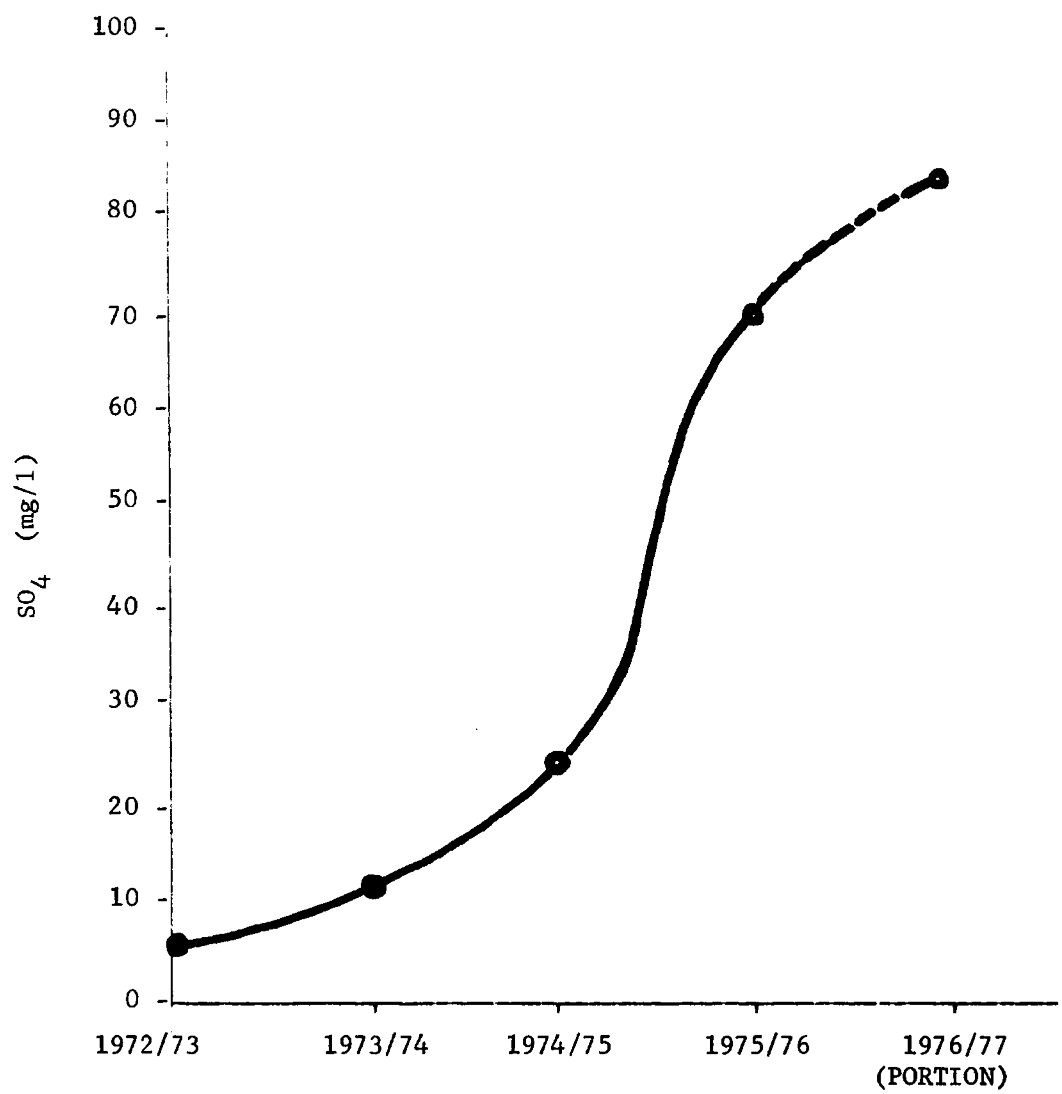

TABLE 5

We are at a stage in our mining history when there is an increasing demand for coal. A number of large properties are scheduled to go into production and these are concentrated along a limited number of watersheds. The best example of this is the Elk River and its tributaries where there are three operating companies and possibly three more properties scheduled for production in the near future.

Generally, the rocks associated with coal production are much more friable than those in hardrock mines so that we are not only dealing with the tailing impoundment but rather the whole disturbed area. Natural comminution will continue under our British Columbia seasonal changes at a much higher rate than is normally encountered at a base metal property. Saturation by heavy rainfall and subsequent slope instability resulting in mud slides has occurred on a number of occasions recently and almost invariably some of the fine material has entered a water course which should be capable of supporting a fish population. Accumulated dust and fine debris from the mine operation, mine roads, plant site, tailing area and plant spills appear in runoff and freshet every year.

Previous speakers have dealt with reclamation methods. It must be emphasized that reclamation is an extremely important aspect for the protection of downstream waters at all mining operations and particularly around soft rock mines.

In the following paragraphs, I will attempt to deal with some of the effects of water pollution caused by abnormal quantities of sediment entering a water course. There is a wide variation in the findings reported, but the end result will be the same whether the contaminated discharge originates at the end of a pipe or is runoff from a waste dump or a mine road.

To simplify the preparation of this section, I have extensively used a paper prepared by O. E. Langer who was with the Federal Fisheries and Marine Services before joining the staff of the Environmental Protection Service Pacific Region. Dr. Langer's paper is entitled "Effects of Sedimentation on Salmonid Stream Life."

In the introduction, Dr. Langer states "Sediments have always been present in British Columbia streams and since the last Ice Age have played an important role in the development of streams and stream life. Large amounts of sediments are presently carried by natural processes into many of our streams. This process is, of course, very active in watersheds that are geologically young, whereas, the more stabliized watersheds have streams that are extremely sediment free during all or at least a portion of the year."

While material of any size and shape may be transported or pushed into a water course, stream sediment is generally considered to be material less than 4 mm in diameter. It is made up of clay - minus 2 microns, silt - 4 to 62 microns, sand - 0.1 mm to 1 mm and fine pebbles - 2 mm to 4 mm.

The first level of the aquatic food chain are the green plants, often referred to as periphyton, and the macrophytes which are attached to the stream bottom. They require sunlight for growth and any increase in turbidity in the stream will reduce the total amount of photosynthetic activity. If the turbidity persists, the entire plant community may be significantly reduced. One study group indicated that aquatic plants cannot be expected to survive if exposed to less than five percent of the light incident on the water surface over periods exceeding seven consecutive days. Whether this means at all times or at critical stages during specific growth cycles, I am not certain but in any event five percent represents approximately half the light that will reach the bottom through six feet of clear water.

The larger sediments, which may appear as suspended solids or moving bedload in the stream, and particularly the more angular sediments originating at a mining operation, will create streambed scouring. When the stream's hydraulic energy cannot maintain the sediment load, deposition will result and smothering of benthic life will occur. Secondly, a mobile substrate travelling along the stream bottom does not provide sites upon which plants can fix themselves and therefore prevents growth.

Second level or benthic and planktonic invertebrates which graze on the algae or feed by filtering organic detritis are also affected by the presence of silt in the stream. They lose their natural food, i.e. algae, their hiding sites are removed or blanketed and their feeding organs are clogged or abraded to the point where they starve.

Fish are also affected by sediments in the stream. Burying of organic material by sediments settling on the stream bottom deprives fish such as minnows and suckers of their food source. When the turbidity becomes excessive, it appears that fish are unable to sight their prey and therefore are unable to eat. In the case of young fry that normally travel at night and hide by day, destruction of hiding areas among the gravel and boulders forces them into open water where they are susceptible to predation. Filling of the larger pools ruins the resident and rearing areas of larger salmoids.

The biologists tell us that the adult salmonids deposit their eggs in clean gravel riffle areas. Percolating water is required for oxygen and the removal of metabolic waste. Any reduction in the permeability or blockage of the interstitial spaces due to siltation has a pronounced effect on survival. For instance, (and I quote from Dr. Langer's paper here) five percent composition of silt and sand in the gravel had a minimal effect, whereas a 10% composition of these fines in gravel reduced survival of eggs up to 50 percent. Since many normal streams can have approximately 15 percent sands and silts in their spawning gravels, any increase in these fines can have disastrous effects on egg survivals. (end of quote).

Gravel beds form efficient filters. The flow velocity within the gravel bed is lower than that of the river, and when this is combined with the small fall distances involved, even the very fine particles can be entrapped. Fine silt or clay, at 5 microns in diameter and with a fall velocity of 0.00223 cm/sec at 20°C, theoretically will not settle in the mainstream but will be deposited in the gravel bed. Add to this any abnormal stream bedload migrating over the gravels and clogging rapidly takes place.

Many people have carried out research on siltation of spawning beds. In 1970 Langer planted chum salmon eggs in a section of the Coquitlam River upstream and downstream of a known sediment release and in a clean tributary nearby. Regular measurements of suspended sediments and subgravel oxygen levels were made. As can be seen in Table 6, a small increase in suspended solids reduced the subgravel oxygen content and the survival rate.

The effects of a high concentration of suspended solids (20,000 mg/1) is reported to have caused serious fish mortality even through the exposure was only for a short term. For example, a Rocky Mountain white fish kill occurred in the Shuswap River when the sluice gate was opened below a B. C. Hydro dam. Suspended solids levels in the river reached 30,000 mg/1.

In another paper, it was reported that gill damage and mortality occurred in rainbow trout after a ten-day exposure to concentrations of suspended solids ranging from 270-810 mg/1. At the Pollution Control Branch, we have noted from 96 hours bioassay results, carried out in response to permit monitoring requirements, that there is an adverse affect on test fish when high concentrations of suspended solids are present in the test solution; however, no hard numbers have been established to date.

Table 7 shows the progression of increase due to suspended solids in a water course running near a coal mine complex. This plant discharges its tailing into an impoundment from which there is no overflow. The suspended solids appearing in the water are originating from around the mining areas and the plant site. Average flow in the river near the property is approximately 100 CFS at this time of year.

SALMON EGG SURVIVAL

VS.

AVERAGE SUSPENDED SOLIDS IN THE COQUITLAM RIVER

(FROM LANGER'S PAPER 1976)

	AVERAGE SUSPENDED SOLIDS (mg/1)	AVERAGE DISSOLVED OXYGEN (mg/1)	AVERAGE SURVIVAL (%)
CLEAR TRIBUTARY STREAM	10	8.5	93.8
COQUITLAM RIVER ABOVE SEDIMENT RELEASE	97	7.8	23.9
COQUITLAM RIVER BELOW SEDIMENT RELEASE	111	4.9	10.7

TABLE 6

RIVER AND EFFLUENT

SAMPLING RESULTS

NEAR COAL MINE IN B.C.

MAY 1976 *

	LOAD TONS PER DAY	FLOW CFS	SUSPENDED SOLIDS mg/1	TURBITY JTU
RIVER (0 MILE)	--	--	4	1.1
1ST SETTLING POND	1.1	16	22	18
2ND SETTLING POND	2.5	22	42	42
CREEK DIVERSION	40-60	50-75	298	88
RIVER (3/4 MILES)	--	--	44	17
3RD SETTLING POND	0.1	2	14	--
PIT WATER **	1-115	2.6-5.2	40-8207	37-4610
RIVER (2 MILES)	--	--	108	27
RIVER (7 MILES)	--	--	4	1.8
RIVER (20 MILES)	--	--	104	26

* ALL SAMPLE POINTS NOT SHOWN

** NOT SAMPLED ON THE SAME DAY

TABLE 7

Various approaches are used by regulatory agencies in setting guidelines and standards for the protection of receiving waters. The British Columbia Pollution Control Branch limits the concentration of suspended solids in a discharge to 50 mg/l while Environment Canada requires 25 mg/l. The State of Oregon allows releases to match background levels up to 30 Jackson Turbidity Units but the release cannot elevate background levels by more than 10%. The U.S. Environmental Protection agency recommends that settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% percent from the seasonable established norm for aquatic life. As more is learned from ongoing research, these criteria or objectives, without doubt, will be modified.

It is the policy of the Pollution Control Branch that mine tailings will be impounded. Deviation from this policy is allowed only after detailed study has been carried out specifically outlining the possible effect on the receiving environment. However, the impoundment of mine tailings and control of seepage is not sufficient by itself. The problems associated with erosion and runoff control must be addressed. Erosion will take place where there is an exposed surface of unconsolidated material and the debris released will find its way into the nearest water course.

This paper has attempted to illustrate some of the findings and concerns of the Pollution Control Branch as they relate to the discharge of waterborne contaminants from the mining industry in British Columbia. The Branch sees reclamation as a very important part of pollution control but all reclamation must not be deferred until the final stages of an operation. It should begin on disturbed areas around the construction camp and continue on every unused piece of disturbed surface until the whole area is stabilized.

WORKSHOP SUMMARIES

IMPACTS ON RESOURCES AND USES

CONCERNING DECISION MAKING

- need more regional decision making.
- differences as to what the decision making body should be
  a) an advisory board with representatives from all agencies
  b) an independent source
- public involvement is important in order to assess regional resource objectives.
- impact assessment should be used to determine cost-benefit and appropriate land use, i.e. may even lead to not mining at all but doing something else.
- sometimes however cost-benefit studies are misleading.
- more time needed in defining ultimate land use and therefore reclamation objectives.
- need more concern on the social aspect of resource use such as managing the public's access to areas opened up by mining.
- what type of values do you put on resources?

CONCERNING MINE DEVELOPMENT SIDE EFFECTS

- side effects of mine developments probably have greatest impact.
- there is a need for careful preplanning of all the ancillary developments to minimize effects on wildlife, fishery and recreational resources.
- suggest that perhaps industry has a certain responsibility in pressuring for tighter controls on areas where they might be familiar with potential impacts.
- recreational use of areas in active mining is a problem.

- there is also a minor problem of nuisance animals.
- quicker response needed from Fish and Wildlife to apply more intensive management strategies in regards to regulating hunting and fishing in mining areas.
- environmentalists may be able to play key roles for companies by improving liaison between company and government and by providing direction towards ultimate land uses.

CONCERNING RESOURCE INVENTORY

- need a detailed resource inventory in areas to be developed.
- should be site specific with emphasis on detailed interpretation.

CONCERNING RECLAMATION STANDARDS

- need greater uniformity in reclamation standards not only between companies but also between different resource agencies.
- minimum reclamation standards should be established for each region.

CONCERNING ENVIRONMENTAL CONSIDERATIONS

- more environmental information should be used in planning process.
- this should be useful for planning auxiliary mine facilities.
- need productivity data.
- baseline data on a general level should be mandatory and this could be used by mining operations to do more site specific studies with more emphasis upon the major land use values expected of that particular environment.
- the absorptive capacity or capability of an environment should be paid more attention rather than just continual monitoring, for this information may be valuable in the case of contamination or accidents.

- need more research on aquatic problems, on reclamation costs and on recreation problems.
- the need for monitoring environmental parameters is well established - however don't need inflexible blanket standards. Site specific decisions should be made and guidelines should be flexible to allow this.
- It is the responsibility of all agencies to develop an environmental awareness within their employees as well as the public.

CONCERNING RESPONSE TO PROBLEMS

- small specific problems are not adequately dealt with by government.
- industry should pressure government for faster response to their localized problems.

CONCERNING IMPACTS

- there is an overemphasis on short term visual impacts.
- the major problem is wildlife.
- poor timing of disturbances can have much more serious impacts on wildlife and fisheries. For example, helicopter surveys can be harmful to wildlife at critical winter periods. Release of sediments during times of spawning can be very harmful.

CONCERNING DOUBLE STANDARDS

- Avoid double standards on reclamation for different resource users.
- why do not parks, forestry, highways, etc. have to satisfy similar procedures as mines when established?

RECOMMENDATIONS ON THE FORMAT AND CONTENT OF THE SYMPOSIUM

CONCERNING THE SYMPOSIUM FORMAT

In general most participants liked the format of the conference which was a mixture of formal presentations followed by round table workshops.

CONCERNING THE FORMAL PRESENTATIONS

Many of the participants felt that the presentations were too long. Some felt that there were too many speakers in a row and that more time was needed for the workshops. It was also suggested that the audio-visual effects needed better organization.

CONCERNING THE WORKSHOPS

In general, most participants liked the workshop format but felt that it would be more productive with fewer or more specific assigned topics for discussion.

In the group discussions, it was suggested that there was a need for concrete guidelines on procedure, especially earlier on. It would also be helpful to get a better cross-section from the different agencies in each of the workshop groups. The presentation of group results also needed improvement as the summaries tended to get repetitive and long.

Because the entire table had to agree on a statement before it was presented to the meeting, minority opinions were thought to be stifled. A few participants felt that these opinions should be able to be presented through the written discussion summaries.

A further suggestion was that the chairperson should be free to provide further input during the discussion period, either to respond to individual questions or to the summaries in general.

It was suggested that workshop groups be given a reclamation problem to work on, perhaps with one third of the groups given the same topic. For each problem a description of the site and its constraints would be given. The group would then try and decide on an overall solution or plan for the reclamation of that site.

CONCERNING THE SCHEDULE OF THE SYMPOSIUM

Biannual scheduling was the most popular recommendation. This would allow time for further developments as well as serious consideration of some of the propositions from the previous symposium. It was proposed that this type of meeting should be carried out at the regional level so that the company men can get to talk with the government men from their area, i.e., the ones with which they have to deal.

CONCERNING THE ATTENDANCE AT THE MEETING

It was suggested that there were a number of other agencies or groups which should have been better represented at the meetings. These included B.C. Hydro, Highways, small operators, public interest groups, landscape architects, Forestry, recreation specialists, fishery managers and environmental organizations. More emphasis was thought to be needed on the technical, economic and conservation aspects of reclamation. There should also be documentation of case histories to give a better picture of the state of the art of reclamation.

CONCERNING FUTURE TOPICS

The following topics were suggested for inclusion in future symposia:

- biophysical classification and how it can help in reclamation planning.

- social impact of mining
- a comprehensive consideration of impact of mining on other resources, e.g. timber, domestic range, recreation.
- specific reclamation programs on specific sites - say what hasn't worked and ask for suggestions
- "education of the public" - mines and their role in reclamation.
- the technology of reclamation - how to reclaim (methods and practises.)

APPENDIX I

PROGRAM

Mine Reclamation Symposium '77

MINE RECLAMATION

SYMPOSIUM ' 77

VERNON, B.C.
VERNON LODGE

March 16, 17, 18 - 1977

B.C. MINISTRY OF MINES AND
PETROLEUM RESOURCES

MINING ASSOCIATION OF B. C.

TECHNICAL AND RESEARCH
COMMITTEE

o o o

J.D. McDonald - Chairman
R. Gardiner - Co-Chairman
A. Milligan
W. Stiles
L. Lavkulich
M.A. Bell
C. Pelletier
D. Eastman
D.M.Galbraith - Symposium
Convenor.

AGENDA

March 16, Wednesday

10:00 A.M.	Registration to noon
12:00	Lunch (ad hoc)

Afternoon Session - The Company Side

1:10	Opening - J.D. McDonald
	Chairman of P.M.Session - L. Cherene
1:20	Reclamation of Higher Elevation Rock Waste - Kaiser Resources A. Milligan
1:50	Reclamation in the Interior Dry Belt - Bethlehem Copper J.Walmsley
2:10	Tailings Re-vegetation Bob Gardiner - Cominco
2:30	Reclamation on the Pacific Coast Clem Pelletier - Island Copper
3:00	Coffee and Introduction of Workshops - Groups chaired by companies
4:30	Workshop summaries
4:55	Chairman's summary
6:00	Refreshments
7:00	Dinner and Guest Speaker

March 17, Thursday

Morning Session - Exploration and Inspection

8:25	Chairman - Art O'Bryan
8:30	Reclamation Peace River Coal Russell George - B.C.Dept. Mines
8:55	Reclamation- S.E.Coal Block R.Berdusco - Kaiser Resources
9:20	Reclamation in Saxon Area Geof. Jordan-Denison Mines
9:45	Reclamation & District Inspection Dan Tidsbury - Prince George
10:10	Coffee at workshop Groups chaired by B.C.Dept.Mines Inspectors & Reclamation staff
11:30	Workshop summaries
11:55	Chairman's summary
12:00	Lunch (ad hoc)

Afternoon Session - Research

1:10	Chairman - Marc Bell UVIC
1:20	1976 Tailings pond program in B.C. Les Lavkulich - UBC
1:50	J.V.Thirgood - UBC
2:10	Research Possibilities in Native Species - March Bell - UBC
2:30	Research - Who does it? - Open
3:00	Coffee at Workshop Workshop session on capabilities, limitations and status of research programs directed from campus. Groups chaired by professors, grad students
4:30	Workshop summaries
4:55	Chairman's summary
6:00	Refreshments
7:00	Banquet and presentation of first annual Reclamation Award

March 18, Friday

Morning Session - Impact on Resources and Uses

8:20	Opening by Chairman Jon O'Riordan -ELUC Secretariat
8:30	Reclamation for Ungulates Don Eastman, Mike Stanlake Fish & Wildlife Branch
9:00	Unique Ecological Considerations Bristol Foster Ecological Reserves Program
9:30	Water Quality and Mine Process Effluent Fred Hodgson - Pollution Control Branch
10:00	Coffee at Workshop Groups chaired by Resource and Environmental Agency Personnel
11:30	Workshop Summaries
11:50	Chairman's Summary
11:55	Closing Remarks
12:00	Lunch (ad hoc)

APPENDIX II

LIST OF REGISTRANTS

Mine Reclamation Symposium '77

MINE RECLAMATION SYMPOSIUM '77

LIST OF REGISTRANTS

NAME	EMPLOYER	ADDRESS
ALLEN, I.	B.C. Research	3650 Wesbrook Cresc., Vancouver, B.C.
BACHMANN, P.	Western Canada Erosion Cntrl.	16653 - 111 Ave., Edmonton, Alta.
BANCROFT, H.	Ministry of Forests	345 Quebec St., Victoria, B.C.
BEETS, M.	Fish & Wildlife (Ministry of Rec. & Con.)	540 Borland St., Williams Lake, B.C.
BELL, M.	University of Victoria	Victoria, B.C.
BELLAMY, A.	Bethlehem Copper	Box 520, Ashcroft, B.C.
BENNETT, R.	Resource Analysis Environment and Land Use Committee (ELUC)	Parliament Bldgs., Victoria, B.C.
BERDUSCO, R.	Kaiser Resources Ltd.	Sparwood, B.C.
BERESFORD, E.	Coleman Collieries	Box 640, Coleman, Alta.
BIK, M.	Elco Mining	2800 Scotia Centre, 700-2nd St., Calgary, Alta.
BLACK, J.	Resource Analysis (ELUC)	Parliament Bldgs., Victoria, B.C.
BLAZENKO, E.J.	Techman Ltd.,	6th Floor, 320-7th Ave. S.W., Calgary, Alta.
BLUMENAUER, D.	Ministry of Agriculture	540 Borland St., Williams Lake, B.C.
BOMKE, A.	University of B.C.	UBC, Vancouver, B.C.
BUSTARD, D.	Ministry of Rec. & Con.	Box 3250, Smithers, B.C.
BUTRENCHUK, S.	Cominco Ltd.	200 Granville Square, Vancouver, B.C.
CAMPBELL, D.	Golder, Brawner Assoc.	224 West 8th Avenue, Vancouver, B.C.
CHERENE, L.J.	Kaiser Resources Ltd.	2600 B - 1177 W. Hastings St., Vancouver, B.C.
CHRISTIE, P.	Talisman Projects Inc. B.C.	1313 W. Pender St., Vancouver, B.C.
DICK, John	Ministry of Rec. & Con.	Parliament Bldgs., Victoria, B.C.
DONALDSON, R.	Buckerfields	Pearson Rd., R.R. #5, Vernon, B.C.
DORAN, G.	Cassiar Asbestos	Cassiar, B.C.
DREXEL, J.	Lands Directorate	#904-1001 W. Pender St., Vancouver, B.C.
DUDAS, B.	Ministry of Mines	101-2985 Airport Dr., Kamloops, B.C.
EASTMAN, D.	Ministry of Rec. & Con.	Parliament Bldgs., Victoria, B.C.
EDWARDS, John	B.C. Hydro & Power Auth.	700 W. Pender St., Vancouver, B.C.
ERRINGTON, J.	B.C. Research	3650 Wesbrook Cres., Vancouver, B.C.
FOSTER, B.	Ministry of Environment	Parliament Bldgs., Victoria, B.C.
GALBRAITH, M.	Ministry of Mines	1835 Fort St., Victoria, B.C.
GARDINER, R.T.	Cominco Ltd.	Trail, B.C.

GARNISCHELLI, C.	Fed. Dept. of Environment	Vancouver, B.C.
GORMLEY, G.	Denison Coal Limited	1500,444-5th Avenue S.W., Calgary, Alta.
HARCOMBE, A.	Ministry of Environment	1873 Spall Rd., Kelowna, B.C.
HARDY, R.	Ministry of Environment	Parliament Buildings, Victoria, B.C.
HEADDON, D.	University of Calgary	Calgary, Alberta
HENDERSON, D.	Ministry of Mines	Box 1290, Fernie, B.C.
HILLIS, R.	Utah Mines Ltd.	Box 370, Port Hardy, B.C.
HODGSON, F.	Ministry of Environment	Parliament Bldgs, Victoria, B.C.
HOFFMAN, E.	Pollution Control Board Ministry of Environment	3691 - 15 Ave., Prince George, B.C.
HOFFMAN, G.	Denison Coal Limited	1500,444 5th Ave., S.W., Calgary, Alta.
HOLDEN, M.	Willis, Cunliffe, Tait	Victoria, B.C.
HOLMAN, P.	Ministry of Rec. & Con.	106,1959 E. Trans Canada Hwy., Kamloops, B.C.
HORSTMAN, N.	Western Canada Erosion Control Ltd.	P.O. Box 5057, Edmonton, Alta.
HUMPHRIES, D.	Environment and Land Use	Parliament Bldgs., Victoria, B.C.
HUTTER, J.	Ministry of Mines	Box 877, Smithers, B.C.
ISSACSON, M.	Nanaimo Schools	Nanaimo, B.C.
JOHNSON, B.	Canadian Climbing Backhoe Ltd.	
JOHNSTONE, J.	Craigmont Mines Ltd.	Box 3000, Merritt, B.C.
JONES, C.	B.C. Research	3650 Wesbrook Crescent, Vancouver, B.C.
JONES, D. J.	I.E.C.	120 560 Cedarbridge Way, Richmond, B.C.
JONES, K.	Lands Directorate	#904 1001 W. Pender St., Vancouver, B.C.
KENK, E.	Ministry of Environment	Parliament Bldgs., Victoria, B.C.
KERR, K. R.	Ker Wood Liedal	144 B. West 16th St., N. Vancouver, B.C.
KILBURN, R.	Lornex Co.,	Box 1500, Logan Lake, B.C.
KIND, R.	T.M. Thomson & Assoc.	1006 Government St., Victoria, B.C.
KING, D.	Ministry of Rec. & Con.	#200 1777 3rd Ave., Prince George, B.C.
KLINE, R.	Ministry of Agriculture	Experimental Farm Site, R.R. #1, Prince George, B.C.
KOCICH, L.	Ministry of Mines	Prince George, B.C.
KUSTAN, E.	Hudson's Bay Oil & Gas	700-2nd St. S.W., Calgary, Alta.
LACELLE, L.	Ministry of Environment	1873 Spall Rd., Kelowna, B.C.
LAMB, A.	Int. Reforestation Ltd.	Box 487, Cranbrook, B.C.
LANT, J.	Coleman Collieries	Coleman Alberta
LEACH, T.	Ministry of Environment	Parliament Buildings, Victoria, B.C.

LIPKEWITCH, M.P.	Afton Mines Ltd.	Vancouver, B.C.
LOCKHORST, G.		
LUBGANS, M.	Noranda Mines	Hendrix Lake, B.C.
LUNN, S.	PanCanadian Petrol.	1904 Tecumsech Rd. S.W., Calgary, Alta.
MACGREGOR, E.	Ministry of Mines	Parliament Bldgs., Victoria, B.C.
McARTHUR, R.	Granby Mines	Box 283, Greenwood, B.C.
McCUE, J.	Newmont Mines	Box 520, Princeton, B.C.
McDONALD, J.D.	Ministry of Mines	1835 Fort St., Victoria, B.C.
McLAUGHLIN, R.	B.C. Research	3650 Wesbrook Crescent, Vancouver, B.C.
MAGNUSSAN, A.	Fording Coal Ltd.	Elkford, B.C.
MARSHALL, I.B.	Environment Canada	Place Vincent Massey, 20th Floor - 351 St. Joseph Blvd. Hull, Quebec
METNEK, B.	Imperial Oil	500-6th Ave. S.W., Calgary, Alta.
MILLIGAN, T.	Kaiser Resources Ltd.	Box 2000, Sparwood, B.C.
MORRISON, R.	Diand	393 Kenwood Avenue, Ottawa, Ont.
MORTON, B.	Ministry of Forests,	Alexis Creek, B.C.
NEWCOMBE, C.	Ministry of Rec. & Con.	#400-1019 Wharf St., Victoria, B.C.
O'BRYAN, A.	Ministry of Mines	310 Ward Street, Nelson, B.C.
OLSON, P.	Ministry of Mines	1837 Fort Street, Victoria, B.C.
OSWALD, E.	C.F.S.	Pacific Forest Research Centre, Victoria, B.C.
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PATTISON, A.	Ministry of Environment	Victoria, B.C.
PEARSON, D.	Ministry of Environment	Parliament Bldgs., Victoria, B.C.
PELLETIER, C.	Utah Mines Ltd.	Box 370, Port Hardy, B.C.
PELLS, F.	Brenda Mines Ltd.	Box 420 Peachland, B.C.
PENDERGAST, B.	Ministry of Rec. & Con.	Parliament Bldgs., Victoria, B.C.
PENNINGTON, K.	Kerr Priestman & Assoc.	400-880 Douglas St., Victoria, B.C.
POPOWICH, J.	Fording Coal Ltd.	Elkford, B.C.
RICHARDSON, A.	Richardson Seeds	7342 Winston St., Burnaby, B.C.
ROBBINS, J.	Soils Dept. UBC	Vancouver, B.C.
ROBINSON, J.	Ministry of Mines	Vancouver, B.C.
ROBERTSON, J.	Acres	950 W. Hastings St., Vancouver, B.C.
ROBERTSON, J.D.	Afton Mines Ltd.	1199 W. Hastings St., Vancouver, B.C.
ROBINSON, B.	Lornex	Box 1500 Logan Lake, B.C.
ROBINSON, W.	Ministry of Mines	2226 Brotherstone Rd., Nanaimo, B.C.

SADAR, E.	Ministry of Mines	101 2985 Airport Drive, Kamloops, B.C.
SAHLSTROM, P.	Terrasol	Box 2092, Vancouver, B.C.
SELKE, S.	Cominco Ltd.	200 Granville Square, Vancouver, B.C.
SHERA, P.	Ministry of Environment	Parliament Bldgs., Victoria, B.C.
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SMITH, D.	Ministry of Mines	101 - 2985 Airport Drive, Kamloops, B.C.
SMITH, E.	B.C. Forest Service	1927 Sierra Place, Victoria, B.C.
SNELGROVE, P.	Crows Nest Industries	Fernie, B.C.
SPENCER, R.	Thurber Consultants	Thurber Engineering, Victoria, B.C.
STANLAKE, E.	Ministry of Rec. & Con.	#400 1019 Wharf St., Victoria, B.C.
STANLAKE, M.	as above	as above
STILES, E.	Canex Placer	Box 183, Fraser Lake, B.C.
STATHERS, E.	Cominco Ltd.	#4-2161 Columbian-Trail, B.C.
THIRGOOD, J.	University of B.C.	Vancouver, B.C.
TIDSBURY, A.	Ministry of Mines	1652 Quinn St., Prince George, B.C.
UIBEL, J.W.	PanCanadian Petroleum	P.O. Box 2850, Calgary, Alta.
VAARTNOU, M.	Vaartnou & Sons Ltd.	Apt. 214, 8510-111 St., Edmonton, Alta.
VERZOSA, R.	Teck Corporation	1199 W. Hastings St., Vancouver, B.C.
VOLD, T.	Ministry of Environment	Parliament Bldgs., Victoria, B.C.
WALMSLEY, J.	Bethlehem Copper	P.O.Box 520, Ashcroft, B.C.
WEENK, B.	Gibraltar Mines	860 Pigeon Ave., Williams Lake, B.C.
WHITLEY, W.G.	Indian & Northern Affairs	200 Range Rd., Whitehorse, YT.
WESTON, S.	Wesago	1850 S.W. Marine Dr., Vancouver, B.C.
WOLFE, Gordon	Ministry of Rec. & Con.	540 Borland St., Williams Lake, B.C.
WONG, B.	Denison Coal Limited	1500 444-5th Ave., S.W., Calgary, B.C.
WOOD, J.A.	Ker Wood Leidal Conslts.	144 B. West 16th St., North Vancouver, B.C.
ZIEMKIEWICZ, P.	University of B.C.	Vancouver, B.C.
ZIRUL, D.	Ministry of Environment	Parliament Bldgs., Victoria, B.C.
WARNER, B.	Ministry of Mines	Prince George, B.C.

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