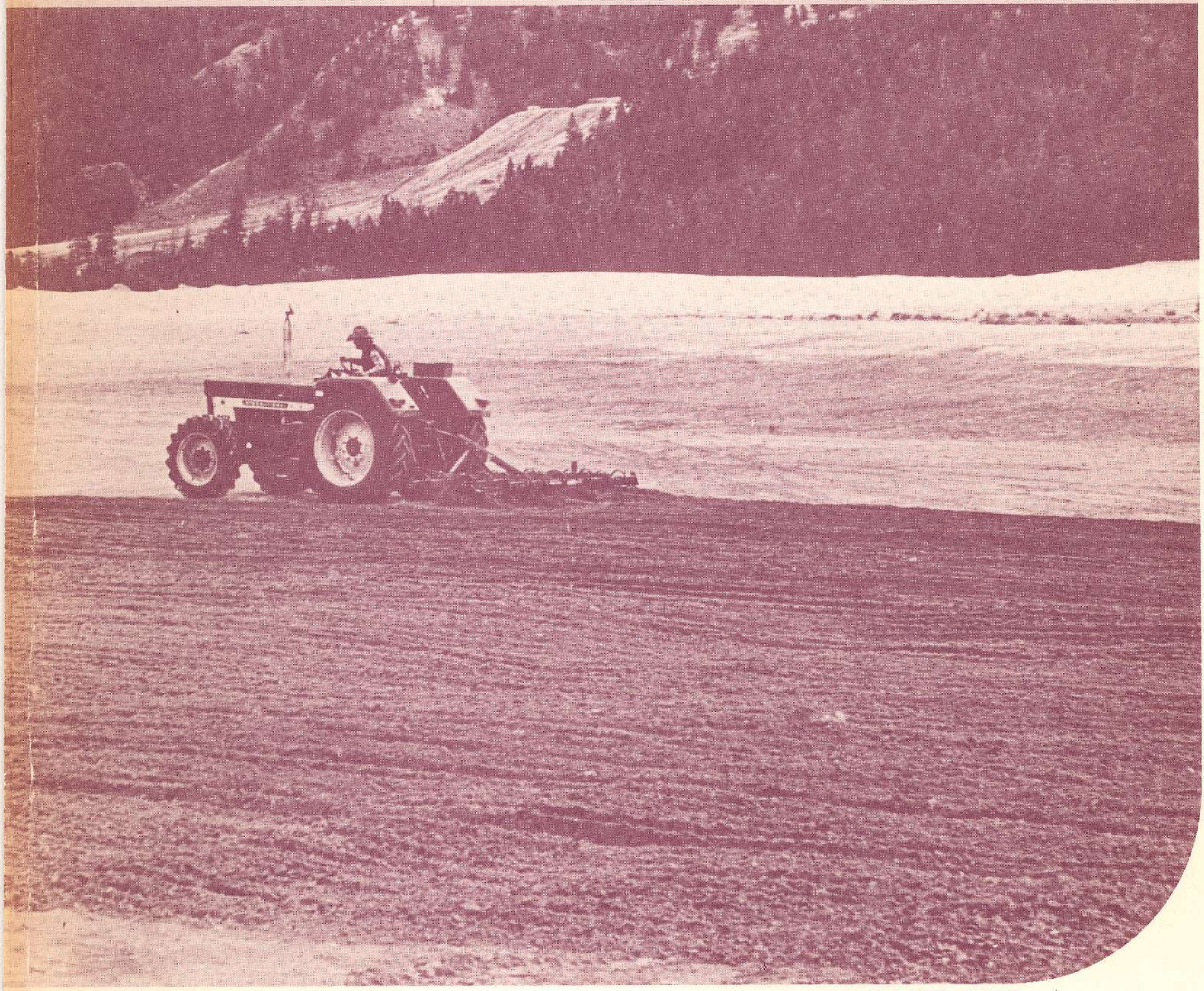
Reclamation of Lands Disturbed by Mining

Proceedings of the Third Annual British Columbia Mine Reclamation Symposium

Vernon, B.C.
March 7–9, 1979



PAPER 1979–4

Province of British Columbia

Ministry of Energy, Mines and Petroleum Resources

INSPECTION AND ENGINEERING DIVISION

SPONSORED BY
TECHNICAL AND RESEARCH COMMITTEE ON RECLAMATION
BRITISH COLUMBIA MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES
AND
THE MINING ASSOCIATION OF BRITISH COLUMBIA

RECLAMATION OF LANDS DISTURBED BY MINING

P R O C E E D I N G S

of the

THIRD ANNUAL BRITISH COLUMBIA

MINE RECLAMATION SYMPOSIUM

Convened at

Vernon Lodge

Vernon, British Columbia

on

March 7, 8, and 9, 1979

Sponsored by

Technical and Research Committee on Reclamation

British Columbia Ministry of Energy, Mines and Petroleum Resources

and the

Mining Association of British Columbia

Canadian Cataloguing in Publication Data

British Columbia Mine Reclamation Symposium, 3d,
Vernon, B.C., 1979.
Reclamation of lands disturbed by mining.

(Paper - Ministry of Energy, Mines and Petroleum Resources ; 1979-4)
"Sponsored by Technical and Research Committee on Reclamation, British Columbia Ministry of Energy, Mines and Petroleum Resources and the Mining Association of British Columbia".
ISBN 0-7719-8210-0

1. Reclamation of land - British Columbia - Congresses. 2. Mineral industries - Environmental aspects - British Columbia - Congresses. 3. Tailings (Metallurgy) - Congresses. 4. Spoil banks - Congresses. 5. Revegetation - British Columbia - Congresses. I. British Columbia. Ministry of Energy, Mines and Petroleum Resources. Technical and Research Committee on Reclamation. II. Mining Association of British Columbia. III. British Columbia. Mineral Resources Branch. Inspection and Engineering Division. IV. Title. V. Series: British Columbia. Ministry of Energy, Mines and Petroleum Resources. Paper - Ministry of Energy, Mines and Petroleum Resources ; 1979-4.

S605.2.C3B75   631.6'09711   C79-092157-X

PREFACE

The Ministry of Energy, Mines and Petroleum Resources is pleased to have played an active role in the sponsoring and organization of the Third Annual B.C. Mine Reclamation Symposium.

This year the Symposium emphasized the reclamation of metal mines and also dealt, in part, in the environmental protection, exploration disturbance and reclamation research related to metal mining. Attending participants represented all sectors of industry, government, consultants and universities concerned in reclamation. Their contributions ensured the success of the Symposium.

Since the First B.C. Mine Reclamation Symposium held in 1977, communication concerning reclamation has been augmented and improved through discussions at the Second Symposium in 1978 and the Third B.C. Mine Reclamation Symposium held this year. It is evident that the symposium approach has contributed greatly to the solutions of reclamation problems and the development of reasonable programs and policy in B.C.

James J. Hewitt

Minister
Ministry of Energy, Mines
and Petroleum Resources

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EDITOR'S NOTE

These proceedings present the Symposium events in chronological order. Presented papers have received minor editing and have been typed. Time constraints prohibited final text proofreading by individual authors, consequently, the editorial staff accept responsibility for any errors.

Question and answer periods were tape recorded. Transcripts of these discussions are given at the end of each presented paper within the proceedings. Severe editing of the transcripts was sometimes necessary to curtail the length of the question and answer dialogue. The Technical and Research Committee apologizes for any unwitting alterations in meaning.

Comments made during the two round-table workshop sessions have also been noted and transcribed. Findings which achieved consensus at the individual tables were read out at the conclusion of each session. There was a considerable variety of opinions expressed and, within the proceedings, an attempt has been made to include all points of view. The opinions most often expressed are listed first.

OPENING REMARKS

by the

SYMPOSIUM CHAIRMAN

D.M. GALBRAITH

Chairman

Technical and Research Committee

On Reclamation

As Chairman and on behalf of the Technical & Research Committee on Reclamation I would like to welcome you to the 1979 B.C. Mine Reclamation Symposium.

I would like to introduce your Committee to you. They are:

Mr. Jake McDonald, B.C. Ministry of Energy, Mines and Petroleum Resources

Mr. Art O'Bryan, B.C. Ministry of Energy, Mines and Petroleum Resources

Dr. John Errington, B.C. Ministry of Energy, Mines and Petroleum Resources (Convenor of Symposium)

Mr. Bob Gardiner, Cominco Ltd. (Past Chairman)

Mr. Tony Milligan, Kaiser Resources Ltd. (Incoming Chairman)

Prof. Les Lavkulich, University of British Columbia, Soil Science

Prof. Marc Bell, University of Victoria, Forest Ecology

Mr. Clem Pelletier, Utah Mines, Island Copper

Mr. Al Bellamy, Bethlehem Copper Limited

Mr. Roger Berdusco, Fording Coal Limited

Mr. Nick Agnew, B.P. Exploration Ltd.

Mr. Ben van Drimmelen, B.C. Ministry of the Environment, Fish & Wildlife Branch

The original concept of this reclamation symposium was to bring together the people who are involved in mining and reclamation so that they could exchange their experiences and ideas.

I would like to do my part in getting this dialogue started by introducing the Chairman of the first session, Dr. Nick Carter, Senior Geologist, Ministry of Energy, Mines and Petroleum Resources

ENVIRONMENTAL PROTECTION AND RECLAMATION OF EXPLORATION DISTURBANCES

Chairman of the Afternoon Session
Wednesday, March 7, 1979

N. Carter, Senior Geologist

B.C. Ministry of Energy, Mines and Petroleum Resources
Victoria, B.C.

RECLAMATION OF EXPLORATION DISTURBANCES
AT SAGE CREEK

Paper presented

by:

M.J. Tapics

Sage Creek Coal Ltd.

RECLAMATION OF EXPLORATION DISTURBANCES AT SAGE CREEK

INTRODUCTION

Sage Creek Coal Limited was incorporated in 1970 under the Companies' Act of British Columbia. It is managed and 60% owned by Rio Algom Limited in Toronto and 40% owned by Pan Ocean Oil Limited in Calgary.

The Sage Creek Property is located in the southeast corner of British Columbia, about 10 miles west of the Alberta border and about 8 miles north of the United States boundary.

Exploration work has been conducted on the property from 1970 through 1977. Approximately 200 acres of land were disturbed through the establishment of 30 miles of roads, 4,400 feet of trenches, 14 adits and drill sites for 159 holes. These disturbances were concentrated on two large hills which are separated by Cabin Creek. Throughout this paper these hills will be referred to as North Hill and South Hill. Cabin Creek is a tributary of the Flathead River.

Due in part to high expectations for obtaining a sales contract and, in part, to a sequence of field programs which were conducted over the same general area, seeding and fertilizing were not carried out from 1970 through 1976. Rio Algom felt that there was no point in reclaiming land one year that would be redisturbed the following summer. However, erosion control was done through the use of ditches, berms on roadways and water bars; and trenches were recontoured soon after they were excavated.

Reclamation of all disturbances was undertaken during the summer of 1977 and 1978. Most of these disturbanoes occurred between the 4,300 and 5,500 foot elevations.

RECLAMATION PROGRAMS

Disturbances were divided into three main areas: the north face of South Hill, the south face of North Hill and general access roads and drill sites. Reclamation was divided into two programs: A 1977 program which concentrated on the first two areas; and a 1978 program which involved general access roads, drill sites and maintenance work on the previous year's reclamation.

The North Face of South Hill

I will concentrate on the north face of South Hill since this area posed the biggest problem. Surface erosion had occurred in the vicinity of adits.

Since this area was saturated with water, it was impossible to use tracked equipment without site preparation. Preliminary work involved the use of a D6C bulldozer to upgrade roads. This upgrading included cleaning out ditches and construction of water bars and diversion berms.

A layer of rock rip rap was spread in the high moisture content areas in the vicinity of adits. To accomplish this, rock was dozed out of nearby roadway rock cuts. This material was also pushed into washouts to stabilize slopes and to form french drains.

Large trees that were undermined by erosion were cut up and removed from the site. To avoid unnecessary damage and to aid in stabilization, minor forest debris was left on the slopes. In addition, the debris acts as a heavy vegetative mulch.

Final control measures included the construction of a cut-off ditch along the toe of the final slope. Water and fines collected by this ditch are discharged into a small settling pond, and the excess water from this pond is discharged into dense bush for further filtering. After one year's use of this system a sediment fan was formed which contained coal fines. A second settling pond was constructed at the base of the hill before final discharge into Cabin Creek.

Three separate seeding techniques were applied to the north face of South Hill. Steep slopes were hydroseeded, mulched and fertilized using 50 pounds of grass/legume mix, 875 pounds of wood fibre mulch and 200 pounds of 16-20-0 fertilizer per acre. Roads were broadcast seeded with 30 pounds of grass/legume mix and 200 pounds of 16-20-0 fertilizer per acre. Steep inaccessible areas were hand seeded with 30 pounds of grass/legume mix per acre.

The seed mix by weight used in all cases was:

Creeping Red Fescue	-	25%
Kentucky Bluegrass	-	20%
Climax Timothy	-	10%
Perennial Ryegrass	-	10%
Vernal Alfalfa	-	15%
Redtop Fescue	-	5%
Chinook Orchardgrass	-	15%

After one year the seed germination results obtained were very good. The slope stabilization program proved to be quite effective with only minor slumps occurring in some of the washouts and steep road banks. Most of the downhill movement of water was restricted to the ditches and settling ponds.

The South Face of North Hill

This area is very dry and exposed, with little or no surface water present. Reclamation was designed to restore the aesthetic values of the site and to speed up the restoration of the area to its principal land use. It was felt that establishment of a grass/legume stand on the area would achieve these objectives. Some minor road work and contouring was done using a caterpillar tractor, primarily to provide access for the seeding equipment. Seeding was confined to hydroseeding and mulching. Specifications were similar to the South Hill, with the following seed mixture by weight being used:

Magna Bromegrass	-	25%
Sweet Clover	-	10%
Crested Wheatgrass	-	20%
Creeping Red Fescue	-	20%
Sainfoin	-	15%
Kentucky Bluegrass	-	10%

In addition, 45 pounds per acre of Fall Rye Grain were sown as a cover crop. The rye germinated rapidly and helped to reduce soil temperatures and hold soil and moisture. Otherwise, seed germination on this particularly dry site was not as successful as it was on South Hill.

Access Roads, Drill Sites and Maintenance of 1977 Program Work

All roads were ditched, water bars were constructed as required, and the areas were seeded, fertilized and harrowed followed by application of the same seed poundage per acre and the same type of fertilizer as was used previously.

Areas from the 1977 program that experienced incomplete stands of grass were either reseeded and fertilized or were hand seeded.

The seed mix used in dry areas was the same as that applied to the south face of North Hill, whereas the seed mix used in wet areas was adjusted slightly from that applied to the north face of South Hill. Since the Alfalfa did not germinate well, it was replaced by Alsike and Double Cut Red Clover in the blend. These were chosen due to our reclamation contractor's success with them at other sites.

COSTS

In 1979 dollars, the 1977 program expenditure was $36,000 for 55 acres, and included substantial dozer time. On this same dollar basis, the 1978 program cost $38,000 for 145 acres. Based on these past programs, approximate 1979 unit costs would be $260 per acre for tractor seeding, fertilizer and harrowing; $165 per acre for hand seeding; and, $540 per acre for hydroseeding, mulching and fertilizing. The average cost per acre to-date for the program is approximately $423. However, some maintenance work will be necessary which, it is anticipated, may reach $500 per acre to completely reclaim the site.

ACKNOWLEDGMENT

In conclusion, I would like to thank Alan Lamb of Interior Reforestation for his considerable assistance in the preparation of this paper.

DISCUSSION RELATED TO MIKE TAPICS' PAPER

Stan Weston, Wesago I do not recommend seed mixes which include sweet clover as it inhibits blood clotting, and causes internal and external bleeding in animals, through dicumarin production. Somebody has to be responsible for seeding an area. They may be liable to claims from cattlemen or wildlife people relating to animal mortality.

Alan Lamb, Interior Reforestation Ltd. I have been working on rangelands for about fifteen years and I have never yet lost a cow to sweet clover.

Stan Weston, Wesago Both Bob Duggan and I could bring in cattlemen who will not cut an animal that has been feeding exclusively on sweet clover, until it has been off sweet clover for at least three weeks. During that time, they will feed the animals themselves. I have worked with cattle and cattlemen for over thirty years and I know a little bit about the problem.

Roger Shaneman, Manalta Coal I'll just rephrase that. It is sweet clover sileage that is a problem, not range sweet clover.

Stan Weston, Wesago It is sweet clover that grows in the field; and I still say cattle should not eat it.

Paul Ziemkiewicz, Alberta Energy A report from Kingsbury in "Poisonous Plants of the United States and Canada" indicates that the only instances of dicumarin problems are with wetbale or from sileage sweet clover, never from field cured sweet clover and never from any animal foraging on green sweet clover.

TRENCHING TECHNIQUES AT THE B.P. SUKUNKA PROJECT

Paper prepared jointly
by:

R.M. Redgate

and

W. Nyland

B.P. Exploration Canada Limited

TRENCHING TECHNIQUES AT THE B. P. SUKUNKA PROJECT

INTRODUCTION

This discussion outlines the trenching programs on our Sukunka property. In addition to detailing the equipment utilized, geological information obtained, and reclamation procedures, a cost comparison of different machines will also be derived.

The Sukunka property is located in northeastern B.C., approximately 60 kilometres south of the village of Chetwynd (Figure 1). The lease occupies 165 square kilometres and is known to contain significant reserves of metallurgical coal. Located in the Inner Foothills belt, access to the property is by a logging road up the Sukunka River Valley (Figure 2).

The area is in the Sub-boreal Forest Region and contains rugged terrain with diverse vegetation patterns: from the alpine tundra zone atop Bullmoose Mountain; through Sub-alpine Engelmann Spruce - Alpine Fir zones in major valleys; to Sub-boreal White Spruce - Alpine Fir zones in the Sukunka Valley. Elevations range from 725 to 2025 metres.

Two mine portals, both located on outcrop, have been developed to access the reserves: the Sukunka Main Mine and the Number 1 Mine.

Coal exploration has taken place on the property since 1969; however, B. P. did not actively explore the lease until the summer of 1977.

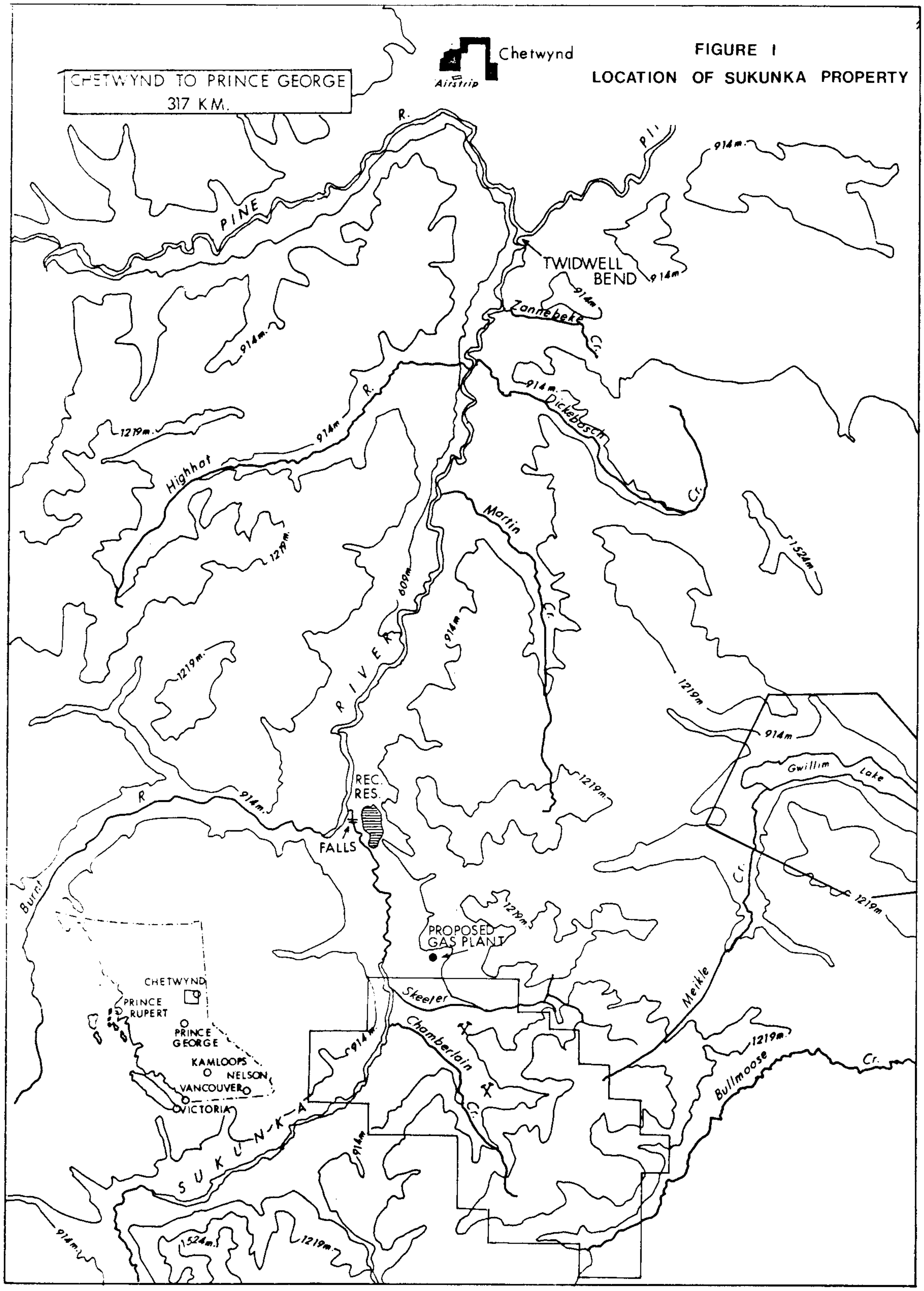

FIGURE I
LOCATION OF SUKUNKA PROPERTY
CHETWYND TO PRINCE GEORGE
317 KM.
Chetwynd
Airstrip
PINE
R.
TWIDWELL
BEND
Zonnebeke
Cr.
Dickebusch
Cr.
Highhat
R.
Martin
Cr.
RIVER
REC.
RES.
FALLS
PROPOSED
GAS PLANT
Gwillim
Lake
Skeeter
Chamberlain
Cr.
Meikle
Cr.
Bullmoose
Cr.
SUKUNKA
Burnt
R
914m.
1219m.
1524m.
609m.
CHETWYND
PRINCE
RUPERT
PRINCE
GEORGE
KAMLOOPS
NELSON
VANCOUVER
VICTORIA

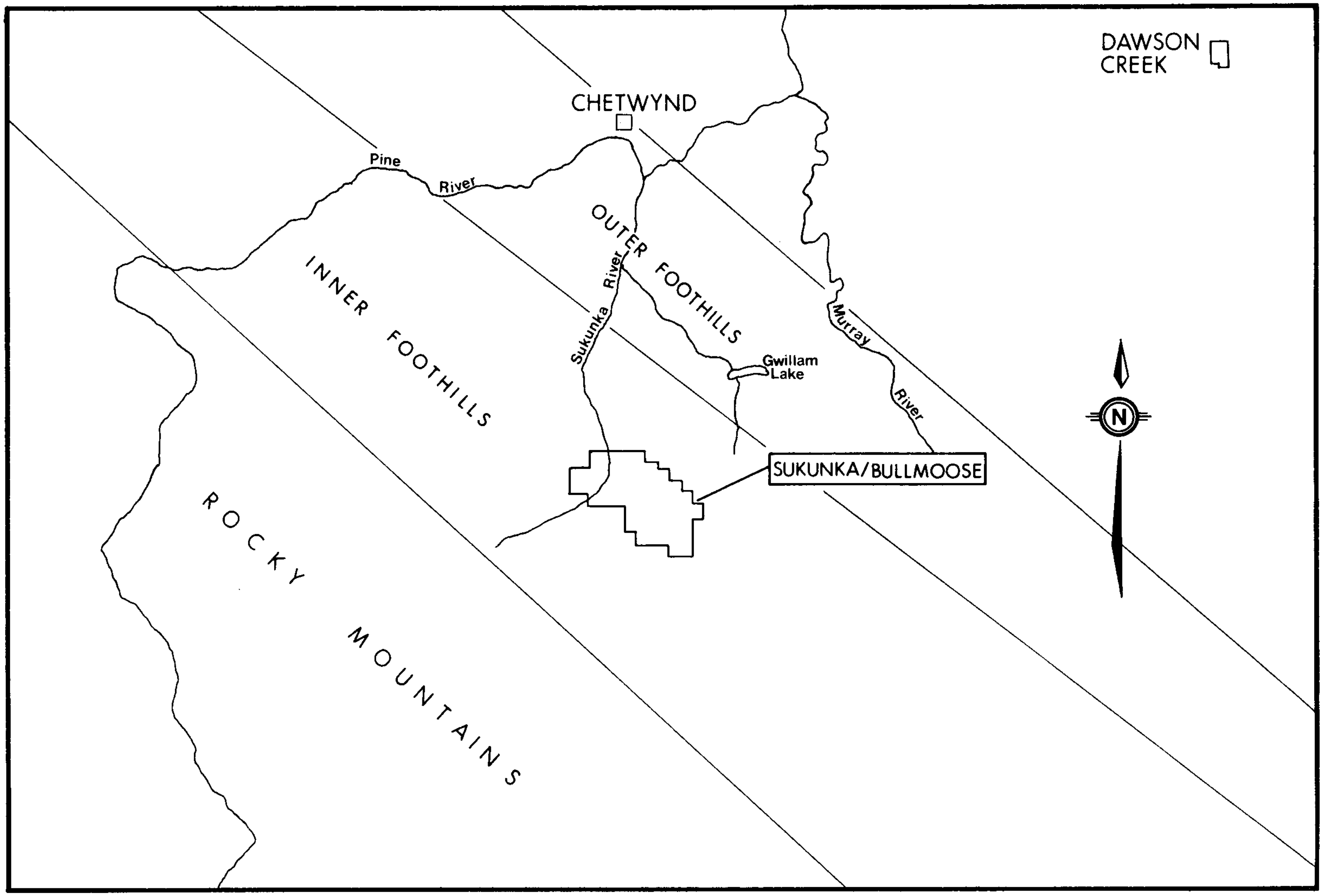

FIGURE 2
TECTONIC SETTING OF
NORTHEASTERN BRITISH COLUMBIA

TRENCHING ACTIVITIES

During the summer of 1978, exploration consisted of a combined program of drilling, trenching and field mapping. The duration of the program was approximately four months, from mid-May through to mid-September. The majority of reclamation work associated with these activities also took place in the summer of 1978.

Trenching provided valuable geological information on structure, stratigraphy and coal quality. Structural information obtained included a description of jointing, cleavage, bedding and faulting. Stratigraphic information included mainly a detailed description of roof and floor contacts not easily observed in drill cores. In addition, although unweathered sections of outcrop are not exposed during trenching, information on raw ash, moisture, volatiles, calorific value and a qualitative assessment of coking properties was obtained.

Generally, trenches were located in three types of locations. First, outcrops along roadsides were trenched to expose a physically undisturbed section. Secondly, to verify previously obtained information, old outcrop strips were trenched at 300 metre intervals, or less if warranted by the geology. And finally, areas of unknown, but inferred, outcrop were trenched to locate the exact position of seams. These trenches were largely unsuccessful due to the excessive depth of overburden.

TRENCHING MACHINES

Within the 1978 exploration program, considerable emphasis was placed on trenching. Therefore, relatively inexpensive and mobile trenching machines were required. This made the choice of machines critical. Six parameters were considered when evaluating the available alternatives:

1. Mobility - the lease area contains an extensive network of roads and outcrop strips, which allows the use of fast rubber-wheeled vehicles, however, the area also contains steep and difficult terrain, necessitating the use of tracked vehicles;
2. Physical size - for maximum mobility and flexibility, machinery had to be small enough to manoeuver in tight spots but large enough to trench in difficult areas;
3. Depth capability - machinery had to be capable of trenching to a depth of 4 to 5 metres;
4. Width of trench - to reduce surface disturbance, a bucket width of just over half a metre was desirable;
5. Cost - all machinery was commissioned on a per hour basis;
6. Availability - it was necessary to work within the limits of machines available in the Chetwynd region.

In the 1978 program, two machines were utilized: a rubber-tired John Deere 510 backhoe and a wide-pad Caterpillar D4. The big advantage of the 510 was its mobility between trench sites, travelling at speeds of 15 to 20 kilometres per hour depending on road conditions. The 510 backhoe also had an effective reach of 5 metres and a heavy boom. The disadvantage of the 510 was its immobility on steep or wet terrain; this necessitated bulldozer support and elevated the cost of trenching substantially. Costs for the John Deere 510 backhoe were 48 dollars per hour.

Under adverse conditions, a wide-pad Caterpillar D4 with a detachable backhoe was utilized. This machine, although slow between trenching sites, proved to be very effective on wet and steep terrain. The backhoe part of the machine had a slightly shorter reach (about 4 metres) and a lighter boom than the 510; however, this was more than offset by its ability to get into otherwise inaccessible areas. A big advantage of the D4 was that in areas where heavy bush was encountered, only a slashed trail was needed for access. A slashing crew went ahead and cut a trail just wide enough for the machine (about 4 metres), bucking the timber into short, 2 metre lengths. When the D4 came in to trench, it walked the bucked timber into contact with the ground. This procedure eliminated the need for road building, and prevented disturbance of the mineral soil and subsequent elaborate reclamation. Costs for the D4 when utilizing the backhoe were 38 dollars per hour; however, when the backhoe was not being used, this cost was reduced to 32 dollars per hour.

TRENCHING METHOD

The actual technique of trenching using either the 510 or D4 was as follows. The trench sites were flagged in geologically pertinent areas as determined by field mapping and, in some cases, drilling. If a trail or road to the trench site did not exist, a trail was flagged and slashed. A 0.7 metre wide bucket was used on all equipment. The material from the trench was piled as close as possible to the trench, usually within the radius of the boom, so that backfilling could be facilitated. Close supervision was exercised during all trenching so that unnecessary work would be eliminated. The trench was usually logged directly after it was opened, so that further cleaning out would not be necessary, and it could be backfilled and levelled before the backhoe moved to the next site.

Materials were immediately backfilled in the reverse order of extraction, which offered a number of reclamation advantages. First mineral and organic components of the soil could be restored in approximately their original order. Secondly, pH and microbial activity in the soil could be retained; and, finally, soil loss through erosion could be minimized. After backfilling, the standard Mines and Petroleum Resources seed mixture (percent by weight) for forested areas was applied and subsequently fertilized at a rate of 44 kilogrammes per hectare:

1. Boreal Creeping Red Fescue - 40%
2. Climax Timothy - 20%
3. Redtop - 15%
4. Alsike Clover - 25%

Cost Comparison between 1977 and 1978 Programs

During the 1977 exploration program, a Caterpillar D6 or D8 was used extensively for trenching. A cost comparison between this type and backhoe trenching has been made (Figure 3). All cost comparisons are based on dollar values during the respective year of operation - 1977 or 1978. Costs are only a comparison between the actual trenching activities; no costs for site access have been included.

In 1977, approximately 80 hours of Cat time were used to cut four trenches to a total length of 178 metres, which varied in width from 10 to 15 metres. In 1978, approximately 82 hours of backhoe time were used to cut 53 trenches to a total length of 153 metres, which had a maximum width of one metre. Costs per linear metre of trench were much lower in 1978 than 1977: Cat work averaged 201 dollars (201.24 dollars) per metre ; backhoe worked averaged only 23 dollars (22.53 dollars) per metre.

SUMMARY

In summary, significant savings can be realized with the use of rubber-tired or wide-track backhoes for trenching. In addition, since the area of surface disturbance is greatly minimized compared to bulldozer trenches and an equal return of geologic information is obtained, the resultant environmental impacts and reclamation costs can be significantly reduced.

FIGURE 3

COST COMPARISONS OF TRENCHING
USING BULLDOZER AND BACKHOE
TECHNIQUES

YEAR	EQUIPMENT TYPE	TOTAL LINEAR METRES	COST/M
1977	D8 & D6	178 metres	$201.00
1978	D4 Backhoe	153 metres	$22.50
	510 Backhoe		

DISCUSSION RELATED TO BOB REDGATE
AND W. NYLANDS' PAPER

There was no discussion about this paper.

EFFECTIVE UTILIZATION OF HELICOPTERS IN RECONNAISSANCE DRILLING

Paper presented

by:

L.A. Smith

Pacific Petroleums Ltd.

EFFECTIVE UTILIZATION OF HELICOPTERS IN RECONNAISSANCE DRILLING

INTRODUCTION

This paper discusses exploratory drilling for coal in remote Foothills terrain in which access is difficult and expensive. Information is based on and derived from 3 years of exploration on the Monkman Coal Project in northeastern B.C. (Figure 1). The property is located near the south end of the Peace River Coalfield. Figure 2 indicates the logistics of the property when we commenced work in 1976. This property is 75 kilometres long and stretches from Kinuseo Creek in the north to the Narraway River in the south. The road network at that time consisted of the Wapiti River Road, the Kinuseo Falls Road, the Triad Prairie Creek Road leading southwest off the Wapiti River Road, Denison Mines' Quintette Road in our Five Cabin area and local access of poor quality in the Duke Mountain area. The physiography is typical of the northern foothills and varies from glacial valleys with thick till and heavy forest cover to forested and poorly drained hillsides, to sub-alpine and alpine ridge tops.

EXPLORATION PROGRAM 1976 TO 1978

Objectives

In 1976 when Pacific commenced work our objectives were typical of first-phase exploration:

1. Determine the extent of coal measures on and adjoining the property.
2. Determine the rank, quality and extent of development of the coal seams.
3. Determine those areas most favourable for follow-up work.

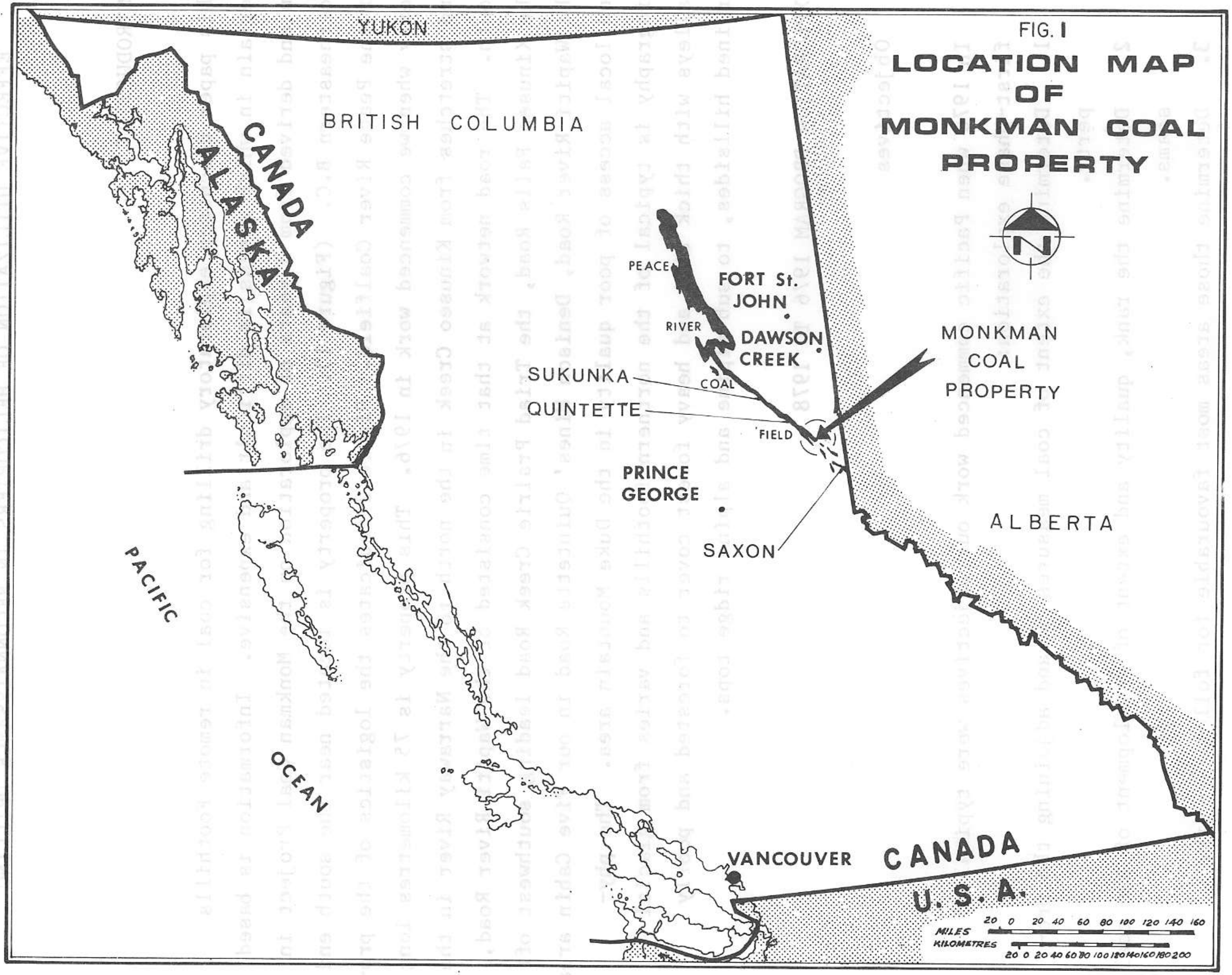

FIG. I
LOCATION MAP OF MONKMAN COAL PROPERTY

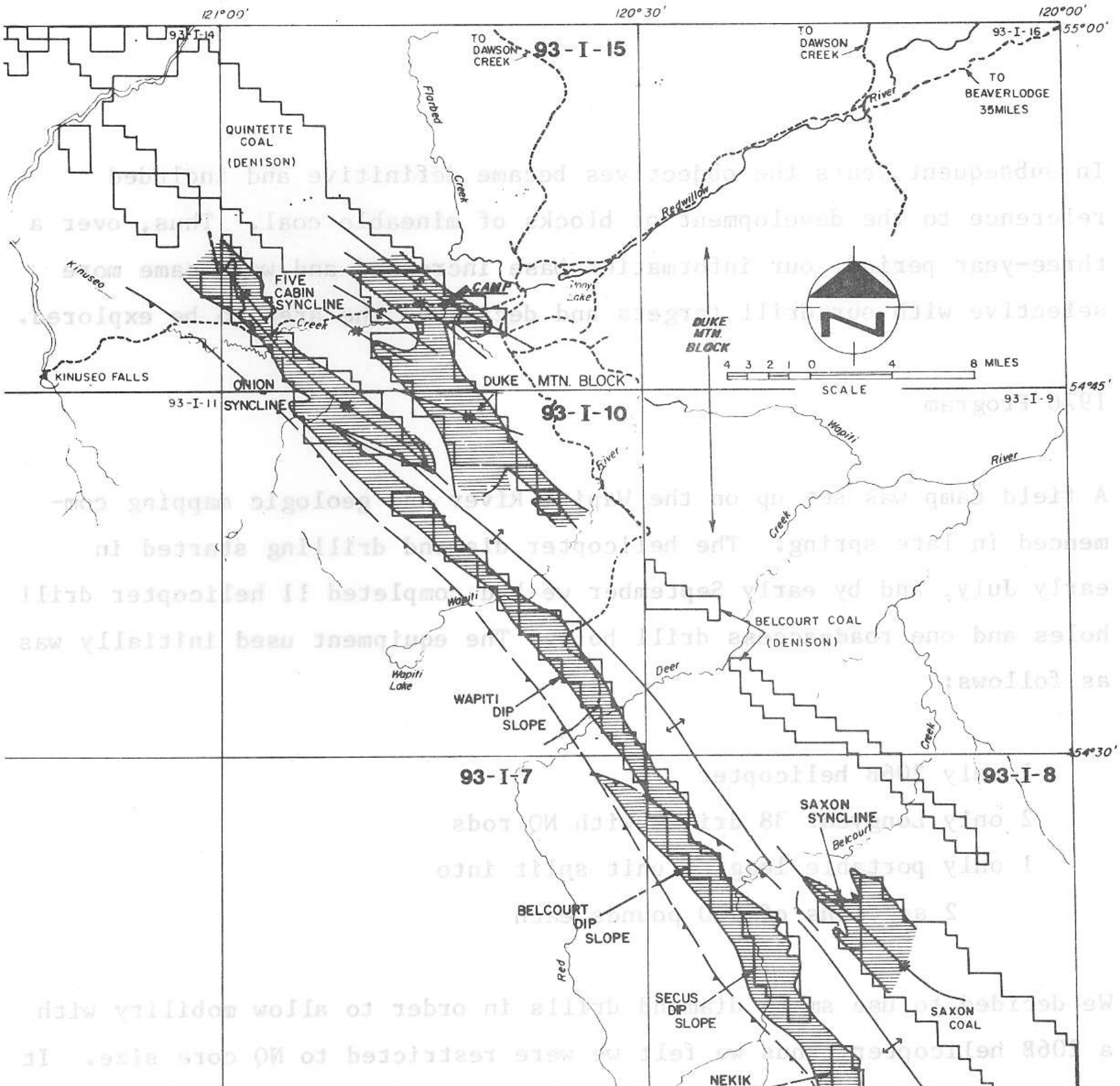

FIGURE 2
PHYSIOGRAPHY OF THE MONKMAN COAL PROJECT

In subsequent years the objectives became definitive and included reference to the development of blocks of mineable coal. Thus, over a three-year period, our information base increased and we became more selective with our drill targets and decreased the area to be explored.

1976 Program

A field camp was set up on the Wapiti River and geologic mapping commenced in late spring. The helicopter diamond drilling started in early July, and by early September we had completed 11 helicopter drill holes and one road-access drill hole. The equipment used initially was as follows:

1 only 206B helicopter
2 only Longyear 38 drills with NQ rods
1 only portable logging unit split into
    2 sections of 900 pounds each

We decided to use small diamond drills in order to allow mobility with a 206B helicopter, thus we felt we were restricted to NQ core size. It did not take long to find out that the costs of rig moves were inordinately high in terms of helicopter and rig time. Therefore medium turbines (205A's and S-58T's) were ferried in for many of the long moves. We found that the ferry costs from Prince George were not a major factor and that the overall cost saving with these larger machines was significant.

The 206B was used to ferry the logging unit from site to site. The large dots labelled 1976 in Figure 3 show the drill holes completed on this program.

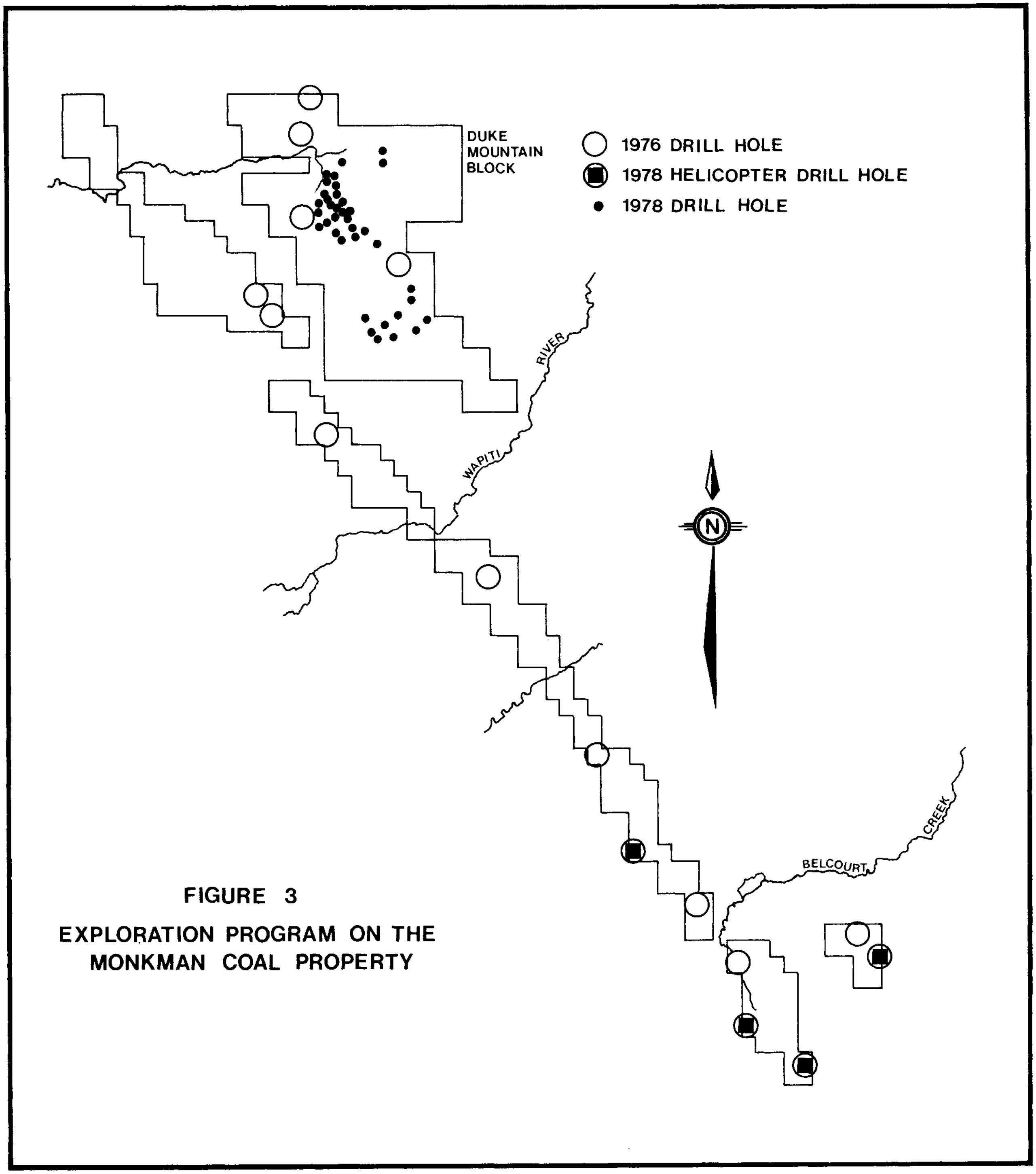

FIGURE 3

EXPLORATION PROGRAM ON THE MONKMAN COAL PROPERTY

1977 Program

This program was all land-supported and all holes were drilled on the Duke Mountain Block. The construction of a new 13.3 kilometre road allowed access to eight drill sites.

1978 Program

In 1978, 46 diamond and rotary holes and 2 adit sites were located on the Duke Mountain Block. They are shown as small black dots and small circles in Figure 3. All of these sites were reached by poor quality roads. Additionally four helicopter-access drill holes and two road-access holes were put in the Western area (large dots labelled 1978 in Figure 3).

Cost Effectiveness and Means of Access, 1976, 1977 and 1978 Programs

The first noteworthy item is that none of the helicopter-accessed drill sites cost more than 500 dollars to slash and reclaim, whereas, the roadbuilding program required nearly 1,500 dollars per kilometre direct cost for slashing, revegetation and erosion control. Table 1 shows the breakdown of the combined drill move and support costs. These figures do not include rig costs for drill moves, and trucking costs that were increased because of required changeover of a diamond drill and a logging unit to portable units. However, Table 1 does indicate the effectiveness of helicopter transport for long distance moves.

Road building costs for 1977 and 1978, which included all site preparation, roadbuilding, road maintenance, cleanup and reclamation costs, averaged 7,440 dollars per kilometre. The reason for this high cost was heavy timber and muddy conditions.

TABLE 1

COST OF HELICOPTER DRILL MOVES

YEAR	NO. HOLES	MOVE COST PER HOLE	SUPPORT COST/HOLE	TOTAL COST PER HOLE	LENGTH OF MOVE (km)	COST ($/km)	SUPPORT COST/ METRE DRILLED
1976	11	3600	6300	9900	12	825	34
1978	4	7600	9400	17,000	26	650	42
AVERAGE	15	4700	7100	11,800		705	37

COST OF ROAD DRILL MOVES

YEAR	NO. HOLES	TOTAL ROAD COSTS	COST PER HOLE	LENGTH OF MOVE (km)	COST ($/km)	SUPPORT COST/ METRE DRILLED
1977	8	66,000	8250	1.7	4850	32.20
1978	48	181,000	3770	0.8	4700	17.50
AVERAGE	56		4410		4740	19.90

Figure 4 consists of two charts which compare the cost of road access versus helicopter access. The left hand chart shows the cost in dollars per kilometre for various moves over varying distances. Three different road costs are presented, which are plotted as horizontal lines. The helicopter costs for the 1976 and the 1978 programs are plotted, and a third point has been calculated for a 1 kilometre move. The helicopter access curve has been developed on this framework. It is immediately obvious that the incremental helicopter costs decrease dramatically with increasing distance to a certain point. The helicopter curve crosses the current Monkman road cost line at the 1.7 kilometre mark. It is noted that, even if we were able to reduce road costs to 3,000 dollars per kilometre, we would only supply 3.5 kilometres of road access before helicopter moves became more economical. At the unrealistically low road cost of 1,000 dollars per kilometre, the breakeven point between road and helicopter access would be 11.2 kilometres.

The righthand chart shows total costs versus distance. The helicopter move curve is obviously shallower than the road access curve. At present Monkman costs, the break-even point is, as we saw on the other chart, 1.7 kilometres.

These figures have been generated for the Monkman property with its own peculiar set of logistics. However, there is no reason to expect that on another property the figures would change by more than 50 percent.

I will now mention a series of constraints that must be considered when evaluating method of access:

1. Weather and climate
2. Physiography of the area to be drilled
3. Local environmental sensitivity
4. Reclamation costs
5. Drilling equipment requirements
6. Availability of equipment

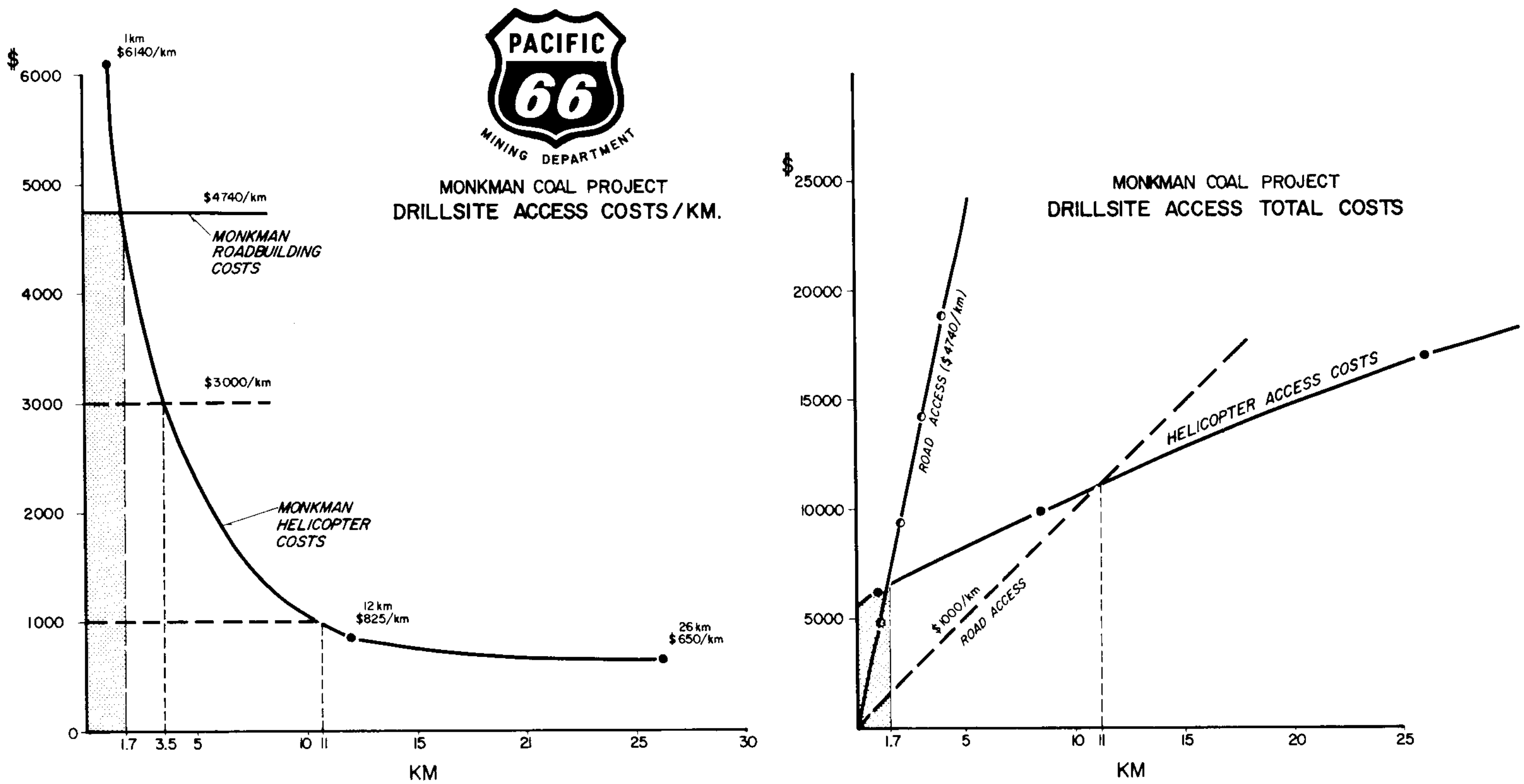

FIGURE 4

COSTS OF ROAD VERSUS HELICOPTER ACCESS

7. Availability of suitable aircraft
8. Length of move
9. Certainty of follow-up drilling

In conclusion I wish to reiterate the following points:

1. Get the right drilling and logging equipment to do the job. Equipment is often expensive so do not sacrifice quality for quantity unless circumstances dictate. Know your equipment weights (Table 2) and use contractors who also know them.

2. For short moves by air a small turbine may suffice, but if distances are 6 kilometres or longer and medium turbines are available, use them. Try to match the helicopter to the equipment and the distances concerned.

3. For preliminary exploration consider flying a rig to isolated drillsites that require a move of more than 2 kilometres.

4. If you are certain that the total follow-up work will result in less than 2 kilometres of road/drillsite, plan access roads as soon as is practical. This will allow more flexibility in choosing equipment, which can significantly lower overall costs.

TABLE 2

SUPER 38 LONGYEAR DIAMOND DRILL

HELICOPTER PORTABLE WEIGHTS

Item	Weight (pounds)
20-foot Aluminum Tower	900
Tabular Skids, fuel tanks and bunks	1200
Folding Drill Shack	700
Super 38 drill with H chuck	3180
353 diesel motor	1230
10-foot HQ rod	77
10-foot HQ casing	113
Portable mud tanks	1000
435 mud pump	1400
Supply pump	820
1000 feet of water line	650
Floor planks	1400
Mud mixer and tank	650
Rod rack and slide	100
Basket	180
Hydraulic cylinder for tower	110
Stiff legs	250
Core barrel with tubes	220
Tidy tank	110
1 HQ core box	12
1 bag mud	50
4 tool boxes	800
100 ft. high pressure hose	100
5 wooden sills	650
Blocks for sills	400

DISCUSSION RELATED TO LES SMITH'S PAPER

Greg Jones, Ministry of Lands, Parks and Housing. You said that you were worried about contractors not knowing the weight of the equipment that they were lifting. Well, previously I was involved with helicopter logging on the Island, and the co-pilot would watch a weight gauge. If it indicated over 20,000 pounds, which was the weight limit for the big bird they were using, the co-pilot could just press the kill button and it would drop everything.

ANS. Lovely.

Greg Jones. I was just pointing out that that's an alternative to having to know exactly what your weight should be, if you have no scale handy.

ANS. Yes, some operators use them. We used a 205 for a couple of moves this summer where we had them on. They had to install scales because there were several crashes with the 205 last summer and they had to put the weights on the machines so that they could delift down to 3,000 from 3,500 pounds.

Neil Duncan, Energy Resources Conservation Board. What was the reason for the four-kilometre spacing of the drill holes, which didn't seem to match into the geology of the place. It seemed like a rather strange type of program.

ANS. No comment.

Jim Meyer, Byron Creek Collieries. Did the drill crew travel back and forth in a helicopter every night, as well.

ANS. Yes. In 1976 and 1978 we used the light turbines for support of the rig.

Jim Meyer. Basically you're saying that you have few roads and therefore the helicopter drilling is cheaper. What if you plan to do more drilling in there? Your exploration costs will get lower each time, if you have the roads to start with.

ANS. Yes. My seminar paper was designed to discuss preliminary exploration and during this past summer we did build 39 kilometres of road to provide access. Our experience on this road gave me a lot of the cost derivation that I have used here. Once you know that you are going into an area and you are sure you have something, then it's worth building the road. All I am pointing out is that when you have a property with difficult access, don't start planning on building 20 kilometres of road. It can produce some problems for you.

Marv Mitchell, Range Oil Ltd. How many man shifts did you lose on the rigs due to inclement flying weather.

ANS. In 1976 we lost quite a few shifts but in 1978 very few. I would say that helicopter drilling raises your drilling costs, particularly your direct drill contract costs, by 15 to 20 percent. This is mainly due to lost time and to night-time equipment failures in the field when you can't do anything about them.

RECLAMATION OF EXPLORATION DISTURBANCES AT THE ISOLATION RIDGE PROPERTY

FORDING COAL LIMITED

Paper presented
by:

A. Magnusson
and
D. Gaspe
Fording Coal Limited

RECLAMATION OF EXPLORATION DISTURBANCES AT THE ISOLATION RIDGE PROPERTY FORDING COAL LIMITED

INTRODUCTION

During the summer of 1978, Fording Coal Limited completed an important reclamation project at Isolation Ridge in the Headwaters of the Oldman River. The property is located in the Rocky Mountains some 40 road miles north of Coleman, Alberta or 16 miles as the crow flies, east of Elkford, B.C.

Fording's predecessor, CanPac Minerals Limited, acquired coal leases to the area in 1969 and spent the next three years exploring for metallurgical coal. In 1973 the property was optioned to the Granby Mining Corporation Limited, of Vancouver, B.C., who performed more exploration work the following year. All work was suspended in 1975 because the Alberta Government was formulating its Eastern Slopes Policy and Granby could not obtain exploration permits. The Policy was issued in 1976 and it classified the Isolation Ridge area as part of Category Two. This category prohibits surface mining and the Granby Corporation did not exercise its option to purchase the property. Isolation Ridge reverted back to Fording Coal in 1978.

PROJECT OBJECTIVE

This reclamation program was undertaken by Fording Coal Limited, as successor to CanPac Minerals Limited, to reclaim disturbed areas which would not be required for exploration purposes in the foreseeable future.

All of the work was to be performed to the satisfaction of the Alberta Forest Service. Regulations required that disturbed areas be brought back to approximate original contour and reseeded to prevent erosion and to establish growth.

Early in 1978, areas requiring restoration and those to be left open for future access were identified by the Land Use Office, Alberta Forest Service in co-operation with Fording Coal Limited personnel.

PROJECT SIZE

Up to the end of 1974, some 56 miles of trails, 82 drill sites, 91 trenches and six adit sites had been constructed. During the fall of 1974, all the adit sites were reclaimed along with some of the larger drill sites.

The 1978 reclamation project was concerned with 43.5 miles of trails and approximately 50 drill sites associated with these roads.

To best utilize the short work period available to the project, it was decided to establish a temporary camp near the work site rather than have the crew commute from Coleman. A camp consisting of seven 30' x 10' trailers was established near the Oldman River. This served as base of operations for the 11 man crew.

Elevations on the property ranged from 5450 feet at the Oldman River campsite up to +8300 feet on Isolation Ridge.

RECLAMATION EQUIPMENT

Some of the initial reclamation work conducted by Granby and CanPac Minerals involved the use of a small crawler dragline, a Gradall 880 excavator and tracked bulldozers. The work carried out in 1974 showed that the Gradall 880 performed satisfactorily in restoring exploration trails.

Subsequent restoration work carried out at the company's Fording River Operations showed that the Caterpillar 225 backhoes also performed satisfactorily under this type of field work.

The backhoes could reach between trees, to salvage soils displaced by the road building process. The safety consideration of better gradeability and a lower centre of gravity led to a choice of Caterpillar 225 backhoes for this project.

Two Caterpillar 225 backhoes with 1 cubic yard buckets were used on the project with a D7E bulldozer employed to open access roads and put in cross drains.

Drain Brothers Construction Limited of Blairmore was chosen as the contractors.

TRAIL RESTORATION

Restoration of the exploration trails consisted of using the bulldozer to establish adequate working width on the old trails. Next the backhoes were used to pull back the material dozed downslope by the road building process. The material ranged in composition from thin soils and coal bloom, to straight rock and various combinations thereof.

Machine productivities varied considerably due to material being moved, and width of the working area. In rock, productivity ranged from 600 to 800 feet of resloped road per 9 hour day. In soil-like material, productivity was as high as 1800 feet of resloped road per 9 hour day.

Generally productivity averaged 131 feet of trail per backhoe operating hour.

Switchbacks on road and drill sites could take up to four hours to recontour because of the size of the site or nature of the material being moved. Several sites required rehandling of the material to reslope the area to the approximate original contour.

The two backhoes on the job were assigned to portions of the property which allowed them to work independent of each other.

A crew of two men was assigned to each backhoe to carry out fertilizing and seeding of the recontoured areas.

Typically the crew would cache bags of fertilizer and seed above the working area ahead of the backhoe and retrieve the material once the recontouring was done. This eliminated the arduous chore of packing bags of fertilizer and seed over recontoured ground.

All seed spreading was done the same day as the recontouring. Past experience showed that upon exposure to the sun for a few days, the soils formed a crust which adversely affected seed retention. By seeding immediately after recontouring, this problem was minimized.

Some trails were comprised chiefly of rock talus and no attempts were made to seed those areas.

On roads that were not recontoured, the fertilizer and seed were spread on the cut bank and side slope, as well as the crown of the trail. These trails were cross ditched to minimize erosion caused by surface water running down the roads.

Another technique used on approximately 3/4 of a mile of flat road, was to rip the road surface with the blade of the dozer. By tilting the dozer blade, the operator was able to loosen the packed road surface to a depth of 18 inches. This furrowed, reclaimed surface was then seeded and fertilized.

A steep adit site was resloped by using a combination of the D7 bulldozer and the backhoe. The bulldozer was used to winch the backhoe down the slope and then anchor the backhoe in position while it resloped the lower area. The backhoe was then winched to a new position up the slope, to repeat the process.

FERTILIZING AND SEEDING

The fertilizer formulation employed on the project comprised of a 13-16-10 mix applied at a rate of 200 pounds per acre plus an additional 20 pounds per acre of 46-0-0 (urea). This combination provided 35 pounds N, 32 pounds P_2O_5, and 20 pounds K_2O per acre. These nutrient values will provide both grasses and legumes with a basis for good growth.

The seed mixtures employed on the project were of two types. At the outset of the project, an order was placed for mix No. 1, described below, but at the end of the project, additional seed, mix No. 2, was obtained from the Fording River Operations. Time constraints prevented the Isolation project from obtaining mix No. 1 and the second mix should provide a comparison between the two.

The second mix has proven equally effective at the company's operations and is best suited for low altitude, less than 7000 feet elevation.

Component	Mix #1	Mix #2
Roamer Alfalfa	15%	-
Rhizoma Alfalfa	-	35%
Sainfoin	20%	-
Alsike Clover	10%	9%
Timothy	10%	17%
Slender Wheatgrass	8%	-
Streambank Wheatgrass	7%	-
Creeping Red Fescue	25%	26%
Redtop	5%	4%
Canada Bluegrass	-	9%
	100%	100%

All legumes were inoculated.

Application rates were 80 pounds per acre. Spreading was accomplished using hand spreaders.

Project timing resulted in Mix #1 being spread at the higher elevations, starting the first week of July. The work continued down to the lower elevations and Mix #2 was spread chiefly in the last week of August and the first two weeks of September.

PROJECT STATISTICS

1) Backhoes resloped
   - 27.8 miles of trails
   - approximately 50 drill sites
   - 1 major adit site

2) Roads seeded and fertilized but available for future access 15.7 miles.

3) Supplies used
   - 18 3/4 tons of fertilizer
   - 4.0 tons of seed
   - 6,800 gallons of diesel fuel
   - 2,650 gallons of gasoline

4) Crew Size

Reclamation	1 Field Supervisor
	5 Labourers
Contractor	1 Foreman
	2 Backhoe Operators
	1 Bulldozer Operator
Camp Catering	1 Cook
	1 Bullcook
Total	12 People

5) Project Completion Time = 78 Days

COSTS

I. Average cost per reclaimed mile of trail = $4,430.00 or $0.84 per linear foot of resloped trail.

II. Breakdown of Project Costs

Item	Costs *
A. Equipment rental; backhoes, dozer, rental vehicles, mobilization & demobilization	47%
B. Supplies seed, fertilizer, fuel, miscellaneous	13%
C. Camp Costs trailer rentals, transportation to and from camp	9%
D. Catering Costs cook & helper, propane, delivery charges	15%
E. Labour & Supervision crew & supervisor	16%
Total Project	100%

* Does not include administrative charges

ADDENDUM

During the summer of 1978, 48,300 feet (9.1 miles) of exploration roads were resloped at the Fording River Operations of Fording Coal Limited using a similar reclamation technique.

ACKNOWLEDGMENTS

I would like to thank the following for their co-operation in the completion of the Isolation Ridge Reclamation Project.

Harold Ganske	Land Use Office	Alberta Forestry Service
Drain Brothers Construction Limited		Blairmore, Alberta
Roger Berdusco	Reclamation Administrator	Fording Coal Limited

DISCUSSION RELATED TO ANTON MAGNUSSON"S PAPER

Jake McDonald, B.C. Ministry of Energy, Mines and Petroleum Resources

With regards to Alberta regulations, what is their criteria compared to British Columbia and our reclaimed roads. We have looked at reclaimed rock piles where you have moved rock from one place to another. Is it the regulations in Alberta that say you have to return the material back to its place of origin, or is there some guideline to help decide that there is no point in reclaming certain areas because no vegetation will grow there. For example, in some areas of B.C. where we have wildlife habitat on the southeast facing grassy slopes in such places as the East Kootenay, it pays to reclaim these roads and return them to their natural state. Is there any criteria in Alberta, or do they just say this is the way it's going to be.

Ans. The discussion we had on the project was with the Alberta Forestry Service. They are the people in Alberta that you actually deal with on reclamation. In British Columbia, of course, it is the Ministry of Energy, Mines and Petroleum Resources. We had some discussions with the Alberta people, but I was dealing with it third-hand because they were carried on in the Calgary office with the Forestry Service. Essentially, the guideline which I worked under was that Alberta would like all the roads that we disturbed restored to natural ground topography. The extreme examples I showed you with the rocks were actually rather limited in area. We had about five or six miles of what you would call major rock falls, that we resloped. A neighbouring project to the south of us also had extremely rocky conditions and they were doing the same work. All we had to guide us was a general guideline set down by the Alberta Forestry Service, which we followed to recontour.

Jake McDonald, B.C. Ministry of Energy, Mines and Petroleum Resources
If you just move rock from one place to the other, is it worth it.

ANS. I don't wish to discuss the government policy of a neighbouring province.

Jake McDonald, B.C. Ministry of Energy, Mines and Petroleum Resources
We do things on a site-specific basis in B.C. We are getting to a point where on one side of the border you can do this and on the other side you can do that. I think people on both sides of the border would like to get together and mutually discuss policy with a view to recognizing site-specific conditions. I think it will come in time, but I am interested in the standpoint of whether we should be doing work which is not very important. It costs money, and it's not for a good purpose.

ANS. I would be inclined to question some of the decisions made, but I know we seeded many areas of the property in 1974 and we had really excellent growth. It seemed a shame to take a dozer and backhoe in and recontour them, but that's actually what we did during the 1978 program.

Stan Weston, Wesago. Up in Alaska we had exploration roads on a coal property near Mt. McKinley. This was a very tough area which was crossed by about 300 acres of roads. Comparing what we did in Alaska to what happened in Alberta, we took in our Cats, then straightened the roads and followed right in with the aircraft. Using fixed-wing aircraft, we seeded in five days, two of which were too windy for aerial seeding. It seems to me that under the regulations you work with, you are compelled to disturb a lot more soil than necessary without any real reason except to bring it back to contour.

Jake McDonald, Ministry of Energy, Mines and Petroleum Resources

I just would like to point out that I am not criticizing what they do in Alberta. I think that they are doing a fantastic job. I wanted to mention that in British Columbia, we take a slightly different approach because of the site-specific conditions of altitude, mountains and rainfall. I think that the work that they have done in the foothills is remarkable and I would like to congratulate them.

Neil Duncan, Energy Resources Conservation Board. Perhaps I could shed a little light on Jake's (McDonald) question. This is Category 2 Land. By the way, this ridge is also known as Grand Ridge because when Granby came along and decided it would never produce any mine it was called Isolation Ridge. Category 2 means "underground mining only" so there would be no real reason to leave any of these roads for access to open pit mining. There is, if I remember rightly, about 80% of the reserves in Grand Ridge or Isolation Ridge that are for underground mining. So really, returning it to its original contour means it will be there for good, because if mining takes place it will be underground. Another reason for totally reclaiming, of course, is the number of recreational vehicles, 4 x 4's and that sort of thing. Therefore, the Forestry Service would like to see a road completely returned to discourage people from wandering off the road into the adjacent wilderness areas. We do try to completely reclaim the road where we'd like to stop any further access. That might shed a little light on the case.

HELICOPTER SUPPORTED DRILLING PROGRAM

AT THE KUTCHO CREEK PROJECT

Paper presented

by:

C. Aird

Esso Minerals Canada Ltd.

HELICOPTER SUPPORTED DRILLING PROGRAM AT THE KUTCHO CREEK PROJECT

INTRODUCTION

The Kutcho Creek copper, zinc, and silver massive sulphide deposit is situated in the Omineca Mining Division in northwestern B.C., 210 kilometres south of Watson Lake, Y.T. and 105 kilometres southeast of Dease Lake, B.C. Ownership of the deposit is shared by Esso Resources Canada Limited and Sumac Mines Ltd., a consortium of Japanese companies. Work on Esso's portion is managed by Esso Minerals Canada and on Sumac's portion by Sumitomo Metal Mining Canada Ltd.

The mineral claims lie within the Mackenzie watershed on the south side of a westerly flowing tributary of Kutcho Creek. The tributary, known locally as Andrea Creek enters Kutcho Creek, 15 kilometres above Rainbow Lake.

Elevations on the property range from 1200 metres in the valleys to 2000 metres in the mountains south of the deposit. The drilling area is at the 1500 metre elevation.

TRANSPORTATION

Originally, the property was serviced by float planes from Watson Lake to Rainbow Lake and the remainder of the distance by helicopter. In 1976, an airstrip was built in the Kutcho Creek valley and extended to a length of 1200 metres in 1977. The cost of the airstrip was borne by the B.C. Ministry of Energy, Mines and Petroleum Resources, and construction was done by Cry Lake Jade Limited whose camp is located at the airstrip.

Heavy air freight is usually flown in by Twin Otter from Dease Lake. Personnel and small freight shipments are normally flown on B.C. Yukon Air Services scheduled flights from Watson Lake. During the summer of 1978 these flights operated three times a week at a cost of 48 dollars per head or 24 cents per pound.

A helicopter is used to service the drilling operations which lie four to five miles east of the airstrip.

In the event of production, it is anticipated that concentrates would be trucked to Stewart, a distance of approximately 450 kilometres.

HISTORICAL AND GEOLOGICAL BACKGROUND

A regional geochemical anomaly was first noted in 1967 but lack of mineral showings precluded further work. Sumac later acquired claims on a surface showing of disseminated sulphides in a creek bed. In 1973, Paul Ziebart, an Imperial Oil prospector, located a boulder of high-grade copper and zinc sulphides downslope from a small gossan. Airborne and ground geophysical surveys by both companies, followed by diamond drilling, led to the discovery of a large body of massive sulphides.

Since that time approximately 90,000 feet of diamond drilling has been completed by both companies.

The massive sulphide bodies occupy a specific horizon within a group of epiclastic and pyroclastic volcanic rocks of acid to intermediate composition. The group is overlain by a thick bed of conglomerate followed by limestone and argillite. The limestone has been correlated with the Upper Triassic Sinwa Formation by the Geological Survey of Canada. All the above rocks strike westerly to northwesterly and dip at 50^{o} to the north.

Folding and metamorphism to lower green schist facies has produced varying degrees of schistosity and foliation in the rocks hosting the deposit. Foliation is commonly parallel to bedding. Schistosity appears to be a mixture of fracture cleavage and axial plane cleavage, which is generally perceived to be subparallel to the regional dip, except in the apices of minor folds where it is normal to bedding and intensified.

The sulphides are enclosed in and underlain by a finely laminated sericite schist, popularly called "paper schist", a core splitter's nightmare. The hanging wall consists of a thick mass of quartz feldspar crystal tuff overlain by a series of intermediate tuffs and argillite containing irregular bodies of metagabbro.

Mineralization consists of massive pyrite containing varying amounts of sphalerite, chalcopyrite and bornite. Silver is also present but no silver mineral has yet been identified. Drilling has identified two or more tabular, massive sulphide bodies occupying the same stratigraphic position over a strike length of 3500 metres. At its easterly end, the deposit approaches to within a few feet of the surface; whereas, on the westerly end, its presently explored depth is at 500 metres. (Figure 1).

DRILLING PROGRAM

All drilling on the property has been performed by Arctic Diamond Drilling Ltd. who have three drills (two Longyear 38's and a Longyear Super 38) on the property at present.

All drill core is BQ size and drilling depths have progressed from one or two hundreds of metres on the east end of the deposit to six or seven hundred metres on the west end. Holes are surveyed with the Sperry-Sun magnetic single-shot instrument.

As depths increased, project geologist Dane Bridge initiated the drilling of branch holes using wedging techniques. By this method two or more intersections are obtained with one pilot drill hole. This produces a major saving in both distance drilled and in moving time.

The heterogeneous nature of the hanging wall rocks, plus the foliation and schistosity, causes strong deviation of drillholes to the south. Controlled bit pressures and frequent bit changes somewhat reduce the amount of deviation; however, acting upon the suggestion of Don Coates of D.W. Coates Enterprises Ltd., a significant reduction in deviation was obtained using the Mini-Deve (registered trademark) reaming shell system. The additional cost of using the Mini-Deve system was more than offset by the saving in drilling distance which amounted to 14% for a target 500 metres deep.

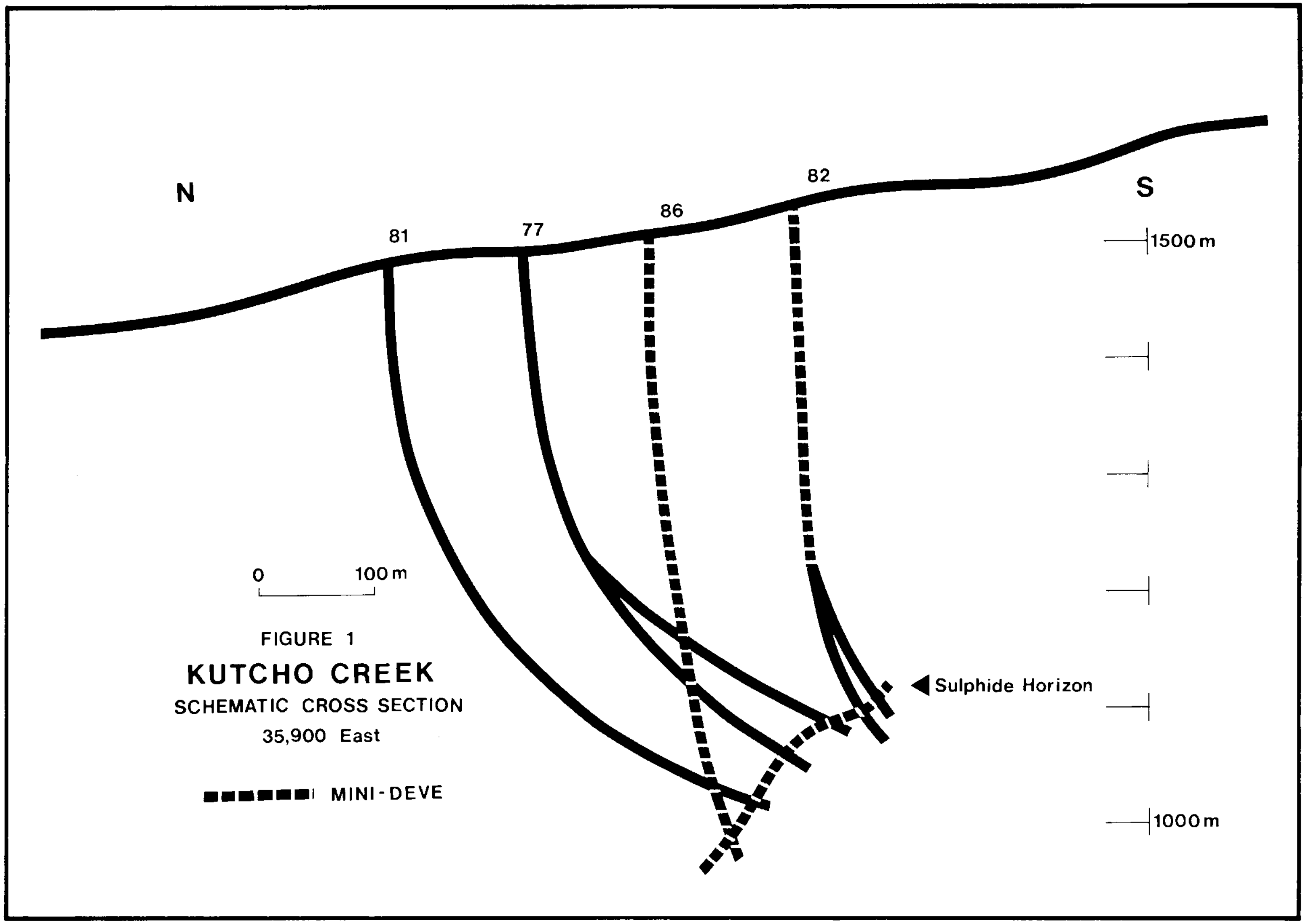

FIGURE 1
KUTCHO CREEK
SCHEMATIC CROSS SECTION
35,900 East

Drilling Costs

Drilling costs in 1978 were 24.82 dollars per foot, excluding office overhead.

Freight costs are best indicated by the cost of a barrel of Turbo B jet fuel delivered on-site versus costs at Terrace, B.C. This figure includes the costs of the drum which is returnable at some future date.

Terrace	Kutcho Creek
88.62 dollars	165.20 dollars

Costs mentioned here refer specifically to Esso's work; however, the diamond drilling and helicopter are contracted jointly by the two companies.

ENVIRONMENTAL BASELINE STUDIES

As mineral reserves were added it seemed appropriate that baseline studies should be undertaken to the specifications of a Stage 1 level. B.C. Research was awarded the contract. However, Esso's Dr. Uly Vagners mapped the surficial geology and reported on the distribution of soils.

Vegetation was assessed as falling into two basic categories; spruce-willow-birch in stream valleys, and alpine-tundra above 1600 metres elevation.

The following conclusions can be drawn from this study of the Kutcho Creek environment:

- It is wilderness area.
- It is a good caribou and moose habitat.
- It lies at the head of an unpolluted watershed.
- Trout, char and whitefish inhabit the creeks.
- Trapping and hunting are conducted in the area.

The chief environmental concern is the detrimental effect that could occur from highly acidic and heavy-metal-contaminated waste waters escaping into the watershed from the mine and tailings area. An additional concern is the reduced flow of water into the Kutcho Creek system that would be entailed by the use of water for milling purposes. With these concerns identified, they can be eliminated in the eventual design of a future mining operation.

CONCLUSIONS

Some advantages of a helicopter-supported drilling operation are:

- No capital equipment outlay.
- Little environmental disturbance.
- Quick transportation in the event of accidents.

Some disadvantages are:

- High hourly cost of operation.
- Sensitivity to bad weather conditions.
- Limited lifting capability for large drills.

There is little doubt that the Kutcho airstrip has been a significant factor in keeping down the cost of this helicopter-drilling project.

DISCUSSION RELATED TO CHARLIE AIRD'S PAPER

John Errington, Ministry of Energy, Mines and Petroleum Resources.
Did you say 28.00 dollars per foot to drill.

ANS. Yes. 24.82 dollars.

John Errington. How does that compare with southern exploration.

ANS. Well, we are doing exploration with Newmont south of Revelstoke and our drilling costs there are well over 50.00 dollars per foot. Mind you that is high. I think our costs four years ago were about 27.50 dollars per foot, and the reduction is, in part, due to the airstrip shortening our ferrying time in a helicopter. Also we are now flying in practically everything that we use on the property. A barrel of turbo B jet fuel costs 88.62 dollars in Terrace and if it is delivered on the property at the drill, it costs 165.20 dollars. Recent quotes that we had to take stuff in this winter by Cat train were three times as much.

EFFECTIVENESS OF THE CLIMBING BACKHOE IN COAL EXPLORATION

Paper presented
by:

K. Pomeroy

Denison Mines Ltd.

EFFECTIVENESS OF THE CLIMBING BACKHOE IN COAL EXPLORATION

INTRODUCTION

This paper reviews the experience of Denison Mines Limited in testing the effectiveness of the climbing backhoe in coal trenching and reclamation activities on the Saxon license area of the Northeast Coal Block in British Columbia. The experiment is followed from the planning phase (outlining the objectives of the trenching program, the environmental considerations, and the specifications of the climbing backhoe which made it attractive) through to evaluation of on-site performance.

LOCATION

The Saxon property encompasses approximately 13,700 hectares of coal licences in the southern portion of the Peace River Coal Block in British Columbia. It is located some 170 kilometres south of Dawson Creek and stretches from the B.C.-Alberta boundary in a Northwestern direction along the eastern foothills of the Rocky Mountains. Elevations within the property boundary range from 1,100 to 2,000 metres.

The main environmental parameters of the site considered in formulating the trenching program were:

1. topographic relief - as a factor restricting road building and tracked vehicle access;
2. variable depth of overburden - which meant variable effectiveness of trenching techniques;
3. presence or absence of seepage - as it limited load-bearing capacity and vehicle access;
4. vegetation types - as they affected vehicle mobility, slashing requirements, and revegetation problems;
5. climatic factors - which dictated a short field season and placed high premium on efficiency.

EQUIPMENT SPECIFICATIONS OF THE MENZI MUCK EH3000 CLIMBING BACKHOE

Two important, somewhat unique, specifications of the Menzie Muck made it a potentially valuable piece of equipment for use in the trenching program on Saxon. First, the Menzie Muck has two rear-mounted, wide-tired wheels, and two forward feet, all fully hydraulic. The two feet can be moved independently in both the vertical and horizontal planes; and the back wheels can be hydraulically raised or lowered, plus the wheels feature a gauge-widening of 2 metres allowing expansion of the wheel base from 1 3/4 to 3 3/4 metres. The result is that the backhoe can achieve increased stability in difficult slope locations, working effectively on 1:1 slopes. Consequently, it offered a potential solution to allow mechanical trenching on steep areas where constructing a road access would have meant significant erosion problems.

Secondly, the machine is light weight, with a total weight of approximately 4.5 tonnes, and it can be disassembled for air lifting by helicopter - a potential solution for machine-trenching alpine areas without the need to build roads which, in that vegetation zone, become serious reclamation problems. The machine's light weight means that it exerts very low ground pressures, only 0.68 psi with standard equipment, or half that value if equipped with special swamp pads. Thus it is suitable for use on ground with low load-bearing capacity, including seepage slopes and swamps. Because of these advantages, the Menzie Muck was considered a viable means of trenching while maximizing environmental protection.

Other specifications to note are:

i) On the ground, the Menzie Muck pulls itself along by maneuvering both the hydraulic feet and the bucket, and it moves very slowly at a rate estimated to be under 1 mile per hour. For moving longer distances, it can easily be loaded on a truck bed, or pulled as a trailer.

ii) Maximum lifting capacity is 1.8 tonnes; maximum reach, 6 metres; maximum digging depth, 4 metres; all of which are were adequate for the planned trenching operations.

EXPLORATION PROGRAM OBJECTIVES

The primary objective of any field exploration program is to acquire sufficient information on stratigraphy, coal seam thickness and variability, and coal quality to allow an assessment, with an acceptable level of confidence, of the exact location, quantity and quality of available coal reserves and the resultant feasibility of mine development. Each of the four main types of exploration techniques used on Saxon, namely geological mapping, trenching, drilling, and adit construction, supply certain types of information critical in increasing the confidence with which reserve assessments can be made.

Trenching of surface coal seams, the exploration technique for which the climbing backhoe was tested, is relied upon primarily to provide information on the variability of coal seam thickness and on the presence of rock splits in the seam. Use of surface seam data is important in linking surface mapping to the detailed but widely scattered data points available from drill cores. Information derived from the trenching program is a function of both the number of trenches and their spacing on the seam, and the quality of trenches constructed. The choice of trenching technique therefore is a function not only of the constraints imposed by the environment, but also of the information required from trenching at a given stage in the exploration program.

Two main techniques have been used in trenching on Denison properties; hand trenching and mechanical trenching by bulldozer or cat-mounted backhoe. Experience with both techniques has shown that, in general, trenching operations conducted by mechanical equipment requiring road access to the site, resulted in comparatively large areas of surface disturbance at high cost. Hand trenching, where field crew support is provided by helicopter, dramatically reduces the amount of surface disturbance, associated reclamation requirements, and overall program cost. Thus, hand trenching has been favoured whenever it can satisfy the information requirements of the exploration program. For example, in 1976 some 60 hand trenches were constructed in alpine areas of Saxon South, yielding good information that greatly increased the knowledge of seam thickness and confidence in reserve calculations. Only 3 mechanically dug trenches were constructed.

Hand trenching however is much less effective in providing good quality trenches in some locations. It has been found that hand trenches must penetrate in excess of 1 metre of coal, to give consistent and reliable measurements of seam thickness and characteristics. Since in almost all locations below the treeline, and in some areas above the treeline, a relatively thick cover of soil and colluvium must be excavated; and, since the maximum practical hand-trenching depth is limited by the height of the trenches, few successful hand trenches are possible in forested areas. Boulders in overburden also limit effectiveness in some hand trenching operations.

CASE STUDY

In 1977, the exploration program on Saxon was at a stage where surface seam information was required from two locations which could not be practically hand trenched due to overburden depth. The areas were:

1. Saxon East: high elevation alpine ridges in a location covered with moderately thick colluvial deposits in an area without existing road access. Road access for mechanical trenching would prove expensive and cause major environmental problems.

2. Saxon East: a forested hillside of low elevation and with deep colluvium cover. Part of the area was in a seepage area downslope of a major swamp. The bearing capacity of these soils was too low to permit bulldozer crossing.

It was felt that the characteristics of the specialized Menzie Muck climbing backhoe outlined earlier would make it an effective tool at this stage in the exploration program, by achieving a trench depth impossible with hand trenching, negotiating difficult terrain, yet meeting the objective of relatively low surface disturbance and reclamation cost. In addition, the backhoe could be used for additional trenching planned for the alpine area of Saxon South, and it would also be useful in road ditching and culverting along the Saxon South exploration road.

Based on the previously discussed factors, the decision was made to lease the Menzie Muck EH 3000 for the summer program from an Edmonton firm at a cost of 3,000 dollars per month.

On-site Performance

1. <u>Trench Quality</u>
   The climbing backhoe proved equal to other backhoes in effectively excavating deep, clean trenches up to 4 metres in depth, achieving complete exposure of seam roof to floor and providing a good section for the geologist to log. An additional operational consideration (as with all deep trenches) was the need to provide a safety cage for the geologist to stand in while logging the trench. A specially constructed steel cage was lowered into the trench by the backhoe, and moved along as the geologist logged the trench.

2. <u>Efficiency in trenching</u>
   The machine was able to quickly excavate a trench, but suffered serious maintenance problems (largely with the hydraulic system) which dramatically lowered overall efficiency.

3. <u>Mobility</u>
   Transportation problems proved to be major factors and they limited the effectiveness of the machine in many applications. For example, the plan to airlift the backhoe to the proposed alpine trenching locations at Saxon East was abandoned when a Bell 205 helicopter could not lift the heaviest section of the disassembled Menzie Muck. Altitude and warm afternoon temperatures limited the lifting capacity of the 205. Success might have been possible with a lighter model backhoe, and this should be evaluated by potential users; but a helicopter with a greater lifting capacity was impractical due to excessive costs associated with the use of a helicopter larger than the 205.

On the ground, the backhoe was towed between widely spaced trenching locations with a skidder, a solution which introduced two major problems. Firstly, it meant that the backhoe could be used only in areas near existing road access (the alternative of new road construction to provide access was not considered); and secondly, the cost of trenching operations was escalated due to the cost of skidder rental and operation.

4. Effectiveness as a technique for minimizing surface disturbance and slashing requirements in trenching operations

   In on-site use the Menzie Muck did result in less surface disturbance than a tracked vehicle--the wheels and feet made only minor indentations on most surfaces and it was judged almost as effective as hand trenching in reducing the impact in alpine areas. Slashing was also minimized as a result of the machine's maneuverability. The Menzie Muck can rotate through a complete circle, thereby minimizing turning area requirements; and in places where turning was required, it could be accomplished by a skilled operator in very small areas. Also, the slashing requirement was reduced by the ability of the backhoe to walk over many small trees by just bending them over.

5. Availability and Cost

   The Menzie Muck is a highly specialized piece of equipment, and not widely available. Equipment rental cost (1977 figures) on the Saxon project were 3,000 dollars per month for the backhoe, and 30.00 dollars per hour for the skidder required to move it.

6. Operator Skill

   The skill level of the operator is very important in extending or limiting the effectiveness of the machine. On Saxon, the lack of experience with the machine was considered to have limited both the working efficiency of the machine and its ability to negotiate difficult terrain.

SUMMARY

In conclusion, our experience with the climbing backhoe on Saxon underlined the need for a careful evaluation of site factors which could limit the effectiveness of the specialized equipment.

The backhoe did meet the objectives of 1) working well on swampy ground, 2) minimizing slashing requirements in forested areas, and 3) minimizing surface disturbance in alpine areas. However, the failure to airlift it to important alpine trenching locations, the requirements for a skidder to transport it on the ground, and the maintenance and operator problems combined to make the climbing backhoe program a poor investment when considered in relation to the useful information we wanted to acquire on this specific project.

DISCUSSION RELATED TO KATHY POMEROY'S PAPER

Question: What maximum steepness of slope can the backhoe operate on.

ANS. It depends on the type of overburden. We had quite a lot of trouble using it in any area where a tracked vehicle couldn't operate if there was a fair amount of loose colluvium over the rocks. The specifications say a 1:1 incline, but again that depends a lot on the skill of the operator that you have. I think that a lack of operator skill was part of the problem on the Saxon project. He was trained particularly for the project, but he had never operated one before and he had some trouble.

Garth Mayhew, University of Victoria. How much would this machine cost to buy.

ANS. The purchase cost we figured a year ago was 39,000 dollars, fully equipped.

KEYNOTE ADDRESS

of the

THIRD ANNUAL

MINE RECLAMATION

SYMPOSIUM

March 7, 1979

Garnet T. Page
President

The Coal Association of Canada

"Keeping Nature in Business - Part Two"

KEEPING NATURE IN BUSINESS - PART TWO

"Keeping Nature in Business" was the title of the Keynote Address which I had the pleasure of presenting at the Coal Industry Reclamation Symposium, sponsored by The Coal Association of Canada in Banff, in February, 1977. Some of you were present, and I trust that you will understand why I have retained the same title for this address. My reason for doing so is two-fold. First, the original paper dealt mainly with the challenges of land reclamation to the coal industry; this evening, as suits the occasion, I want to present my philosophy to representatives of both the government and the mining industry of British Columbia. I believe that this philosophy is supported by the Canadian coal industry in particular, and the mining industry in general.

Second, I have not wavered in my own belief that it is essential for all of us - coal miners and all miners - to "keep nature in business" to the maximum extent possible, in all of our operations.

We know that we do not have all the answers. We know that there is no one standard recipe for all reclamation, because of greatly differing soils, topographies, climates and desired uses. We know the serious dangers of making superficial comparisons between problems in one area or country and another. And we know that a sufficient range of technology exists to carry out successful reclamation for almost any specific mining situation in this country. That technology is continually being improved, in every annual cycle of nature. Even in the two years since Part I, we can see marked progress.

The environment is what is all around us and is where everything happens. Where it all happens is not just air, land and water, but all of nature. Environment is defined more formally as the surrounding conditions, influences, or forces which influence or modify. Within this context there is a host of physical, biological, physiosocial, biosocial and psychosocial factors. The term environment encompasses every aspect of life and living - every aspect of nature.

The environment undergoes and adjusts to change caused by natural phenomena. Man has added to these changes because of his own activities. He has overgrazed pastures, cleared steep slopes, blocked rivers, over-farmed land, over-killed wildlife, felled too many trees, built roads and communities, drained swamps - and has surface and underground mined many commodities. In order to adjust to the man-made changes, nature needs man's assistance.

In the past, relatively little concern was given to the impact of man's actions upon the environment. However, in recent years, many people have insisted that we become aware of air and water pollution, soil erosion, stream siltation and mutilated landscapes as major obstacles to both the quality of the environment and man's future condition on earth. Perhaps man has been greedy, thoughtless, careless or just plain ignorant; and he is just now learning that he must keep nature in business because it is necessary for his own continued happy existence. He is learning, and learning fast, that to stay in business, <u>he</u> must help to keep nature in business.

It is clear that we are on the threshold of a great mining expansion on this continent. As the world economy grows, and what we now call developing nations evolve into more or less developed countries and regions, so will grow the demand for all minerals: minerals for metals; minerals for fertilizers; minerals for energy.

Many of the new mines will be operated on the surface rather than underground, for many good reasons. And they will be operated by a mining industry that recognizes and accepts its responsibilities to preserving the environment; and that when the environment must be disturbed, the industry must restore it to an acceptable standard and make it suitable for whatever land use has been agreed in advance by all concerned.

As well as employing the best technologies to produce larger amounts of coal and minerals, the industry must also employ the best technologies to protect the environment.

Surface mining is the safest and most efficient method of removing coal from its bed. In the past it has had undesirable effects. But new awareness, and new technologies arising from research and experiments in many countries now enable coal operators to mine and reclaim so that the land is restored - and very often improved - in a relatively short time. This work must continue, so that some damages we now think of as inevitable can be minimized.

It is clear that disturbanee of the environment to meet man's energy needs can no longer be allowed to leave behind a heritage of devastation. The alternative course which we must follow is expensive and demanding. It is the course of planned and effective land reclamation, of continuous striving to explore and develop improved methods, and of educating and training people in their effective application.

For the reclamation of surface mined land, feasible criteria should be established by governments in consultation with the coal industry and with all concerned citizens. The criteria should recognize that each surface mining operation and locality has its own unique characteristics, and that the criteria will probably be more effective if they are stated in terms of results and objectives.

Having referred to governments, perhaps a few words would be in order regarding their role in keeping nature in business. The provincial government departments charged with the responsibility for mines and for the environment have a special contribution to make in reclamation. For this is not an issue which lends itself to pontification by an effete mandarin in a distant capital for its solution. Rather, it calls for reclamation experts and engineers in these departments with the same qualifications and skills as those working in the mining industry itself, who are not too proud to put on their waterproof boots and go sloshing in the mud with their industrial counterparts, looking for the most practical way of doing things, recognizing that each mining situation is unique, and that no one imposed set of standards can possibly apply to even one mine. Flexibility and good professional common sense, based on the best available technologies and applied specifically to each mine, are the essentials of good reclamation.

With coal's renaissance there has been some fear and speculation that environmental concerns would fall by the way-side. This is far from reality. In recent years the nation's awareness of its many-sided dependence on energy has sharpened. Over the same period, Canadians have grown increasingly conscientious in respect to their unparalleled environment. Can these concerns be reconciled? I think they can. A synthesis seems to be developing which could result in a new concept - an energy-environmental balance. The coal industry - and I am sure the same can be said for the mining industry - recognizes its role in creating and maintaining this balance, and will continue its programs for the improvement and application of environmental safeguards and the reclamation of disturbed lands.

What we have witnessed over the last few years in the resurgence of coal as a major source of energy is relatively insignificant compared to the requirements for this commodity in the not too distant future. The experts who predict coal demand to the end of this century and beyond put different numbers in their forecasts. What these numbers have in common is that they are all very large. I do not intend to become involved in a guessing game, but merely wish to point out that if you take the most conservative of predictions, you will conclude that by the year 2000, the annual production of coal will be in the order of four to five times its present level; and that may well double by 2025.

That is a lot of coal, and it means a lot of land will have to be disturbed in order to win it, and that land will have to be reclaimed. The conventional mining industry is more cyclical than coal, and it might not expand as dramatically as the coal industry must. But expand it will. Obviously, in total, we are talking about mining and consequent land reclamation on a scale never before dreamed of in Canada.

Those of you attending this Symposium are, for the most part, professionals in the field of reclamation. You represent several sciences, all of which have a specific and essential contribution to make to the complex mixture of knowledge, skills and experience which results in reclamation. Your future responsibilities will be very closely tied to the various commitments the mining industry must meet. You have a big load to shoulder. That load is not merely quantitative, although the expansion I have referred to does indicate large quantities, but also you are going to have to do your share in raising the state-of-the-art of reclamation from its present relative infancy to that of a mature technology in a matter of a few years only.

Your professional competence must be maintained and improved. Today's students; and I am so pleased that they are represented at this Symposium, have chosen a career which offers them a tremendous future. If I were a young Canadian, I know exactly what I would be doing today to develop a satisfying career, and that is what you are doing.

Man is supposed to manage his activities in relation to nature so that his needs may be met with least harm to nature. Because there are many people and they all want different things at different times, but often in the same place, it is important to have a good criteria and guidelines. If we know what we want, we should be able to know how we are to get it, making sure that we don't upset nature or our communities. How we do this should be discussed with all concerned and after agreement, should be written down. These are the "rules of the game", as people should play it.

Discussing reclamation, agreeing on some rules, recommending what should be done by whom, how, when and where, and seeing that it gets done fairly and properly; this is what governments and the mining industry must do to meet our needs and keep nature in business.

The mining industry has a real concern with discharging its responsibilities. It is prepared to do the things that it can believe in as fair, clear, practical, reasonable and necessary. It is prepared to work with governments in deciding what these things should be.

All of this implies that we are going to have to work hard, perhaps I should say we are going to have to work harder and work together, to keep nature in business. But it will be worth all our efforts.

I hope that in say 1994, my successor, or somebody else who cares deeply about the environment, will come to this annual Symposium and deliver Part III of this paper. I hope it will be possible for him to say that in the fifteen years since Garnet Page spoke on Keeping Nature in Business, Part II, more than half a billion tons of coal have been taken out of the ground in Western Canada, scores of metal mines have been added to those already in operation, and no matter where the coal miners and the hard rock miners have worked, the land they once disturbed is available for Canadians to enjoy in perpetuity, be it for forestry, agriculture, recreation or for nature herself. No one has been a loser: the coal and minerals were fairly won with skill and hard work; and nature was properly restored with skill and hard work.

Ladies and gentlemen, it all depends on your skills, your mutual cooperation, and your hard work. I wish you well!

RECLAMATION OF METAL MINE WASTES - PART I

Chairman of the Morning Session

Thursday, March 8, 1979

A. Bellamy

Bethlehem Mining Corporation

OPERATIONAL RECLAMATION EXPERIENCE AT COMINCO'S BLUEBELL AND PINCHI LAKE MINES

Paper prepared jointly
by:

J.E. Stathers and
R.T. Gardiner

Cominco Ltd.

OPERATIONAL RECLAMATION EXPERIENCE AT COMINCO'S BLUEBELL AND PINCHI LAKE MINES

INTRODUCTION

Operational reclamation experience at Cominco's lead-zinc and Pinchi Lake mercury properties will be described. The history of mining, ecological setting, land use capability, and the nature and extent of land disturbance will be briefly summarized. The objectives, approach, and method of implementing the reclamation plan including short-term results and costs will be discussed in more detail.

BLUEBELL MINE

Location and History

Bluebell is located within the village of Riondel on the east shore of Kootenay Lake, about 50 kilometres east of Nelson. The property has had a colourful mining history. Over a century ago Indians were reported to have smelted crude musket bullets using ore from the Bluebell outcrop (1). At the turn of the century about 8300 tons of ore were mined and treated in the nearby Pilot Bay mill and smelter. Before 1927 when Cominco acquired the property, about 560,000 tons of ore were mined and shipped to the Trail Smelter by barge and railway (2). During 1952-71 Bluebell produced about 4.8 million tons of ore grading about 5 percent lead and 6 percent zinc (3). Ore was mined by underground methods from sulphide replacements in limestone located under Kootenay Lake.

Ecological Setting and Land Use Capability

Bluebell is situated on Galena Bay at 560 metres elevation. The moderating climatic influence of Kootenay Lake provides more than 150 frost-free days per year and about 2 centimetres of precipitation per month during the growing season. Total annual precipitation is 90 centimetres (4). The mine is located within the Interior Western Hemlock Zone on a southern exposure (5). The soils have developed on colluvium from the bedrock outcrop and shallow glacial till. Forests are dominated by Douglas fir, white pine, cedar, larch, birch, and cottonwood.

Riondel land has a best physical capability for outdoor recreation and agriculture according to the Canada Land Inventory (6). Deer winter on the south-facing slopes in the area.

Nature and Extent of Land Disturbance

Total land disturbance at Bluebell was 13 acres. About 11 acres were occupied by the industrial site and a small waste rock dump. The remainder consisted of a small tailings spill, an open pit, and a mill site remaining from earlier mining activity. Tailings containing limestone, quartzite, schist, and smaller amounts of sulphides were deposited in Galena Bay.

During 1972-76, equipment was removed from the property, and buildings were levelled to concrete foundations. Mine portals were sealed and the open pit and industrial site were fenced.

Reclamation Plan

Objectives. The objectives of revegetation were to stabilize disturbed land surfaces against erosion, discourage refuse disposal, enhance lakeshore recreation potential, and improve the appearance of the site.

Approach. Plant species and fertilizer programs were selected for the reclamation plan based on the results of a modest field study program carried out during 1976-77. Chemical and physical properties of waste rock and disturbed soils were characterized using conventional soil tests. The main plant growth limiting factors were deficiency of organic matter, lack of the essential plant nutrients nitrogen and phosphorus, compaction, and moisture deficiency. Species selection trials showed that grasses such as Timothy, Canada Bluegrass, Orchardgrass, and Redtop established themselves satisfactorily with fall seeding. Spring seeding was necessary for the establishment of legumes such as Alfalfa, Birdsfoot Trefoil, and Alsike Clover. Short-term fertilizer experiments showed that incorporation of the equivalent of 56 kilograms per hectare N, 112 kilograms per hectare P_2O_5, and 56 kilograms per hectare K_2O before seeding, resulted in satisfactory establishment of a grass-legume mixture.

Implementation. Operational reclamation was initiated in November 1977 based on a reclamation plan submitted to the Ministry of Mines and Petroleum Resources.

Site preparation was carried out using a D8 Caterpillar with rippers and a 3 cubic yard Caterpillar 950 Payloader. Waste dumps were resloped to 10° slope angle and graded to blend with the lakeshore terrain. Cemented tailings and, where possible, concrete foundations were buried with a 45 centimetre depth of overburden. Metal objects, timber, and garbage were either removed from the site, burned or buried. The Payloader removed larger rocks exposed in ripping dump surfaces and left a tidy surface appearance. Site preparation was carried out in 7 days (21 man-days).

After resloping, ammonium phosphate fertilizer was broadcast on waste surfaces at 407 kilogrammes per hectare using an "Erocon" air applicator. Fertilizer was incorporated to a 15-30 centimetre depth by backblading with the Cat's brush blade, or by dragging back the teeth of the payloader bucket. Compact surfaces were scarified in two directions before applying the seed mixture. Creeping Red Fescue (40 percent), Canada Bluegrass (27 percent), Timothy (26 percent), and Redtop (7 percent) were surface broadcast at 34 kilograms per hectare using Erocon applicator and cyclone spreaders. Seed was incorporated by payloader bucket leaving contour furrows for trapping moisture on the dump surface. Seed and fertilizer were applied in one day (27 man-hours).

In April 1978, Rambler Alfafa (50%) and Birdsfoot Trefoil (50%) were surface broadcast on all areas at 22 kilograms per hectare using cyclone spreaders. Later in June and September 1978, split maintenance fertilizer applications were broadcast at 224 kilograms per hectare in the form of a complete fertilizer (13-16-10). During the initial growing season the grass-legume mixture established and grew satisfactorily on areas having sufficient fines and was dominated by Creeping Red Fescue and Timothy.

About 1800 trees and shrubs were planted in April 1977-78 to screen the open pit and concrete foundations. Bare root 2+0 Douglas Fir, Ponderosa and Lodgepole Pine, and Paper Birch seedlings were supplied by the B.C. Forest Service in Nelson. Arnot Bristly Locust, a spiny acid-tolerant nitrogen fixing shrub, and Black Cottonwood were planted to restrict access to the open pit. A local resident donated 28 four-year old Eastern Maple trees. Trees were planted by hand, using picks.

Costs Reclamation costs since 1972 have totalled 35,000 dollars including 8,000 dollars spent on research and administration and 27,000 dollars spent on planning and implementing operational reclamation (Table 1).

Reclamation planned for 1979 will include application of maintenance fertilizer and additional tree planting. Total costs are projected at 45,000 dollars or 3,500 dollars per acre.

Although future plans for the property are currently undecided, revegetation has made the Bluebell compatible with neighbouring residential areas and has discouraged refuse disposal on the site.

TABLE 1

OPERATIONAL RECLAMATION COSTS AT COMINCO LTD.
BLUEBELL AND PINCHI LAKE OPERATIONS DURING 1978

Property	Task	$	$/acre	%
BlueBell				
	Site Preparation (including supervision)	15,000	1154	56
	Vegetation Establishment and Maintenance (materials, labour*, travel expenses	9,000	692	33
	Administration (reclamation plan, reporting results)	3,000	230	11
	Total	27,000	2,076	100
Pinchi Lake				
	Materials (including transportation)	12,600	166	41
	Administration (Planning, reporting, and analysis)	8,600	113	28
	Labour*	4,200	55	13
	Helicopter	2,900	38	9
	Travel Expenses	2,700	36	9
	Total	31,000	408	100

Note: *Cominco labour rates include overhead, vacation/sick leave, and administration levy costs.

Bluebell costs were incurred in 1977 and 1978.

PINCHI LAKE OPERATIONS

Location and History

Pinchi Lake Operations is located on the north shore of Pinchi Lake, about 50 kilometres northwest of Fort St. James and 160 kilometres northwest of Prince George. The mine was first operated by Cominco during 1940-44 and produced 53,000 flasks of mercury from 700,000 tons of ore (1 flask=76 pounds). The mine was re-built in 1968 and produced close to 2½ million tons of ore and 176,000 mercury flasks before shutdown in 1975 (7). Cinnabar ore was mined by open pit and underground methods from the Pinchi limestone outcrop and treated in a concentrator and roaster.

Ecological Setting and Land Use Capability

The mine is situated within the Sub-Boreal Spruce Zone at an elevation of 716-814 metres (5). The climate is characterized by cold winters and a short growing season. Annual precipitation averages 46 centimetres with 2.5-5 centimetres per month during the growing season (4). Forests on the Pinchi outcrop are dominated by Lodgepole Pine, Trembling Aspen, and scattered White Spruce, Black Spruce, Douglas Fir, Cottonwood, Birch, and Alder trees. Soil parent materials vary from fine-textured glacio-lacustrine silts near the lakeshore to shallow coarse-textured glacial till and colluvium at higher elevations (8).

The Pinchi Lake area is reported to have moderately high outdoor recreation capability near the lakeshore and is an important winter range for moose (9). Forest capability on the Pinchi outcrop is low.

Nature and Extent of Land Disturbance

The total land disturbance at Pinchi Operations is 200 acres consisting of about 34 acres of open pits and waste rock dumps, a 60 acre tailings disposal area, and 106 acres of other disturbances such as roads, the industrial site, lagoons, portals, etc. Twenty-five percent of the disturbance consists of tailings, 25% of waste rock, and about 50% of disturbed soils.

During mine shutdown, hazardous chemicals were removed from the property, mine portals were blocked, the West Zone Pit was fenced, the tailings dyke was raised, and a spillway was constructed to control drainage overflow from the tailings pond. A watchman-caretaker currently resides at the site.

Reclamation Plan

Objectives. The objectives of revegetation were to improve plant growth conditions on disturbed mined-land to encourage succession of self-sustaining native and naturalized plant communities. An initial vegetative cover of suitably adapted grasses and legumes were established using commercial fertilizer. This was intended to rapidly stabilize waste surfaces against erosion and improve the appearance of the site.

Approach. The revegetation approach was based on a laboratory growth room and field research studies conducted since 1970, in accordance with the surface work permit. Pertinent results will be briefly summarized.

Disturbed soils and parent materials were revegetated naturally within 2-5 years following disturbance. Natural regeneration was unsatisfactory on waste rock and tailings. Application of the plant nutrients nitrogen and phosphorus as commercial fertilizer was essential for establishment and growth of both native and commercial plant species on waste rock and tailings.

Rambler Alfalfa, Alsike Clover, Canada Bluegrass, Creeping Red Fescue, Timothy, Hard Fescue, and Crested Wheatgrass were established and grew satisfactorily on waste rock and tailings, and produced seed during seven growing seasons of evaluation. Grasses and legumes were established by broadcast application of seed and fertilizer with no site preparation. Legumes and legume-grass mixtures have provided satisfactory vegetative cover, biomass, and seed production for four growing seasons, since the discontinuation of maintenance fertilizer applications.

During the first few growing seasons, invasion of dense legume-grass cover by native plants was limited by competition. Eventually as cover decreased, invasion of native plants accelerated.

The mercury content of grasses and legumes grown on waste rock and tailings was slightly elevated compared to values reported for the same species grown on normal soils; but was lower than values for vegetation growing in the vicinity of mercury mineralization in B.C. (10, 11).

Implementation. Reclamation at Pinchi has been on-going for a number of years. In 1971, roadcuts, a borrow pit, and portal entrances totalling 15 acres were hydroseeded. Mulch, ammonium nitrate-phosphate fertilizer (24-24-0), and a seed mixture were broadcast at 1120, 233 and 84 kilograms per hectare respectively.

In 1973, the 4-acre West Zone Pit waste dump was revegetated using a pull-type fertilizer applicator and pick-up truck. Before seeding ammonium phosphate, ammonium nitrate and muriate of potash fertilizer were surface broadcast to supply 56 kilograms per hectare N, 112 kilograms per hectare P_2O_5, and 56 kilograms per hectare K_2O. The seed mixture was surface broadcast at 112 kilograms per hectare. Maintenance fertilizer applications of 466 and 233 kilograms per tare applied as 24-24-0 were surface broadcast using hand-operated cyclone spreaders in May 1974 and 1975.

In May 1978, 76 acres consisting of the tailings disposal area, open pits, waste rock dumps, and areas not likely to be disturbed during removal of surface structures were revegetated using a Jet Ranger helicopter. Saturated tailings conditions in spring limited access of conventional seeding equipment.

Materials were broadcast on waste surfaces without site preparation. A complete fertilizer (13-16-10) was broadcast on waste rock and tailings at 431 and 862 kilograms per hectare respectively. A Rambler Alfalfa (30%), Alsike Clover (20%), Creeping Red Fescue (25%), Redtop (10%), and Canada Bluegrass (15%) mixture was broadcast at 56 kilograms per hectare.

Fertilizer and seed were applied as follows:

a) at the staging area a 4-man crew loaded 700 pounds of fertilizer or 300 pounds of seed in 30 seconds into two 45-gallon barrels attached to each side of the helicopter.

b) a fifth person lined up the flight path of the helicopter to control material application.

c) application rates were controlled by the helicopter engineer by sliding a metal plate to vary the size of opening on the bottom of each barrel, and by varying altitude and speed. At 200 feet altitude and 25 miles per hour, materials covered a 25-foot wide strip.

d) the total time required to load, fly to the site, apply materials, and return to the staging area varied from 4 1/2 to 5 minutes.

e) the staging area was generally about one half mile from the point of material application.

Twenty-five tons of fertilizer and 2.2 tons of seed were applied by helicopter in 7 hours; 1.6 hours were required to fly the helicopter to and from Prince George.

Seed and fertilizer applications were uneven in some areas. To improve coverage on these areas, cyclone spreaders were used. This will be remedied in the future by using two people to align the helicopter and by using proper cyclone applicators mounted on the helicopters.

By late October 1978, waste rock and tailings were covered with relatively uniform seedling populations. Seedlings did not establish satisfactorily on waste rock left at the natural angle of repose, or where seed and fertilizer applications were uneven. Fertilizer accelerated the regeneration of native conifer and deciduous seedlings on waste rock. On tailings, the invasion of native Nuttall's Alkaligrass was promoted by fertilizer. Establishment of Creeping Red Fescue and Redtop was satisfactory on portions of the tailings pond; but legume establishment was poor and confined to cracks. Relatively poor establishment of legumes on tailings was attributed to a drier than normal summer.

Costs. Reclamation costs since 1970 have totalled 108,000 dollars, including 69,000 dollars spent on research and administration and 39,000 dollars spent on operational reclamation. Reclamation costs during 1978 totalled 31,000 dollars or 408 dollars per acre (see Table 1).

The 1979 reclamation program will include helicopter application of maintenance fertilizer to areas seeded in 1978 and tree planting in selected locations.

Dismantling and removal of tailings and surface structures will begin in 1979. Reclamation of the remaining land disturbance will be carried out when site clean-up is completed.

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DISCUSSION RELATED TO ERIC STATHERS AND R.T. GARDINERS' PAPER

Neil Duncan, Energy Resources Conservation Board. Why did you leave the concrete foundations at the Bluebell mining site.

ANS. The land use for the area had not been decided, and it was felt by some people that the foundations may possibly be used for future buildings. Also, the cost of hauling materials away would have been quite high.

Kerry Clark, Arcon Associates. I wonder if the vegetation that grows on these sites is suitable as a crop or does it contain metal residue.

ANS. Yes, the vegetation contains metal residue. We have monitored the vegetation annually for nutrient content and metal content and have reported the results to the Ministry of Energy, Mines and Petroleum Resources. In the case of the reclaimed vegetation grown at the Pinchi operations, the metal content is elevated compared to agricultural species grown elsewhere, but is similar in level to native shrubs and trees growing on the Pinchi rock outcrop.

Kerry Clark. Does that mean that it would be unsuitable as a forage crop.

ANS. I don't know, as I am not an expert in the area. All I am saying is that it's similar to the native vegetation growing in the area.

RECLAMATION OF DUMP SLOPES

Paper presented
by:

J.D. Graham
Lornex Mining Corp.

RECLAMATION OF DUMP SLOPES

INTRODUCTION

In past meetings we have heard a number of good papers describing what is being done with dumps at various coal mines. I would like to discuss the reclamation of dump slopes, dwelling particularly on the underlying philosophy of reclamation. In addition, I will briefly review experiences at several mines.

RECLAMATION

Reclamation is the first word in the title of my paper. But what does it mean? Vast sums are spent in the name of reclamation. It employs the energies of many people; those in environmental groups, in government, industry and in universities. Yet its definition remains unclear.

It is obvious that there is no consensus on the meaning of reclamation. The organizers of this Symposium made this discovery in 1977. In response to a questionnaire, they received 105 definitions of reclamation. The definition varied, I suspect, depending upon the primary interest of the individual.

Let me review two of the more popular definitions derived from the questionnaire, namely:

1. Return the land to a useful state; and
2. Return the land to its natural state.

We must reject the latter definition in a literal sense. Taken literally, it means back-fill the excavations and reslope the dumps to the original contour. The costs of this would be staggering.

Taken in a more liberal context, these two definitions combine to become "return land to the useful state existing before disturbance".

Is this a reasonable definition of reclamation? When viewed from an economic standpoint the definition breaks down. The fact is that mining renders the land vastly more valuable than the original use. Let me use Lornex as an example. The original economic base of this mine site was a forest. The value of this renewable resource on a 100 year cycle is 1/4 million dollars over all the disturbed area. This amounts to one hundred and thirty dollars per disturbed acre. I would like to compare this with the new economic base, mining. In 6 years the mine has paid out in wages, taxes and purchases over 470 million dollars. I might add that Lornex is still in debt. These payments have rendered the land over 1000 times more valuable than the 100 year forest. Is it therefore realistic to further burden this enterprise with the cost of re-establishing a forest? Does it make economic sense to spend 300 dollars per acre to create a 130 dollar per acre forest?

While reclamation may be difficult to describe in an economic sense, it can be defined in the environmental context. Simply stated, mine sites should not be left in a state dangerous to the environment. In terms of dump faces, reclamation should render the slope environmentally stable.

Specifically, dump faces should not be subject to rapid erosion. Slow erosion on a geological scale cannot be avoided; however, rapid erosion silts lakes and streams through wind and water action. Reclamation must prevent silting.

Under this definition there is no intent to spend millions in rapidly changing the visual impact of a dump. Many people feel dumps offer no more visual offence than a talus slope. See Figures 1 and 2.

I suggest that it is misuse of our precious economic resources if the sole purpose of a reclamation project is to change the aspect of a dump face from multi-coloured rock to grass green.

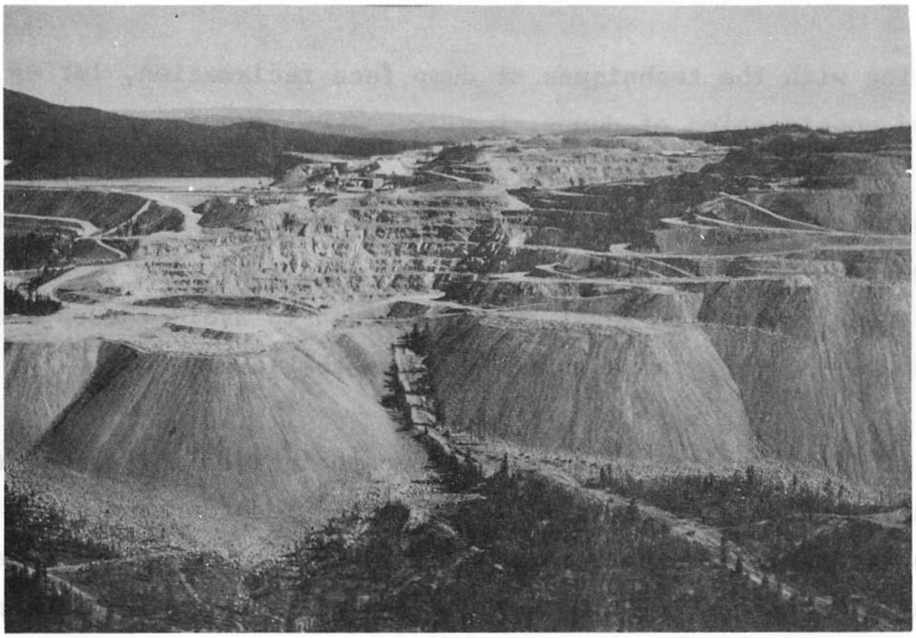


FIGURE 1

WASTE DUMPS AT LORNEX

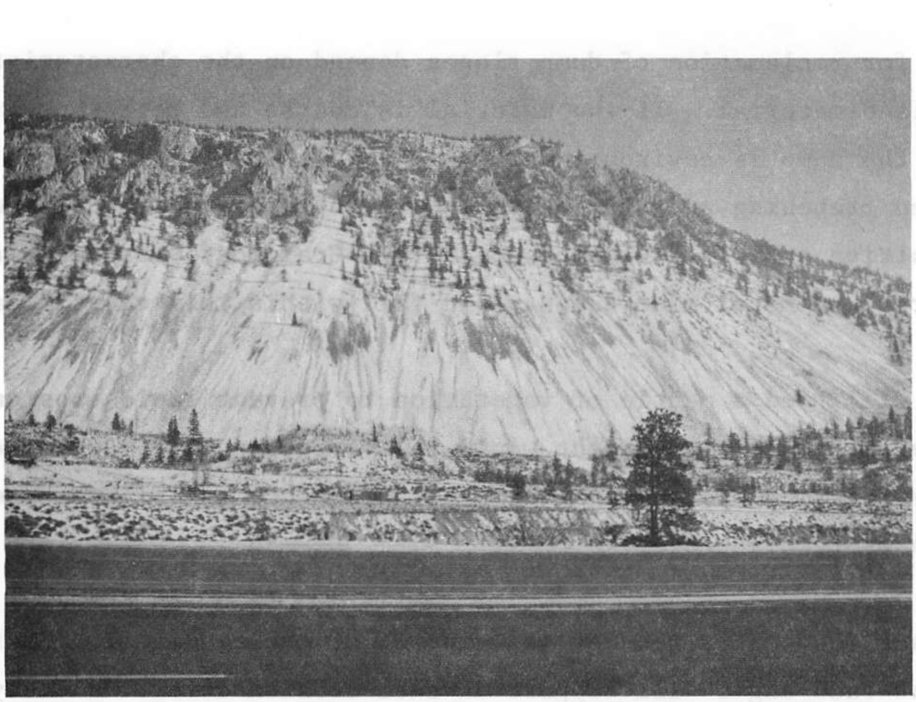


FIGURE 2

NATURAL TALUS SLOPE

STRUCTURE OF MINE DUMPS

Before dealing with the techniques of dump face reclamation, let us examine the form and construction of dumps.

Most open pit mines in B.C. are developed into the side of a hill in a series of benches 30 to 50 feet high. Every effort is made to haul the waste from these benches on level roads in order to avoid the up and down hauls which are generally more expensive than the level haul.

The result of level haul roads is a dump face height roughly equal to the bench height. The dumps so formed may be termed "contour dumps". However, as the mine matures the dumps become higher. When haul distances reach a certain length, attempts are made to find shorter routes. One technique is to dump out into the valley, thus creating a higher dump face. These higher dumps, while more economical to build, are more difficult to reclaim.

RECLAMATION OF DUMP SLOPES

Techniques for reclamation of dump slopes depend on the characteristics of the slope face material. If the material is coarse and resistant to weathering the dump is environmentally safe. Reclamation may be as simple as localized trenching and sloping to ensure that seasonal runoff does not attack sensitive areas. I would suspect that Craigmont, Bethlehem and many small underground metal mine dumps would fall within this classification.

Some dumps will need a mantle of vegetation to prevent rapid erosion. Material requiring this treatment would be overburden, and rapidly eroding sedimentary rock. Dumps in high rainfall areas such as Island Copper may also need a protective cover.

One important economic aspect of reclamation of these dumps is the face angle. What face angle will support an anti-erosion cover? A study of papers presented at previous Symposiums indicates that 26° was the first recommended angle. Milligan and Berdusco of Kaiser reported in their 1977 and 1978 papers that some dumps could be left at 30°. They pointed to the considerable cost savings of the steeper angles. Popowich also commented on dump face angles in his 1978 description of the Fording dumps. He questioned resloping to 26°, "when natural areas in the Fording Valley support vegetation growth on slopes in excess of 30°".

Popowich quotes costs of 1,000 to 5,000 dollars per acre for resloping. Mine developers studying new projects would therefore be wise to determine the degrees of resloping, if any, that is required for their future dumps. At these costs, dump resloping can have an important economic impact on a production decision.

Turning from the coal mines, other operations have shown success in planting at the angle of repose. Jim McCue will describe in his paper tomorrow, the very visible planting carried out at Similkameen. Lornex has several 37° planted test slopes. Bethlehem has made extensive use of steep slope planting with hydroseeding, and the Ministry of Highways has had success at the angle of repose when planting the flanks of fill sections.

Mother Nature gives perhaps the best example of all, illustrating that planting can be successful at the angle of repose. These examples of naturally vegetated talus slopes can be seen throughout the province (Figure 3).

CONCLUSIONS

To conclude this paper I would like to review the main points:

1. The cost of returning most B.C. mining land to the natural state is prohibitive.

2. The primary objective in dump face reclamation should be protection of the environment.

3. Visual impacts of dumps are in the eye of the beholder. Clean rock dumps are comparable to the natural talus slopes that decorate many B.C. valleys.

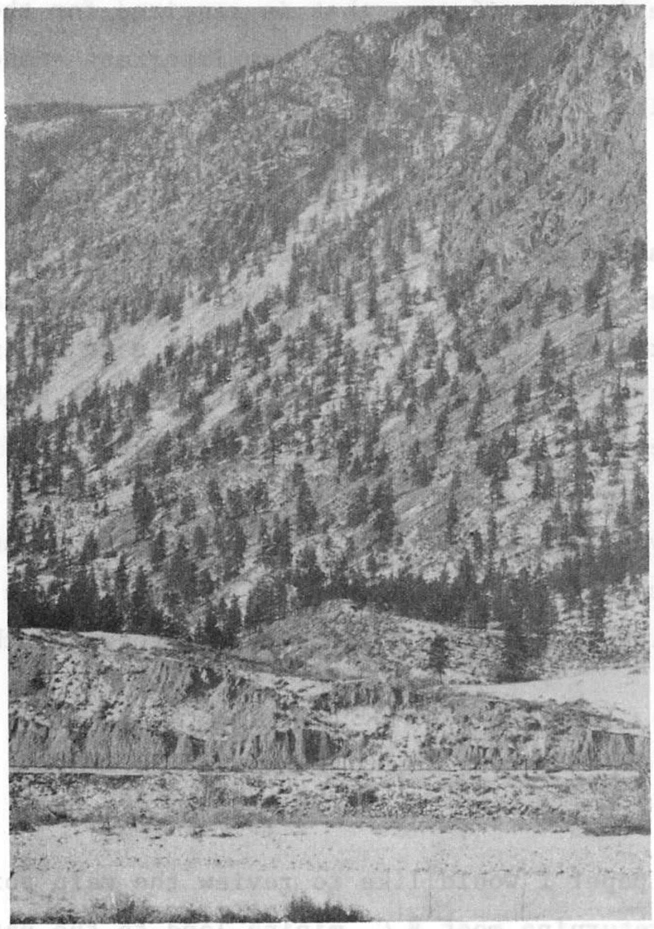


FIGURE 3

NATURALLY VEGETATED SLOPE

AT THE ANGLE OF REPOSE

4. If planting is necessary for environmental protection, the face planting angle depends on the material, climate and dump dimensions. The dump angle need not be as flat as 26° and can often be at the angle of repose.

If reclamation is viewed in this context, society will be able to maintain a common sense balance between a strong mineral based economy and meaningful environmental protection.

DISCUSSION RELATED TO DON GRAHAM'S PAPER

John Dick, B.C. Ministry of the Environment. You have dealt a lot with slope, and of course the most important relationship is between the degree of slope and the slope length. In fact, just about every one of the slopes that you have shown at the angle of repose was less than 100 feet long. Have you done anything to look at the relationship between degree of slope and slope length?

ANS. I know that this question has come up before and we are endeavouring to do some hand seeding on longer slopes at Lornex. I think they were actually seeded last fall so it will be a year before we really know how well they germinate. The only thing I can say, is in relation to some of these natural slopes. You have probably got quite a bit of experience in the coal mines in the south, but in the metal mines we just don't have that much experience, yet.

Dave Poster, Techman Ltd. Regarding your comment on the natural slopes. I studied talus slopes a while ago and found that when vegetation was obtained at the top when the dump material is fine and at the bottom where there is moisture so that it's probably a moisture related thing. In the middle where you have coarse material and where little moisture exists, is where you will have difficulty getting vegetation.

ANS. That would seem to make sense. Certainly there is a segregation due to the gravity, and generally you get the coarser material on the bottom. One of the points in my thesis is that if it's environmentally stable, that is, if the coarse rock isn't breaking down, you don't really have a threat to the environment from a silting aspect.

Neil Duncan, Energy Resources Conservation Boards. In the kinds of things you refer to, you may have some success in establishing vegetation on the benches between the slopes of the natural angle of repose. Have you done any work in that quarter in the hope that the vegetation would establish itself on the bench and then spread upwards and downwards from the benches.

<u>ANS.</u> Well, we have done test work for a number of years on plots on the flat of the dump, but unforutnately these dumps are active and we have had a heck of a time keeping the test plots from being covered over by the next year's operations. So we just haven't been able to get into that aspect. You have raised an interesting point, though, Neil. Of course, if we don't reslope these dumps, and if we could leave them at the angle of repose, then that leaves a substantial flat area. In other words, instead of going for a compromise of a long steep slope, you are left with a very steep slope plus the flat areas and we are hoping that the flat areas will be much more productive. It depends on what your objectives are of course, but if you are interested in producing a productive crop area or forest, I really think you have a much better chance on the flat areas of the dump.

IRRIGATION WITH SEWAGE EFFLUENT ON THE OLD GRANBY TAILINGS AT PRINCETON, B.C.

Paper presented jointly
by:

J.D. McDonald and D.P. Lane
Ministry of Energy, Mines and Petroleum Resources

IRRIGATION WITH SEWAGE EFFLUENT ON THE OLD GRANBY TAILINGS AT PRINCETON, B.C.

INTRODUCTION AND BACKGROUND

During 1978, the Ministry of Energy, Mines and Petroleum Resources obtained funding under the Accelerated Mineral Development Program to revegetate mining areas that were not covered by present reclamation legislation. Under this program, several areas were treated. This talk discusses the program conducted on the old Granby Tailings at Princeton, B.C.

The tailings at Princeton were produced by the Allenby concentrator, which processed the ore mined at Copper Mountain. The mine was active intermittently from 1919 to 1957. The ore mined at Copper Mountain consisted of basaltic and andesitic breccia, which had been intensely altered by biotization, foliation and fracturing. Copper was removed from the ore as a concentrate by crushing and flotation methods. Total production from Copper Mountain was 39,774,902 tons of ore, which produced approximately 1,043,247 tons of concentrate that averaged 33% copper. Approximately 33,731,655 tons of tailings were produced, the majority of which were deposited in the tailings ponds adjacent to Princeton.

The main tailings pond covers approximately 300 acres and was purchased by the Village of Princeton when mining operations terminated at Copper Mountain. Dust from the pond is often a source of irritation to the residents of Princeton during the summer months. This dust nuisance has resulted in many attempts at revegetation during the past twenty years. Treatments over small portions of the pond have included disposal of woodwaste on the surface, surface dressing of a portion of the pond with gravel, planting of trees and seeding of grass. Although most of these treatments met with some success, the funding necessary for an overall reduction of dust has never been available.

In 1960, the Village of Princeton constructed a sewage disposal system which terminates in sewage lagoons located immediately adjacent to the Princeton tailings pond. With the opening of new primary industrial plants in the area since 1960, the population has grown, with consequent increases in input to the Village's sewage system. The larger volume of effluent has decreased the efficiency of the lagoon system and eventually it may reach levels in the future which will not meet pollution control requirements.

Given the foregoing conditions, the Village of Princeton Council realized that proper use of the tailings pond might permit simultaneous abatement of the dust nuisance and provide low cost disposal of sewage lagoon effluent.

In 1976, the Village of Princeton commissioned Shultz International Ltd. to prepare a study on the feasibility of a sewage spray irrigation program on the tailings ponds. The report entitled "Revegetation of the Princeton Tailings Pond Using Sewage Lagoon Effluent for Spray Irrigation, 1976 Pilot Project", proved that:

1. Commercial species of legumes, cereals and grasses can be established as ground cover for control of dust and surface erosion.
2. The sewage lagoon effluent is a good source of irrigation water, but the quality and quantity of effluent are unknown for heavy demands.

With this information, the Ministry began its program to reclaim the tailings pond by engaging the professional services of R.A. Nelson, P. Eng., to design a pumping and irrigation system.

The sewage pumping records for Princeton indicated that the average availability of effluent was about 12,928,000 U.S. gallons per month (or about 300 U.S. gallons per minute). Soil samples of the tailings pond were taken across the field in a diagonal transect to determine the maximum water application rate for irrigation. The samples were sent to the Kelowna Soil Testing Laboratory for analysis.

The results of the soil tests showed that there was considerable variation in surface textures and variable contents of silts and clays in subsoil layers with very fine categories of sands. Tests also indicated a general absence of organic matter.

PROJECT DESIGN

On the basis of soil sample results and sewage effluent availability, 40 acres of the 70-acre lower tailings bench will be supplied with water by the irrigation system. Of these 40 acres, 33 acres are the main portion of the field, 2.5 acres the sloping embankment bordering the sewage lagoons, and 4.4 acres the elbow on the northeast end of the tailings pond. (Figure 1).

Site Preparation

The surface of the tailings pond was levelled with a 966 front-end loader and a grader equipped with front-mounted rippers.

After recontouring, a Ministry of Highways' survey crew surveyed the tailings pond to define the mainline layout and mark the 60-foot set intervals of the irrigation laterals.

Fencing was constructed, where necessary, around the tailings pond area and sewage lagoons, to prevent access by cattle, all terrain vehicles and snow mobiles. The non-irrigated portion of the tailings pond was included in the fenced area to enable future expansion of the irrigation system.

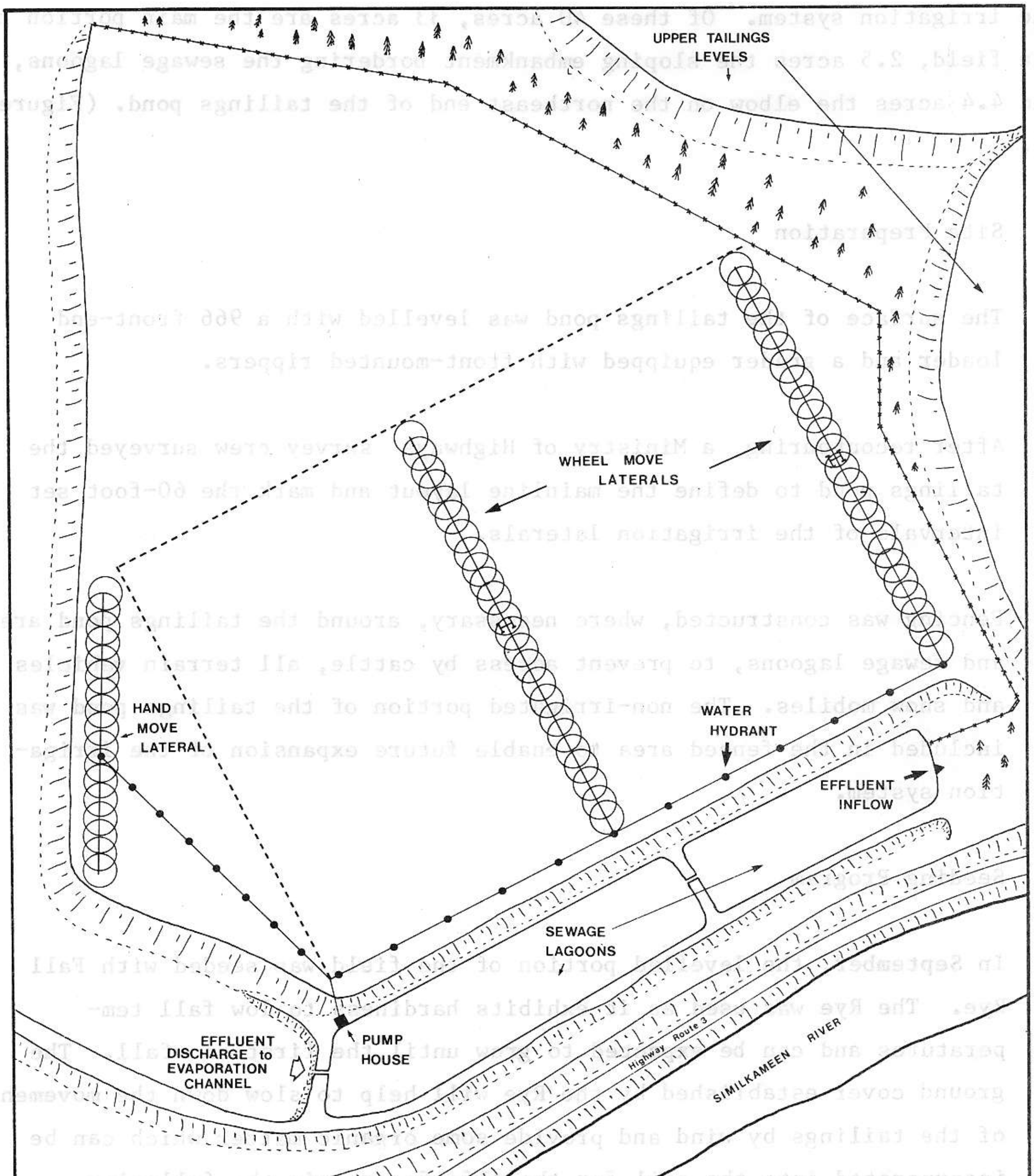
Seeding Program

In September, the levelled portion of the field was seeded with Fall Rye. The Rye was used as it exhibits hardiness to low fall temperatures and can be expected to grow until the first snowfall. The ground cover established by the Rye will help to slow down the movement of the tailings by wind and provide some organic matter which can be incorporated into the soil for the Alfalfa crop in the following spring.

Before seeding the Rye,the field was fertilized with 300 pounds per acre of 13-16-10 and harrowed to a depth of one foot. The fertilizer

FIGURE 1

LAYOUT OF IRRIGATION SYSTEM
PRINCETON RECLAMATION PROJECT



was spread with a 10-foot fertilizer spreader and the field harrowed with a 10-foot vibra-shank cultivator. A 10-foot seed drill was used to seed the Fall Rye at a rate of 50 pounds per acre.

In the spring of 1979, the level area of the tailings pond will be seeded with Vernal Alfalfa at a rate of 30 pounds per acre. An additional fertilizer application will be made with 300 pounds per acre of 13-16-10 and 300 pounds per acre of 11-48-0.

In late September, the sloping embankment bordering the sewage lagoons was fertilized with 300 pounds per acre of 13-16-10 and seeded with 30 pounds per acre of the following seed mix:

Species	% of mix by weight
Creeping Red Fescue	20
Crested Wheatgrass	50
Drylander Alfalfa	15
Sainfoin	7
Sweet Clover	8

Both the seed and the fertilizer were spread, using a broadcasting unit mounted on the back of a tractor.

IRRIGATION SYSTEM

The main portion of the field will be irrigated with two 980-foot wheel-move lateral sprinkler systems, each with 24 5/32 inch x 3/32 inch sprinklers on a 40 foot x 60 foot spacing (Figure 1). The elbow on the northeast end of the tailings pond will be irrigated with a 640 foot hand-move lateral with 17 3/16 inch x 1/8 inch sprinklers mounted on 18-inch risers on a 40 foot x 60 foot spacing. The hand-move lateral is variable in length, due to the triangular shape of the elbow.

Irrigation on the sloping embankment bordering the sewage lagoons will be applied through a fixed system of twenty-four 75 foot x 3/4 inch diameter plastic pipes, each with two Rainbird #20 x 7.64 inch sprinklers mounted on stands with a sprinkler spacing of 40 foot x 60 foot. Water is supplied by one-inch gate valves that are attached to the hydrants supplying the wheel-move laterals.

The sewage effluent is pumped by a 25 horsepower vertical turbine with a pumping capacity of 300 U.S. gallons per minute. The water mainline is made from 20-foot sections of 6 inch diameter lightweight steel pipe coupled with victaulic fittings. Hydrants are spaced every 120 feet along the mainline supplying the wheel-move laterals and every 80 feet along the mainline supplying the hand-move lateral (Figure 1). The hydrants for the wheel-move laterals serve two successive settings through a 30-foot length of aluminum pipe and a 6-foot length of high pressure flex hose. The hand-move lateral has a centre connection to the hydrants which serve a single setting.

The pumping system has been designed for daily non-supervised pumping. There is a low pressure cut-out switch to prevent bank erosion by mainline pipe breaks, a high pressure cut-out switch to protect the motor from overloads arising from human error, and a liquid level regulator to prevent water from dropping to a level, in the lagoon, which could lower the effluent retention time to less than 30 days.

PROJECT COSTS

The total expenditure for the Princeton Reclamation Project was 52,000 dollars, creating a total of 1340 man-hours of employment. The cost per acre for the project was 1,300 dollars.

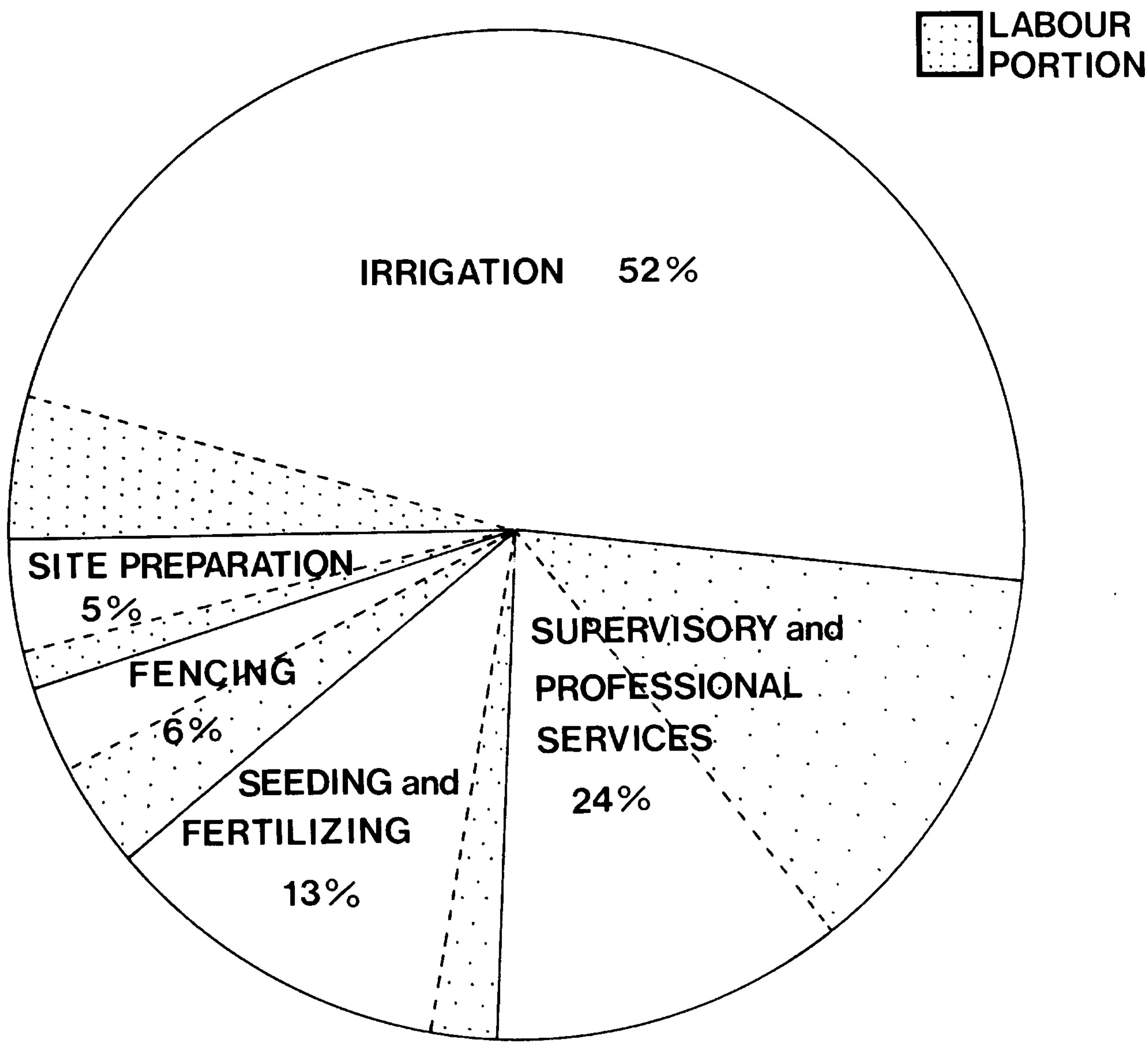
The largest portion of the cost is represented by irrigation which was 52% of the total (Figure 2). The rest of the cost was divided as follows: supervisory and professional services - 24%, seeding and fertilizing - 13%, fencing - 6%, and site preparation - 5%. The labour portion of each category represents a much smaller fraction of the cost than materials (Table 1).

OPERATIONAL ECONOMICS

The Ministry of Energy, Mines and Petroleum Resources will be signing ownership of the irrigation system over to the Village of Princeton, who have decided to lease the field to a local rancher. The rancher will be responsible for the care and harvesting of the crop. The Village will pay

FIGURE 2

COST BREAKDOWN OF B.C. M.E.M.P.R. RECLAMATION PROJECT ON THE PRINCETON TAILINGS POND.



power and maintenance and recover these costs by charging the rancher a fee on a per-ton-of-hay-produced basis.

The power cost per year for the irrigation system has been estimated at 800 dollars. The maintenance cost may run as high as 1,100 dollars per year. Total yearly production of hay should be about 110 tons when the field becomes established. Using these figures, the Village of Princeton would charge 20 dollars per ton of hay.

Future expansion of the irrigation system on the tailings pond may be possible as the soil conditions in the irrigated area improve.

DISCUSSIONS RELATED TO D.P. LANE AND J.D. McDONALDS' PAPER

Garth Mayhew, University of Victoria. Could you explain a little more about the kind of effluent that is being used. Are you putting on raw sewage at Princeton or are you taking effluent from the treatment centre.

ANS. Well, Princeton doesn't have a treatment plant. They have an old type of system that was used by a lot of small towns starting in the 1960's. It is just a system of two lagoons that are essentailly settling ponds. The volume is worked out so that it takes about 30 days for water coming in at the inlet to get to the outlet and then into the evaporation channels. I might add that this type of lagoon system is rather old fashioned and I don't think they are permitted anymore. We are just taking water straight out of the lagoons.

Dave Polster, Techman Ltd. What about heavy metal content in the effluent. I seem to recall reading that that might be a problem in the future.

ANS. That's right. There is no industrial effluent in the sewage lagoon, the effluent is strictly municipal. The system is set up and will be in operation, so we are going to have to test the vegetation over time to find out if there will be any future ill effects from heavy metal contamination.

Ross McDonald, University of Victoria. Can you tell me something about the bacteria counts.

ANS. Vernon has a large sewage irrigation project, and we discussed this with them. They assured us that there would be very little to worry about in terms of diseases when people handled the equipment. As a matter of fact, they said that they have found that personnel who presently handle the sewage equipment are much healthier than those who don't.

Tony Schori, Techman Ltd. Maybe there is no problem with sewage but what about contamination from the tailings. Is there any problem there in utilizing the Alfalfa grown for cattle feed. Has that been looked into. Generally when sewage is used it is put on natural soils.

ANS. Right. No, we didn't examine that but, once again, will look at that when we test the vegetation. You must remember that the tailings are quite old. They have been around now since 1957, and we hope that there has been enough time to wash out the heavy metals.

Terry Rollerson, University of British Columbia. Did you do any analysis on these soils to test for the metal content.

ANS. No, we only did an analysis for growth potential. The system was going to go ahead anyhow and it was considered to be an added benefit if the Alfalfa could be used for a crop. As I mentioned before, there are three things involved: dust, getting rid of the sewage effluent, and producing a crop.

Terry Rollerson, University of British Columbia. What about the heavy metals.

ANS. Well, the tailings pond is not being used right now and it does present really bad dust nuisance. If you have ever driven through Princeton in the summer time when there is a heavy wind, it is like going through a snow storm. So even if all that is accomplished is getting rid of the dust problem and the sewage effluent, then our project has done its job.

John Railton, Calgary Power Ltd. Could you tell me about the parameters you used to measure growth potential, also what was the pH of your tailings material. If the pH was too high, it wouldn't leach out the heavy metals, and they would remain intact at higher alkaline pH's.

ANS. I don't remember exactly what the pH readings were, but I remember there were no severe restrictions from the soil analysis results, except for the lack of organic matter and of course water retention.

Stan Weston, Wesago. We have done some work on tailings of the new operations in that area. They are highly basic, and some run up to pH 8.7. We did run pH's on the Old Granby tailings pond in 1970 and we tested the sewage material. We were given a figure for a typical sewage outflow material of 45 parts per million of nitrogen and 25 parts per million of phosphate, and that is indicative of what we were looking at in 1970, but the tailings pond didn't belong to the mine at that time. It sounds like the Ministry of Mines has carried out an excellent program.

EXPERIMENTS IN TAILINGS RECLAMATION AT GRANISLE COPPER

Paper prepared jointly
by:

W.F.B. Tripp
and
J.R. Chalmers

Zapata Granby

EXPERIMENTS IN TAILINGS RECLAMATION AT GRANISLE COPPER

INTRODUCTION

Zapata Granby Corporation's Granisle Copper Division is located in North Central British Columbia. The property itself is located on McDonald Island in Babine Lake, which is the largest natural lake in the province. All traffic to and from the island is by means of a 1 1/3 mile barge crossing.

The mine began production in 1966. At present we are mining at a budgeted tonnage of 50,000 tons per day, processing 14,000 tons of ore per day. The porphyry ore deposit is low grade with the present cut-off grade at 0.20% Cu. The tailings disposal system is rather unique in that the tailings are dumped into a portion of the lake that has been totally enclosed by dams constructed of pit waste rock and cycloned sands.

The tailings sands on the dormant No. 1 pond range from medium to very fine in soil texture with an average pH of 8.1, potassium 179 pounds per acre, phosphorus 4.3 pounds per acre, and nitrogen 1.4 pounds per acre.

RECLAMATION PROGRAMS

Our tailings reclamation objectives to date have been mainly of an experimental nature with the transplanting of native species common to the area.

In 1977, an eleven acre area was transplanted with Common Horsetail on a staggered 50 foot x 50 foot pattern. The clumps of Horsetail used for the program were obtained from a nearby area of natural growth in soil similar in composition to the tailings pond. In October of 1977, three areas of natural invasion of Horsetail on the southern end of the tailings pond were staked out to monitor their growth rate. In the late spring of 1978, it was found that the circular patches of Horsetail had spread about two feet. This increase in the diameter represents an increase of approximately 21%. This along with the 95% success we realized from the 1977 transplanting led to the transplanting of the balance of the pond as part of the 1978 program.

Also as part of the 1978 program, we established seven test plots where various native species were transplanted. The species tested were:

Fireweed (*Epilobium angustifolium*)
Thimbleberry (*Rubus parviflorus*)
Common Wild Roses (*Rosa spp*)
Red Raspberry (*Rubus idaeus*)
Solomons Seal (*Similacina amplexicaulis*)
Flat Top Spirea (*Spiraea lucida*)
Purple and White Pea (*Lathyrus nevadensis*)
Lodgepole Pine (*Pinus contorta latifolia*)
Black Spruce (*Picea mariana*)
Northern Black Cottonwood (*Populus trichocarpa*)

Each test plot was halved with one half being lightly fertilized with 34-0-0 chemical fertilizer. The monitoring of these test plots and success ratios will be an integral part of the 1979 Reclamation Program.

At the suggestion of the Reclamation Branch of the B.C. Ministry of Energy, Mines and Petroleum Resources, three test plots were established on the south side of the No. 1 pond. The plots were treated with 34-0-0 fertilizer at various rates of concentration.

The Reclamation Branch felt that the fertilization alone would enhance the natural invasion of indigenous species. The plots were therefore located in the vicinity of the previously reclaimed No. 1 dam face.

The major thrust of the tailing portion of the 1978 program was the seeding of the No. 1 pond.

This aspect of our program, although experimental in nature, could provide Granisle with a successful basic formula for future work on the No. 2 and No. 3 tailings impoundments.

Prior to the actual seeding of the pond, an attempt was made to scarify the surface. A John Deere 410 backhoe was used to drag a custom made scarifier over the sands. The attempt was considered unsuccessful due to the fact that the machine was too heavy to negotiate the extremely fine textured, dry tailings. Consequently, the majority of the 28 acres was hand-raked before seeding.

Richardsons' "R.S. Tailings Pond Mix" was chosen for the pond seed mixture. The mixture breakdown was as follows:

Creeping Red Fescue 20%	Sweet Clover 10%
Alfalfa Blend 10%	Birdsfoot Trefoil 5%
Crested Wheatgrass 10%	Canada Bluegrass 5%
Orchardgrass 10%	Redtop 5%
Slender Wheatgrass 10%	Tall Wheatgrass 5%
Smooth Bromegrass 10%	

In early October, four wedges were cut from a fallen Cottonwood. These wedges had sprouts growing from them ranging from 18 to 30 inches in length. The wedges were soaked in water for two days and planted approximately 8 to 10 inches deep and about 15 feet apart in the No. 1 pond.

The rapid decaying of the water-soaked wedges should hopefully provide the sprouts with sufficient nutrients to sustain initial growth.

As a result of the unusually hot, dry summer experienced throughout most of the province, an attempt was made to irrigate the No. 1 pond. A 2 1/2 inch plastic line was tapped into our mill reclaim water supply and run to the edge of the pond (approximately 100 yards). At this point the line was reduced to a 1 inch diameter perforated plastic line that ran approximately 375 yards out onto the pond. Due to low head and friction losses, the system was ineffective after the first 200-300 feet.

FUTURE RECLAMATION PLANS

Our 1979 reclamation program for the No. 1 tailings pond hinges a great deal on the success of last years' transplanting. Hopefully some of the native species will indicate a reasonable survival rate warranting further transplanting, as was the case for the Horsetail transplanting. Also for the upcoming season, plans have been made for more test plots on the No. 1 pond. These plots will be seeded with a variety of legumes and fertilized at various concentrations.

The area on the west side of the pond that was seeded and fertilized in 1972 will be harrowed, re-seeded and fertilized. It is felt that turning under the existing sod would hasten the natural decaying process and provide a more desireable base for a new crop of legumes.

CONCLUDING STATEMENT

At the time when the public is taking a more serious interest in the environment, we as industry are being put in the spotlight more and more. I would like to think that through Symposiums such as this one and through concentrated efforts in the field, that mining will set the standards for industry in surface reclamation.

DISCUSSION RELATED TO BARRY TRIP AND J.R. CHALMERS' PAPER

Ben van Drimmelen, Ministry of the Environment. I was wondering about the use of these native transplants. Are you looking for a species that will grow on a tailings pond.

ANS. Yes, during the last year's program the idea was to encourage the native species for the tailings area.

Dave Polster, Techman Ltd. Have you any ideas of what the cost effectiveness is of transplanting onto the tailings on that sort of scale.

ANS. No. Not really. I'm sorry I haven't got any figures on that.

WORKSHOP SUMMARIES

RECLAMATION OF EXPLORATION DISTURBANCES AND METAL MINE WASTES - PART I

Thursday, March 8, 1979

Following completion of the first two Technical Sessions of the Symposium, participants entered into workshop groups to debate a series of workshop questions. This section of the Symposium Proceedings summarizes their findings.

WORKSHOP - THURSDAY MORNING

Discussion topics should consider environmental protection and reclamation of exploration disturbances and reclamation of metal mine wastes. Please feel free to discuss any topic of interest. The following four questions should initiate discussion:

ARE PRESENT REGULATIONS GOVERNING COAL AND MINERAL EXPLORATION TOO STRICT OR TOO LAX?

TO WHAT LEVEL SHOULD GOVERNMENT DICTATE THE TYPE OF EXPLORATION TECHNIQUE?

WHAT DO YOU FEEL ARE THE MAJOR ENVIRONMENTAL PROBLEMS ASSOCIATED WITH EXPLORATION?

WHAT SHOULD BE CONSIDERED IN DEVELOPING STANDARDS FOR RECLAMATION OF METAL MINE WASTES?

WORKSHOP 1

QUESTION 1 - ARE PRESENT REGULATIONS GOVERNING COAL AND MINERAL EXPLORATION TOO STRICT OR TOO LAX.

Findings Related to Question 1

- Government guidelines should be flexible to accommodate site-specific needs, so the guidelines should remain guidelines and not become regulations.

- Government at the management level should dictate objectives and policy, however, on-site reclamation must be site-specific.

- Regulations should remain flexible at this stage of development, as the industry is still in the process of learning how to deal with reclamation problems.

- The relationship between government and industry should not be antagonistic, rather, government should set broad expectations and provide general information and guidance. Industry must be unhindered in developing its own solutions to specific reclamation problems. Guidelines must be flexible to allow this.

- Present requirements for reclamation "to the satisfaction of the Minister" probably are better than standardized regulations, since this allows for site-specific interpretation.

- Guidelines must allow for site-specific interpretations.

- Too many government agencies are involved. Government policy should be determined by dealing with one agency.

- Present regulations are generally reasonable and flexible, and therefore are acceptable.

- Individual reclamation proposals should become an agreement between the company and the government.

- Problems vary between different types of mines (i.e. - coal and metal). This should be recognized by government.

QUESTION 2 - TO WHAT LEVEL SHOULD GOVERNMENT DICTATE THE TYPE OF EXPLORATION TECHNIQUE

Findings Related to Question 2

- Government should specify goals of reclamation rather than techniques. This encourages company initiative.

- Stress importance of pre-exploration planning to avoid sensitive areas.

- Exploration reclamation should reflect levels of potential land use.

QUESTION 3 - WHAT DO YOU FEEL ARE THE MAJOR ENVIRONMENTAL PROBLEMS ASSOCIATED WITH EXPLORATION

Findings Related to Question 3

- Wildlife problems associated with access. These areas could be closed to hunting without closing them to the public.

- Dump face stability.

- Minimize the area used, so as to minimize disturbance.

- Maintaining high water quality against pollution, siltation, etc.

QUESTION 4 - WHAT SHOULD BE CONSIDERED IN DEVELOPING STANDARDS FOR RECLAMATION OF METAL MINE WASTES

Findings Related to Question 4

- The potential future use (i.e. - reprocessing) of "waste" materials must be considered before the reclamation plan is finalized. A balance must be found between total reclamation and leaving an area completely open.

- Acid drainage from tailings waste dumps must be considered in reclamation.

- Chemical stabilizers should be studied more for use in neutralizing tailings.

- If toxic metal concentrations build up in plants grown on tailings, tests with unpalatable species should be tried.

OTHER FINDINGS

Uniform Standards

- Uniform reclamation standards should be applied to all resource users and industries.

- Other industries and agencies disturbing the land surface should be subject to similar reclamation regulations as the mining industry.

- Mining access roads should be treated like other access roads (e.g. forestry), and used as emergency access roads.

- The Forest Industry and B.C. Hydro should be responsible for the damage done to the environment.

Information and Research

- A centralization of research developments in reclamation is required, to eliminate duplication of effort.

- A need exists for dissemination of information by government and industry. This information must be updated yearly.

- Methods and results of experiments, tests, and actual reclamation are not recorded accurately enough or in enough detail.

- Government should provide information to industry on reclamation practices.

Pre-legislation Sites

- All old mine shafts should be sealed for public safety, however, the sites should be left for natural revegetation.

- Government funds should be used for reclamation of abandoned mine sites.

- Industry and government should both contribute to a fund for reclamation of pre-legislation sites.

- Industry should be taxed to help pay for reclamation of old mine sites.

Communication, Government-Industry-Public

- Communication between government and mine operators is improving daily, which is a positive thing.

- The government and industry interaction is fairly clear now. Public involvement and education is now of greater importance.

- Public input into guidelines should be encouraged by government agencies.

- The public areas around mines should be notified of the mines intended operations and plans.

- It is important for industry to inform the public of reclamation technology and successes. Positive information about reclamation activities should be conveyed to the public.

Helicopter Supported Drilling

- Should be encouraged where applicable.

Miscellaneous Topics

- Economics will ultimately dictate final land use, which may or may not correspond to the original land use. The land should be made productive, but only if it is economically feasible.

- Proper planning for long-term use is essential, so the long-term use must be determined early in the planning stages.

- Short-term goals in both exploration and production phases are primarily of an environmental protection nature.

- The long-term reclamation goals (for post-operational phase) are primarily protection of the environment and transformation of the land to some predetermined use.

- Long-term stability of dump faces is of paramount importance in long-term planning.

- Public access should be restricted on access roads. The development company should be responsible for any damage caused by the increased access.

- Sewage effluent irrigation is good if a source of effluent is readily available.

RECLAMATION OF METAL MINE WASTES - PART 2

Chairman of the Afternoon Session

Thursday, March 8, 1979

B. Burge

Sage Creek Coal Ltd.

GOVERNMENT FUNDED RECLAMATION PROGRAM ON PRE-LEGISLATION TAILINGS PONDS

Paper presented

by:

A.L. O'Bryan

B.C. Ministry of Energy, Mines and Petroleum Resources

GOVERNMENT FUNDED RECLAMATION PROGRAM ON PRE-LEGISLATION TAILINGS PONDS

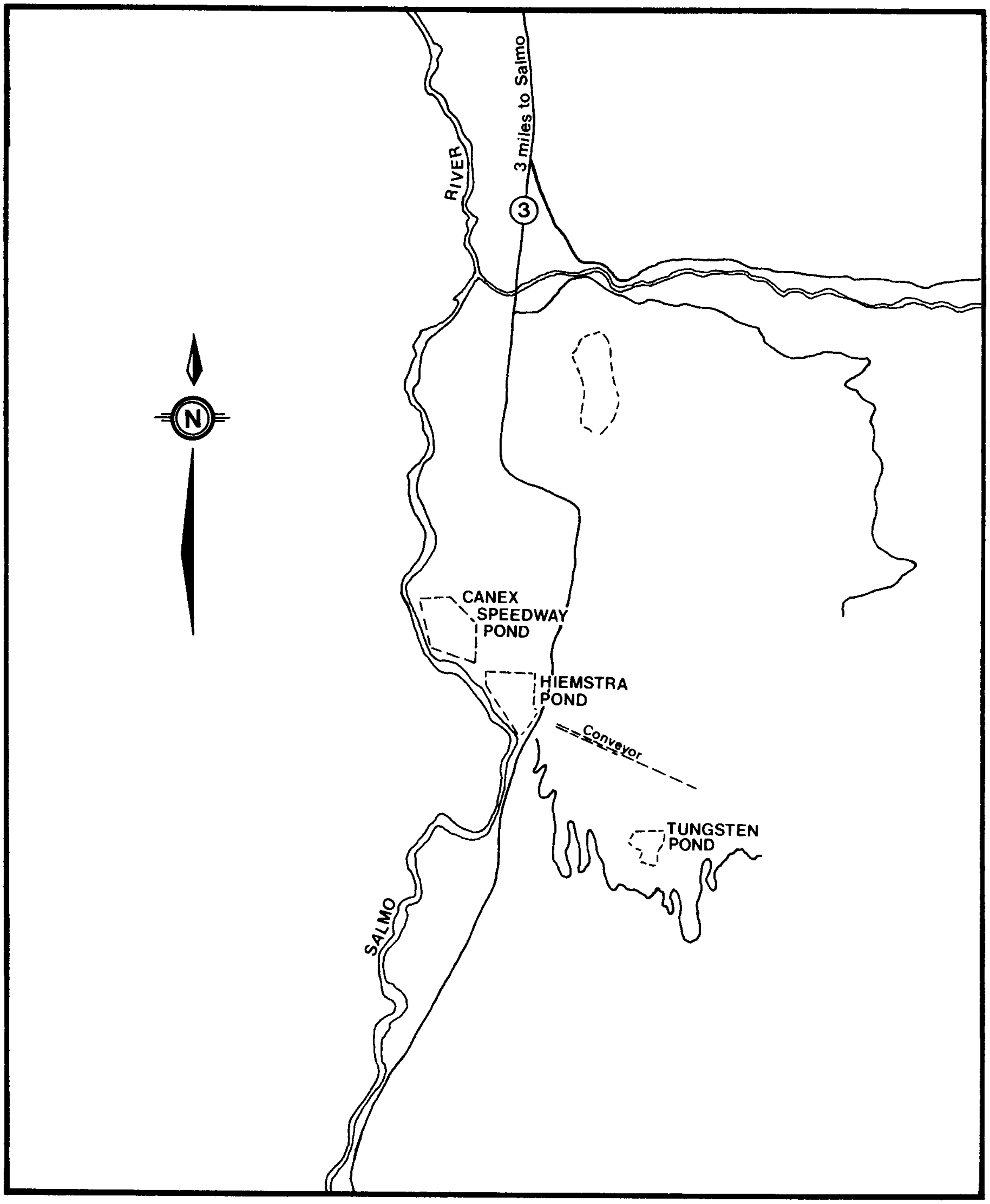
INTRODUCTION

Not until 1969 did public reaction against possible damage of the wilderness areas bring about provincial regulations for reclamation, specifically Section 8 of the Coal Mines Regulation Act and Section 11 of the Mines Regulation Act. Disturbances in existence before this date were not covered and generally remain unreclaimed. In 1978, the provincial government, through the Ministry of Energy, Mines and Petroleum Resources, established a fund to finance the reclamation of pre-legislation tailings ponds. The overall aim of this Government program is to provide financial assistance in order to return the disturbed areas to a state of use and appearance that will be compatible with the surrounding areas. In 1978, the Ministry of Energy, Mines and Petroleum Resources inititated programs on tailings ponds at Princeton (see paper by Lane and McDonald), Phoenix and at Salmo. This paper discusses work undertaken on three tailings ponds near Salmo, B.C.

EMERALD MINE TAILING IMPOUNDMENTS

The Emerald Mine began production in 1906 and was in operation sporadically until 1972. Originally lead and zinc ores were mined, but in 1942 it began production of tungsten. The workings over the years left behind three tailing impoundments of various sizes, most of which were pre-legislation. These ponds, known as the Salmo Tailings ponds are situated on and at the foot of Iron Mountain at Latitude 49°N. and Longtitude 117°W. (Figure 1). The ponds are named Tungsten Pond, Hiemstra Pond, and the Canax Speedway Pond, and all three are subjected to the climatic conditions in the area, which are typical of the Southeastern Interior. The frost-free period is only 71 days with an extreme minimum temperature of -35°C and an extreme maximum of 42°C. Annual precipitation averages 25 inches (63 centimetres) with approximately one-third falling as snow.

FIGURE 1
LOCATION OF TAILING PONDS IN THE SALMO AREA



Soil Analysis

From the soil analysis report undertaken during the initial reclamation survey, it was determined that the average pH of the three pond areas was 7.5 and that the material was extremely deficient in nitrogen, phosphorus and potassium, with phosphorus as the main limiting mineral nutrient in all samples examined. The tailings material is easily eroded by wind and water, but was found to have fair to good moisture retention. It was also felt that once vegetation is established on the tailings, the moisture retention will increase, permitting the plants to survive on natural precipitation.

Previous Reclamation Program, 1973

Two of the three tailings ponds were seeded and fertilized in 1973. The Tungsten Pond was broadcast seeded and harrowed and the Hiemstra Pond was seeded and fertilized by aerial means. No reclamation work was done on the Canax Speedway Pond. A local farmer has built a house and has planted a large lawn and garden on the Hiemstra Pond. Mr. Hiemstra claims that he built the soil up by mulching and working the ground as only a farmer can do, and that commercial fertilizer was used. During the initial aerial seeding of the Hiemstra tailing pond, much of the seed was lost due to a combination of hard ground surface and surface wind. However, some seed remained and germinated which resulted in approximately 30% of the pond being covered with excellent vegetation. This is the area in which we will use the "green manure" approach, to build up humus and nutrients in the tailings.

RECLAMATION PLANNING AND METHODS

After a visit to the sites in the summer of 1978 with Mr. Lloyd Gavelin, of Craigmont Mines and Mr. George Efanoff, long time Placer employee, it was decided to carry out a general clean up of the three ponds.

The first step involved the removal of all old lumber and trestles as well as the standing dead trees. This rubbish was then piled and burned.

Step number two was the grading and shaping of the pond surfaces in order to make the land usable for all types of equipment in the future. This was a problem when our first try, which employed a grader, ended in failure. The grader was unable to operate on the loose tailings and in the moist areas in the centre of the ponds. Next we tried a 450 John Deere Crawler Tractor with a hydraulic blade and were more successful. It was fast and we had little difficulty in smoothing out the irregularities.

Step number three was to mark out the area in one-acre plots and apply fertilizer with a hand-operated cyclone spreader. The fertilizer, 13-16-10, was applied at a rate of 300 pounds per acre. A six-acre area was fertilized using 70 pounds of nitrogen, 200 pounds of phosphorus and 30 pounds of potassium per acre. The fertilizer was then worked down into the tailings to a depth of 8 to 10 inches, or in some areas as deep as possible. For this we used a two-way agricultural disc, pulled by the John Deere 450. This worked very well except for the area that had the excellent vegetation cover. On this area we had hoped to use the "green manure" approach, in order to, build up humus and nutrients in the tailings to a point where vegetation would be self sustaining. This area should have been deep plowed, but when a plow was not available, we disced the fertilizer and vegetation into the ground by going over the area as many as four times.

The ponds were then harrowed with a light spike-tooth harrow, pulled by a small rubber-tired tractor. The harrowing left the ground in a fairly smooth condition which made it easy to walk on when seeding, but the most important part was that little trenches about 1 - 1-1/2 inches deep were formed. Seed was applied by the use of hand-operated Cyclone Seeders. The rate of application was 40 pounds per acre and was a customer-specified mix, with all legumes inoculated.

Crested Wheatgrass	-	15%
Creeping Red Fescue	-	15%
Orchardgrass	-	15%

Smooth Bromegrass	-	15%
Alfalfa	-	15%
Sainfoin	-	15%
Alsike	-	10%

The entire area was then floated using the harrows in the inverted position. This left the seed with approximately 1 to 1-1/2 inches of cover.

1979 PROGRAM

In the spring, as soon as work is possible on the tailings ponds, 100 pounds per acre of 21-0-0 fertilizer will be applied to the entire 70 acres. It is anticipated that adequate self-sustaining growth will be established in 4 - 5 years.

During the previous programs, no reclamation was undertaken on the tailings dam benches; however, if funds are available, reforestation of these areas could be undertaken successfully considering the excellent natural revegetation of Poplar and Cottonwood on the surrounding area.

COSTS OF THE RECLAMATION PROGRAM

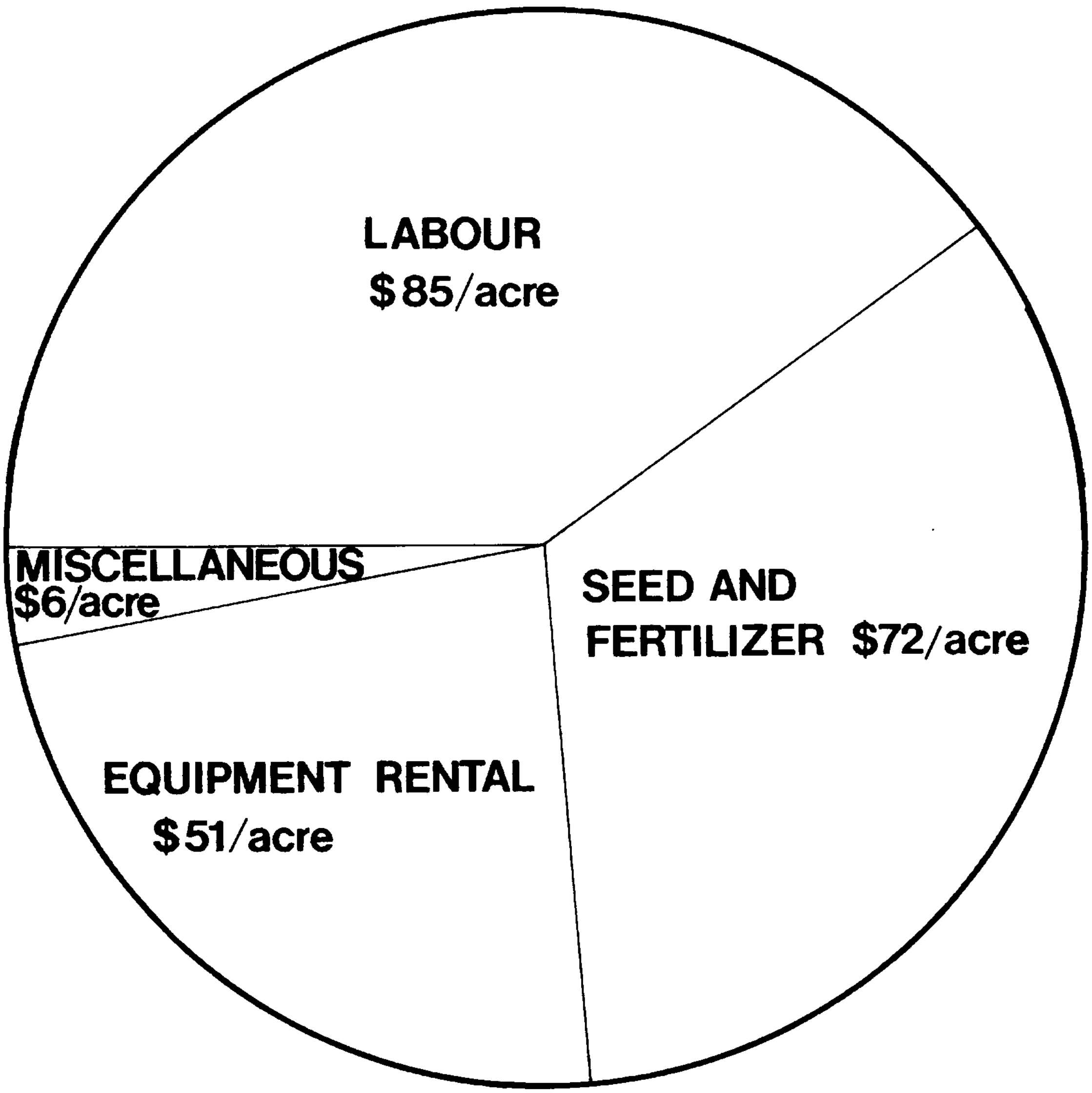
Total costs for the site general clean up, conditioning of the tailings, seed, fertilizer and equipment rental can be broken down as follows:

Labour - 775 manhours @	$85.00	per	acre.
Equipment Rental	51.00	"	"
Seed and Fertilizer	72.00	"	"
Miscellaneous Expenses	6.00	"	"
Total	$214.00		

Total cost for 63 acres of level ground and 7 acres of sloped ground including some recontouring, amounted to 214 dollars per acre and Figure 2 shows the proportions of expenditure in relation to total costs, and Table 1 provides a more detailed analysis of costs on an acre and hectare basis.

FIGURE 2

COST BREAKDOWN OF B.C. M.E.M.P.R. REVEGETATION PROGRAM ON THE SALMO TAILINGS POND



TOTAL COST - $214/acre

TABLE 1

DETAILED BREAKDOWN OF COSTS ON 70 ACRES OF THE SALMO TAILINGS POND RECLAMATION PROGRAM

LABOUR

773.5 manhours at 8.16 dollars (average) per hour
= 85.27 dollars per acre (35.53 dollars per hectare)

EQUIPMENT RENTAL

Half-ton pick up	2 weeks
J.D. 450 tractor (Cat)	141.5 hours
Massey Harris tractor	94.0 hours
Harrows	70.0 hours
Disc (two-way)	70.0 hours

Total rental: 3,572.37 dollars = 51.03 dollars per acre (21.26 dollars per hectare)

SEED AND FERTILIZER

Seed	2,744.00 dollars
Fertilizer	2,308.07 dollars
Total	5,152.07 dollars

= 72.17 dollars per acre (30.07 dollars per hectare)

MISCELLANEOUS EXPENSES

Freight charges	308.20 dollars
Supplies and material	123.98 dollars
Total	432.18 dollars

= 6.17 dollars per acre (2.57 dollars per hectare)

CONCLUSIONS

The 1979 follow-up work will include fertilization in the spring, and a program to evaluate vegetation growth with respect to plant species will be started.

It has been my experience that the first attempt at a project is most difficult, if one has no significant previous experience but wishes to do a good job. Reclamation, however, is a long-term proposition and time is the essential element in determining our success or failure.

DISCUSSION RELATED TO ART O'BRYAN'S PAPER

Stan Weston, Wesago. Mr. Chairman, I would like to correct a few things. In 1969 I seeded the Tungsten pond. Nothing further was done there, but tailings were dumped on top of this area when the mine started up again. I don't know what happened after the three years that I had worked there. The No. 1 pond was seeded and fertilized at that time and was not covered up. We tried to use hand seeders but they did not work. We used aircraft, and the seed did not blow away. It seems that you are inventing the wheel, because you are going backwards and ending up with the bucket method. My concern from the industry point of view is that your techniques are somewhat expensive. I am sure that the results that you get will not improve over what we did at the start. The problems you have had are well known, so I don't know if the intent was just to spend money. If you are spending money and putting it"down the drain", you should be accountable for it, and I don't think you are under this program.

ANS. Well, I hope that we would be Stan. We are all learning and part of the problem that has developed is that some of the previous work that has been done wasn't correctly documented. The area had had some work done on it before and we were just continuing along those lines. Allan Lamb, I believe, did some work for Placer on the Tungsten Pond after you. I wasn't aware that you had done any work in 1969, Stan, but then as you stated nothing had been done on the Number 2 Pond, which I now call the Canex Speedway Pond. That's originally where we started, and we just expanded to the other two ponds to try and enhance them. We hope to keep the 30% vegetative cover on the No. 1 pond going. After talking to the farmer who had been doing a lot of little farming methods there such as going out in the fall to spread the seed and trying to keep growth going, we just hope that in the end this money wasn't wasted.

Jake McDonald, Ministry of Energy, Mines and Petroleum Resources. This is not a question, Mr. Chairman, but I would like to make an overview of this program. The money was spent on these tailing ponds which are pre-legislation. At that time, some of the ponds had no vegetation. It was our mandate as the Ministry of Mines to go in and try to revegetate these ponds for a useful purpose. The method which we chose is a relatively cheap one and it creates employment. We, as a Ministry, are not saying this is the total answer but we have done this and we hope to get some answers to many of the problems. I think that it's a step in the right direction and, that in the next couple of years, we are going to derive a lot of answers and we hope that this will continue and benefit the mining industry.

ANS. Thank you Jake. Just one other point, we did use more modern methods on the 45-acre Tremblay pond near Grand Forks at the Phoenix mine. We used more up-to-date methods because the equipment was available. But during the Emeralds Mine project the equipment was not available and we wanted to create some employment as well as get some results.

Stan Weston, Wesago. Well, Mr. Chairman, let me make one point in regards to the remarks made by Jake (McDonald), who talked about the program being cheap. Now, I don't know what is being paid to the help that is used, but to the mining companies, (I think this is true and the people here can verify it) the cost of a labourer in the field is going to be something like 100 dollars a day, and that is a fairly recent figure. Now that gets to be quite expensive. In addition, as soon as you put a piece of equipment--ground rig equipment--onto this type of land your costs of reclamation are going to go up from maybe a few hundred dollars to a few thousand dollars. That's about what's happening today, what the costs will be a little further down the line should make interesting comparison. So I am concerned with what I have heard on the tailings pond here and at the tailings pond near Princeton. We have worked on the tailings pond and we feel we have the answers, furthermore, the Department has actually inspected it and yet there is no reference to the work that has been done. I thought that these reports were filed in Victoria and were available. I am rather surprised that they were not available to you and that I would have been asked about it, because if we could have been helpful we certainly would have been glad to have been so.

ANS. Thank you. Any further questions.

<u>John Dick, Ministry of the Environment.</u> I have looked at quite a few projects around the province where techniques varying from broadcast seeding to seeding with harrowing, and aircraft seeding have been used; and I say my experience is that in good conditions, broadcast seeding gives equally good results as seeding with harrowing. When the conditions become more adverse, for a given level of results, you have got to go to the more expensive methods. You may have to broadcast three or four times to get a given level of ground cover and you may only have to seed once to the same level of ground cover by seeding with harrowing. As long as we talk only about the techniques, the cost of techniques without relating those to a given level of results, our discussions are meaningless.

RECLAMATION AT NEWMONT MINES, PRINCETON, B.C.

Paper presented

by:

J. McCue

Newmont Mines Ltd.

RECLAMATION AT NEWMONT MINES, PRINCETON, B.C.

INTRODUCTION AND BACKGROUND

Mining commenced at the Newmont property near Princeton, in December, 1970, in the Ingerbelle pit, with the first concentrate production in early 1972. Present planning foresees production until the late 1990's.

For open pit mining, disturbance of the original surface is necessary to extract the metallic content of the ore body. To date, at Newmont's Ingerbelle pit, about 1.8 pounds (0.8 kilogram) of copper have been recovered for every ton (0.9 tonnes) of rock removed. In other words, about 0.09% of the material removed has value. This waste material consists of about 34% finely ground rock or tailings from which about 7 pounds (3.2 kilograms) of copper per ton is recovered, the remaining 66% is waste rock ranging from fine to very coarse material that has to be removed to get at the ore.

This waste material is stored on nearby areas giving a new surface configuration that has to be reclaimed to a useful, stable state. Tailings and waste rock each offer a slightly different reclamation challenge.

Climate

Climatic conditions control growth and determine the scope of the reclamation that can be expected.

Near Princeton, the following weather data summary is for the last 10 years:

Precipitation:	35 centimetres average, with extremes of 20 to 46 centimetres
Snowfall:	62% average of precipitation, with extremes of 36 to 81%
Temperature:	Mean 5^{o}, extremes of +38 to $-41^{o}C$

The climate is semi-arid with wide ranging variations.

Chemical and Physical Environment

Vegetation requires a limiting minimum of moisture, nutrients, microorganisms, and pH range for germination and self-sustaining growth.

In the Ingerbelle mine area, humus derived soil ranges from an inch (2 centimetres) or so to being entirely absent. Glacial sand and gravel alluvium covers some of the rock surface. Testing of the rock and alluvium materials show that they are sterile, non-phytotoxic, contain no available nitrogen or potash, and have a minute trace of phosphorus, possibly from apatite. The pH averages about 8.4.

Physically, the sizes of material range from sand to very coarse. The tops of waste dumps usually develop a fairly fine surface material due to preparation, and operation of the haul trucks. Roughening of the harder packed portions can be done prior to seeding.

RECLAMATION OBJECTIVES

Given the relatively restrictive conditions of the area, the reclamation program had to be directed to revitalizing the new host surface, and, using the existing climate, setting an eventual target of self-sustaining perpetual, useful growth. Experimentation with grass seed types, inoculated legumes, and varying fertilizer nutrients was essential.

Experimental Test Plot

In 1971, a one acre (0.4 hectare) level test plot was constructed with pit waste rock. As only limited amounts of alluvium would be available, only half of the plot surface was covered with alluvium. While irrigation would obviously have advantages in accelerating growth, natural precipitation would be the norm, hence only half of each of the above areas were set up for irrigation. Two seed mixtures were used, with one to take advantage of the irrigation. One hundred each of four types of coniferous seedlings were planted--because the surface was difficult to dig, a tank drill with a large bit was used to prepare the seedling holes.

This plot was maintained and studied until October, 1972, when production requirements turned it into part of a large waste dump. The test was valuable by showing that, while alluvium cover and irrigation aided more rapid growth, satisfactory seed growth progressed on both the alluvium and waste rock without irrigation. The seedling test was not conclusive but indicated that tree growth could be a problem.

Highway Safety Berm

A decision was made to place a protective barrier beside the newly constructed highway to prevent any future dump waste rock from reaching the highway and to provide a "greenbelt" along this publicly prominent portion of the operation. This berm is about 4000 feet (1200 metres) long, up to 100 feet (30 metres) wide at the top, some 15 feet (5 metres) above the highway surface, and contains over two million tons of waste rock.

As the objective was to obtain rapid growth, the berm was coated with alluvium and the top surface covered with a layer of imported "soil" that turned out to be predominately sand. An irrigation system was installed. Seeding, fertilizing, and the planting of 4600 mixed deciduous and coniferous seedlings was done in 1972, with good growth apparent in the fall of 1972.

The winter of 1972-73 "graciously" provided one of the infrequent "winterkill" conditions and less than 10% of the Green Ash and Siberian Elm were the only partial survivors. Some sprouted from their base in 1973; at present, there are only a few Siberian Elms remaining from this original planting. The grass and legumes survived the winter satisfactorily.

Irrigation ceased after the 1974 growing season and resulted in a change in the growth patterns. The drought resistant plant types became predominant while moisture dependent types receded. Numerous transplantings of indigenous seedlings were carried out, but none have survived--Forestry officials believe that the pH is too high for coniferous adaptation. In 1977, 600 Siberian Elm seedlings were planted and appeared to be doing well in 1978.

Some losses are expected from deer and elk stripping off the succulent small leaves.

Waste dumps against the berm are nearly completed. The "greenbelt" has been provided and results of this reclamation phase have been quite useful for other areas.

PROGRESS

Several other waste dump surfaces are being reclaimed without alluvium or irrigation. There are usually good patches of growth after the initial seeding and these spread to areas of poorer growth from natural reseeding. The slopes in front of the concentrator are irrigated to keep them green throughout most of the growing season. Each spring, there are sections here to re-do as the result of snow removal which usually dumps a new layer of road gravel on portions of the face.

Waste Dump Slopes

The main Ingerbelle waste dump is built up in a series of lifts ranging from 100 feet (30 metres) to 200 feet (60 metres) high. The toe of each lift is set back 100 (30 metres) to 150 (45 metres) feet from the crest of the lift upon which it is being built as a safety feature, resulting in an overall face slope of 26° or less. The actual face of each lift is sloped at the angle of repose--about 37°. As the waste rock is dumped over the face, it tends to segregate with finer material at the top to very coarse at the bottom. Because of this natural segregation, most of the face has fairly coarse rock that is not suitable for seeding. To overcome this, alluvium from production or from stockpiles is dumped over the face from the top, filling in most of the spaces between the coarser rock, and providing a better surface upon which seed can take hold. The alluvium settles somewhat after placement and is usually left unseeded for a year.

Seeding and fertilizing is done with a special aircraft, as are all the larger areas. As with the flat dump surfaces, growth is preferential but spreads each year. Growth in other portions of the face is not as obvious, but sparse growth is evident over most of the faces. The areas of more concentrated growth are outlined in the snow as deer graze on these in the winter.

The dump slopes have remained stable with the lowest 180 foot high (55 metres) face now 6 years old. The first slope seeding was done in 1974.

Mine Tailings

The tailings dams are being constructed by a downstream method which adds new material each year, precluding any major reclamation until near the end of the property life.

In 1974, a test plot of tailings about 50 feet (15 metres) square and 3 feet (1 metre) deep was prepared and seeded. Analysis indicated that the tailings were similar to the waste rock in that it was sterile, non-phytotoxic, and lacking any available plant nutrients.

Good grass growth was immediate with legumes becoming apparent in 1977, and well established now. This plot was not irrigated, and was only refertilized in 1975 and 1976.

These results suggest eventual good growth potential for the tailings surface. Cattle have twice eaten the growth down to the surface on the plot.

Princeton Tailings

Newmont acquired some 70 acres (30 hectares) of old Granby tailings with its purchase of the Copper Mountain property in 1967. These are immediately west of the tailings owned by the Town of Princeton, where the Ministry of Mines is doing some experimental reclamation.

Early concern about the dust from these tailings resulted in some locally inspired small-scale experiments by Dr. L.H. Burr, a local medical practitioner, but these were abandoned. As a dust control measure, arrangements were made with Northwood Mills to dump wood waste materials on the tailings, which stopped the spreading of dust and helped to reduce the local smoke pollution.

In 1976, Newmont decided to seed these tailings. Unfortunately, a considerable number of waste logs were included with the wood waste cover so these had to be bulldozed into windrows before seeding, leaving a cover of fine wood waste on the tailings. The seeding has taken fairly well. Cattle got in and ate the first growth so the area has been fenced to permit the growth to become well established before allowing cattle to harvest the growth.

SEEDING AND FERTILIZATION

Seeding

Seed mixtures have been gradually modified from experience through a series of 12 combinations, mostly as a result of performance, but also due to the lack of availability of some seeds and excessive cost increases. All seed is minimum Canada No. 1 grade.

Because of their obviously successful adaptability, five inoculated legumes are in the current seed mixes together with primarily drought resistant grasses, including short lived fast rooting types to give initial control of the surface. Sweet Clover is avoided because of the potential danger from its anti-coagulant properties.

Original seedings were at 80 pounds to the acre (90 kilograms per hectare) with a subsequent increase to 120 pounds to the acre (135 kilograms per hectare). Seeding is usually done in late summer or early fall.

Fertilization

Initially, the commercially available fertilizers contained about 40 to 50 units of usable plant nutrients. We now use specially prepared mixtures containing more than 60 units of nutrients, nutrient proportions being dependent on the growth stage at which the fertilizer is applied.

Nitro prills (blasting agent) were used in some spring fertilizing, but for a cost differential of about 1 cent a pound, fertilizers containing more available nitrogen as well as other nutrients can be used and nitro prills are no longer necessary. Application rates started at 300 pounds per acre (340 kilograms per hectare) but have been increased to 500 pounds per acre (550 kilograms per hectare) with initial seedings. Fertilizer application is planned for twice a year over three years by which time the areas are expected to become self-sustaining. The spring application is frequently done while snow remains on the ground to take advantage of the moisture it will provide.

Aircraft Application

In 1974, aerial application of seed and fertilizer was commenced as larger areas became available for reclamation. The specially adapted, single-seat, low-wing monoplane carries 1000 pounds (450 kilograms) of seed or fertilizer per trip in a bin located in the nose of the aircraft. Flying this aircraft is not for amateurs as very precise navigation is required at heights ranging from 50 to 150 feet (15 to 45 metres).

The bin in the aircraft is loaded with a special truck driven up to the aircraft. The aircraft bin has a spreader plate at its base which gives positive deposition in a 30 foot (9 metres) wide strip with reduced deposition for 10 feet (3 metres) on either side so that full coverage requires careful overlapping of the flight strips. If a very precise limit to seeding is required, the spreader plate is removed and a tightly confined 25 foot (8 metres) strip can be placed. Seed application requires relatively calm conditions to accomplish the precision desired. Fertilizing is usually done at a greater height as precision is not quite so critical. The bin opening is varied to provide the rate of application requested.

Precision is excellent with an experienced pilot, and distribution is very uniform as indicated by one foot (0.3 metre) square heavily greased boards placed in an area being seeded.

The Princeton airport is used as a base for flying the nearby tailings and a good air strip has been prepared on the surface of a completed waste dump at the mine. Usually two days are sufficient for each application program.

Fertilizer placement costs about three times as much as seeding due to the heavier application rate. Current costs for 100 pounds of seed, 400 pounds of fertilizer, and placement is about 220 dollars per acre (494 dollars per hectare)

Arnot Bristly Locust

In 1971, Mr. Peck of the, then, Department of Mines suggested that the Arnot Bristly Locust had proven an excellent hardy bush for reclamation projects in parts of the U.S. and might be worth trying. Some seed was finally obtained and, in 1973, 5700 seedlings were planted on the property. To my knowledge, there were none left in 1978 because Princeton's climate is just too tough.

Hydroseeding

In 1975, a 10-acre (4-hectare) hydroseeding experiment was carried out on a dump face with the operator using his own formulation. Growth was no more effective than with the aerial seeding and was excessively costly at 785 dollars per acre (1,900 dollars per hectare) compared to the total cost of aerial application at 135 dollars per acre (335 dollars per hectare) at that time. The cost comparison is undoubtedly biased by the size of the test, but even large area hydroseeding could not provide a satisfactory cost comparison.

PHOTOGRAPHS

A comprehensive photographic record has been kept throughout the program and, after considerable justifiable persuasion, photo targets were set up in 1977. These consisted of an angle-iron fence post with a permanent number. A company sign with the applicable date was placed on the post for identification on the photographs. The objective is to obtain "before and after" photos to record progress.

Only a very limited number of transparencies have been taken for slide projection.

CONCLUSIONS

Although growth can be sustained under almost any conditions with water and plant nutrients, the key to successful and economical reclamation is to develop, through experience, a program for the existing local conditions in order to reach self-sustaining growth as soon as possible.

ACKNOWLEDGEMENTS

I wish to thank Newmont Mines Limited for permission to present this paper and to express my sincere appreciation for the conscientious and expert guidance provided by Mr. Stanley Weston since the inception of our reclamation program.

DISCUSSION RELATED TO JIM McCUE'S PAPER

There was no discussion about this paper.

REVEGETATION FOR WILDLIFE USE

Paper presented

by:

B. van Drimmelen

Ministry of the Environment

REVEGETATION FOR WILDLIFE USE

INTRODUCTION

For this year's Symposium, I was requested to provide a short ten-minute instructional talk on how I, as an employee of the Wildlife Branch, would like to see an area revegetated for wildlife. The above title can be subtitled, "Once more with feeling", for reasons which will become apparent.

First, let me put revegetation into its proper perspective. Obviously, revegetation for wildlife use is only a small aspect of reclamation for wildlife. Before such revegetation is considered, one must consider whether reclamation for wildlife is necessary and, if so, what wildlife species are to be considered. Then, some large-scale habitat manipulation or landscaping is usually required, such as resloping, re-shaping for hydrological or cold-air drainage considerations in order to provide the necessary variability in microclimatic conditions.

Finally, after the previous processes have been completed it is time to revegetate your newly created habitat base to suit the desired wildlife species. Here then is where this talk really begins. Incidentally, for those of you who may be anticipating a series of "Wild Kingdom" photos, I should apologize for our Information Section who were unable to supply very many good photos.

In the next few minutes, I shall endeavour to serve up a "cook-book" prescription for the creation of habitat for six representative species, including Rocky Mountain Elk, Mule Deer, Bighorn Sheep, Mountain Goat, Moose, and Caribou. Unfortunately, it will be necessary to discuss these specie requirements in generalities, as my time at the podium is very short.

ELK

We have two sub-species in B.C., each with very different habitat needs. One of these, the Roosevelt Elk, is however limited to Vancouver Island, so I will deal here with the more abundant Rocky Mountain Elk. This animal is much more adaptable and prefers habitat of mid-successional stages.

Habitat for Elk is relatively easy to define, because a great deal of investigation has been done in the United States. Clumps of coniferous cover are required to provide shelter, and these shelter stands should be interspersed among deciduous groves with an understory of shrubs, grasses, and forbes.

Revegetation for Elk should, therefore, involve the following:

a) Where possible, plan "islands" of coniferous timber to be left intact, composed of Lodgepole Pine, Larch, White Spruce, and/or Douglas Fir, as site conditions dictate.

b) Plant deciduous trees such as Black Cottonwood, Birch, Trembling Aspen, and especially Willow.

c) Add a shrub layer of Red Osier Dogwood, Silverberry, Chokecherry, Wild Rose, and/or Thimbleberry, to provide browse foods.

d) Plant forbes including Aster, Bead Lily, Columbine, Dandelion, Fireweed, Goldenrod, Fleabane, Marsh Marigold, Clover, and Vetches.

e) In open areas and through the deciduous timber, plant grasses which are palatable and nutritious to Elk, including Bluegrass, Brome, Wheatgrass, June Grass and Sedge.

MULE DEER

Mule deer are primarily browsers (that is, shrub eaters) rather than grazers. Good mule deer range is similar to that for elk, but with greater emphasis on shrubs and trees and correspondingly less concern with the forb and grass layers. Provision of food and shelter are of primary concern.

Therefore, revegetation to favour Mule Deer should involve the following:

a) Retention of islands of natural forest is a big asset. If shelter stands must be planted, Douglas Fir and/or Ponderosa Pine are preferred.

b) As for Elk, the shelter stands should be scattered throughout a deciduous forest, but for Mule Deer, a heavy shrub layer is required. Therefore, revegetation should concentrate on Aspen, Birch, Willow and Douglas Maple, with an understory of Ceanothus, Salal, Red Osier Dogwood, Bitterbrush, Serviceberry, and Vaccinium.

BIGHORN SHEEP

The Bighorn Sheep is primarily a grazing animal found on climax grassland habitats on dry sidehills. Their grazing habits necessitate shallow snowdepths to permit access to grasses in winter.

Another habitat requirement for sheep is a proximity to steep, rugged escape terrain. Such a feature is, however, achieved during the "landscaping" phase of reclamation to which I referred earlier, and is beyond the terms of reference of this presentation which relates particularly to revegetation for wildlife.

Food species which sheep prefer include Wheatgrass, Bluegrass, and Junegrass, as well as some browse species such as Alpine Willows.

Scattered thickets of coniferous cover of a type to be determined by local site conditions should fringe the grass ranges.

Because Bighorn sheep occupy very small, discrete winter ranges, the creation of such ranges should be considered a very feasible and desirable outcome of mining reclamation work.

MOUNTAIN GOATS

Mountain goats differ from Bighorn sheep as they demand proximity to very steep, rough rock bluffs or crags which constitute escape terrain, rather than selecting a habitat by the more typical variables of food and cover. If such mountainous terrain is present, Mountain goats will derive nourishment from almost any grasses, herbs, shrubs, or trees which are available, however they prefer grasses and sedges.

Based on these considerations, the topic of revegetation for goats becomes inconsequential during reclamation, as the creation of habitat for goats would depend almost entirely upon the "landscaping" phase.

MOOSE

I regret that I was unable to get a satisfactory photo of this common species, but I think we are all familiar with its appearance. Moose are less dependent upon shelter than most other native ungulates, and can withstand snowdepths of up to one metre. Revegetation for moose should, therefore, concentrate upon the provision of food.

During the critical winter season, Moose feed almost exclusively on twigs and small branches of trees and shrubs, consequently, vegetation species for Moose should include Willow, Serviceberry, Maple, Birch, Red Osier Dogwood, False Box, Aspen, and Poplar.

Although the animal's diet changes rather drastically in other seasons, vegetation for non-winter ranges is available naturally, therefore, it is unlikely that revegetation for such non-winter ranges will be requested by the Wildlife Branch.

CARIBOU

The caribou is a very nomadic and wild-ranging species with a highly specialized food source of Lichens and Forbes. These two factors make it virtually impossible to artificially create habitat for the species. It is in cases where areas are heavily utilized by such "unmitigable" species that the Wildlife Branch will be seen to strongly resist any efforts to explore for, develop, or produce minerals. When revegetation and reclamation will not serve to mitigate a disturbance, the only way to ensure the maintenance of a viable wildlife population is simply to stay out of the area.

SELECTION OF VEGETATION SPECIES

During the preparation of this presentation, I re-read my previous statements concerning the types of vegetation preferred by the B.C. wildlife and tried to assess its usefulness to the mining industry. And it is here that the subtitle of my talk, "Once more with feeling" becomes appropriate.

The preceding discussion of the habitat requirements of the wildlife utilizing native species, and not the commonly used agronomics, leads to an important question: Can anyone here specify the precise horticultural requirements for native species such as Red Osier Dogwood, Gooseberry, Paper Birch, Vetches, or even the native grasses?

While recognizing that some good pioneer work has been done by companies such as Cominco and Kaiser Resources, it is evident that the mining companies; The Ministry of Energy, Mines and Petroleum Resources, and the Ministry of Environment have generally ignored a significant presentation made at the 1977 Symposium by Mark Bell and Del Meidinger of the University of Victoria. Their talk dealt with the use of native species in the reclamation of disturbed lands, and several vital points were made.

DISCUSSION RELATED TO BEN VAN DRIMMELEN'S PAPER

Jake McDonald, Ministry of Energy, Mines and Petroleum Resources, Having just come back from Fiji, I want to ask you how the wildlife was in Fiji?

ANS. No comment.

Doug Christie, Reid Collins & Associates. I think one problem that we have had is simply this: we grow new plants but when the mining company comes to us and says we would like to order a thousand Red Osier Dogwood and two thousand Paper Birch, then we cannot supply them. The simple reason is that there isn't much sense in growing a certain plant if you are hoping that that plant will maintain itself in that area. Therefore, the demand has to be a planned operation where there is lead time allowed for the commercial person to get out and collect proper material and grow it for that particular area. It just isn't practical for a commercial supplier to keep stock of all the different provenances of these plants available. But the capability to grow these plants does exist.

ANS. Okay, I'm not talking here of reclamation of exploration roads or drill sites. If reclamation were to be done for wildlife, and I don't think that it would be in that many cases, it would be done over fairly large areas after a mine has ceased production. I think that along with the planning that goes into the mining, there should be proper planning for reclamation. If this planning is done, then you should have all the lead time you need.

CURRENT REVEGETATION TECHNIQUES AT CRAIGMONT MINE

Paper presented

by:

L. Gavelin

Craigmont Mines Ltd.

CURRENT REVEGETATION TECHNIQUES AT CRAIGMONT MINE

INTRODUCTION AND HISTORICAL BACKGROUND

Reclamation at Craigmont commenced in 1969. Dormant pit waste dumps and completed sections of the tailings toe dam were seeded and fertilized by aerial spraying; the method considered most economical and expedient at that time. A sprinkler irrigation system was installed on the tailings toe dam to maintain optimum moisture conditions during the dry period to sustain plant growth. The continuing reclamation program from 1969 to 1977, as outlined in Appendix I, basically consisted of maintenance of seeded areas as well as new seedings and fertilization as areas became available, including a test plot of hydroseeding on the dump slopes to determine if plant growth could be enhanced in this difficult area. The success of the reclamation program up to this time is best described as marginal, due to (1) the hit and miss nature of aerial spraying; (2) the compaction of the waste dump berms where either the seed was blown away or root development was impossible; and (3) overgrazing by cattle of the new plant life and subsequent loss of seed production. Very reasonable results were obtained on the tailings toe dam under irrigated conditions.

In 1978, a complete review of our program was undertaken and modifications made to hopefully improve and accelerate the results which would be conducive to returning the disturbed land to an economic use. The outcome was an intensified program to provide answers for our final reclamation program prior to our pending closure.

RECLAMATION IN 1978

The 1978 reclamation program consisted of:

1. the use of land-borne equipment to provide a more consistent plant cover.

2. Scarification of the compacted surface to enhance seed germination and plant growth.

3. Fence construction around the pit waste dumps to keep the cattle from grazing the area.

4. The setting up of five large test plots on the tailings impoundment area to test possible economic use and methods of establishing a self-sustaining plant growth.

Comparisons and results of the 1978 reclamation program with respect to past practices will indicate that our re-evaluation and revised procedures have been well founded by the initial results obtained. However, a total assessment will require 2 to 3 years of follow up.

Technical details regarding the tailings impoundment test plots is attached as Appendix II, as well as various seeding application costs relative to work done at Craigmont which is attached as Appendix III.

APPENDIX I

Seed and Fertilizer Mixtures and Application Rates for Reclamation Program to Date

(a) <u>October 1969</u>

Seeding and fertilization of 100 acres of south pit waste dump, 107 acres of north pit waste dumps and 14 acres of tailings dam (bottom 4 benches).

Seed mixture applied aerially at 76.6 pounds per acre

Annual Ryegrass	- 15%
Boreal Fescue	- 20%
Crested Wheatgrass	- 20%
Streambank Wheatgrass	- 8%
Slender Wheatgrass	- 10%
Pubescent Wheatgrass	- 7%
White Clover (double inoculated)	- 8%
Rhizoma Alfalfa	- 12%

Fertilizer 10-30-10 applied at 289 pounds per acre.

(b) <u>April 1970</u>

Re-fertilization of areas seeded in October 1969.

Fertilizer 20-20-10 applied at 200 pounds per acre.

(c) <u>August 1970</u>

Re-seeding and re-fertilization of 14 acres of tailings dam (bottom 4 benches) and 24 acres of south pit waste dumps previously seeded.

Seed mixture - as above applied aerially at 64 pounds per acre.

Fertilizer 10-30-11 applied at 211 pounds per acre.

(d) September 1971

Re-seeding and re-fertilization of 14 acres of tailings dam benches (bottom 4 benches) and re-fertilization of 207 acres of pit waste dumps initially seeded in 1969.

Seed mixture - applied aerially at 36 pounds per acre.

Creeping Red Fescue	- 19%
Annual Ryegrass	- 16%
Crested Wheatgrass	- 32%
White Clover (double inoculated)	- 16%
Rhizoma Alfalfa (double inoculated)	- 16%

Fertilizer 13-16-10 applied at 200 pounds per acre.

(e) September 1972

Seeding and fertilization of 100 acres of north pit waste dumps.

Seeding mixture applied aerially at 70 pounds per acre.

Tetraploid Perennial Rye	- 5%
Annual Ryegrass	- 5%
Perennial Ryegrass	- 3%
Creeping Red Fescue	- 15%
Crested Wheatgrass	- 10%
Pubescent Wheatgrass	- 15%
Tall Wheatgrass	- 15%
Intermediate Wheatgrass	- 5%

Sainfoin	- 5%
Trefoil	- 7%
Rhizoma Alfalfa	- 15%

Fertilizer 19-19-19 applied at 200 pounds per acre.

(f) 1976

Based on results of tailings dam soil samples, the 14 acres (bottom 4 benches) were re-seeded, re-fertilized and the remaining 6 acres (the two top benches) of the tailings dam were seeded and fertilized.

Seed mixture applied by broadcasting with a hand cyclone seeder at 80 pounds per acre.

Creeping Red Fescue	- 19%
Annual Ryegrass	- 16%
Crested Wheatgrass	- 33%
White Clover (double inoculated)	- 16%
Rhizoma Alfalfa (double inoculated)	- 16%

Fertilized 19-19-19 at 210 pounds per acre.

(g) 1977

Hydroseeded four test plots totalling 5 acres of pit waste dumps.

Seed mixture applied by hydroseeding at 85 pounds per acre.

Fall Rye	- 41%
Nordan Crested Wheatgrass	- 12%
Streambank Wheatgrass	- 12%
Creeping Red Fescue	- 12%
Hard Fescue	- 5.5%

Cicer Milkvetch - 5.5%
Sweet Clover - 12%

Fertilizer 12-15-15 applied at 200 pounds per acre.

1977 seeding and fertilizing of the two top benches of the tailings dam:

Seed mixture applied by range drill 50 pounds per acre on one bench and 100 pounds per acre on the other.

Sainfoin	- 20%
Roamer Alfalfa	- 20%
Cicer Milkvetch	- 20%
Crested Wheatgrass	- 15%
Slender Wheatgrass	- 10%
Streambank Wheatgrass	- 5%
Annual Ryegrass	- 10%

Fertilizer 28-16-10 at 300 pounds per acre.

Seeding of test plots on bench of tailings dam:

Plots 1-7 - Seed applied by broadcasting with a hand Cyclone Seeder at 100 pounds per acre.

7 plots each seeded with one of the seeds comprising the above mixture.

Fertilizer 28-16-10 at 300 pounds per acre.

Plot 8 - Seed mixture as above at 100 pounds per acre.

Fertilizer - none.

APPENDIX II

Tailings Impoundment Test Plots

This report details the sequence of work done with the results to-date from the test plots on the west side of the tailings disposal, outlines the work for 1979, and sets out the objectives of the test program.

I. Green Manure Plots - Three, 1-acre plots

These plots will determine which combination of fast growing plants provides a good green manure for improved soil texture and, in conjunction with the barley test plots, will determine the most appropriate method of establishing a permanent crop. The green manure plots were irrigated as required (except for a dry period at the start of the growing season that may have inhibited growth) to provide optimum moisture conditions for the growing season. For the purpose of this report, the green manure plots will be identified as follows:

G1 - Cereal and legume mix - 86% Oats, 14% Austrian Peas.

G2 - Legume mix - 72% Sweet Clover, 28% Red Clover

G3 - Grass and legume mix - 48% Annual Tetraploid Ryegrass, 18% Sweet Clover, 40% Spring Vetch.

The following sequence of work was done to each plot:

- 150 pounds of 20-24-15 fertilizer applied to each G1 and G3
- 175 pounds of 8-20-20 fertilizer applied to G2.
- The ground plowed.
- 150 pounds of 20-24-15 fertilizer applied to each of G1 and G2.
- 175 pounds of 8-20-20 fertilizer applied to G2.

- The ground harrowed twice.
- The Cereal-Legume mix seed at 100 pounds per acre in plot G1.
- The Legume mix seeded at 16 pounds per acre in plot G2.
- The Grass-Legume mix seeded at 45 pounds per acre in plot G3.
- The ground compacted.

July (Plot G1 only)

- 125 pounds of 21-0-0 fertilizer applied.
- The growth plowed under.
- 425 pounds of 13-16-10 fertilizer applied.
- The ground harrowed.
- The Cereal-Legume mix again seeded at 100 pounds per acre.

September

- The growth on plots G1, G2, and G3 were plowed under.

October

- The plowed ground harrowed twice.
- Each plot divided in half and seeded at 15 pounds per acre with a permanent seed mix.
- Fall barley seeded at 65 pounds per acre to half of each plot seeded with permanent seed mix.

Observations to Date

1. The Red Clover died out in the Legume mix of plot G2.

2. The most dense growth and sod formation was achieved by the grass and legume mix of plot G3.

3. The strongest individual plant growth was achieved in the Sweet Clover of plots G2 and G3 - averaging $\pm$3-1/2 feet in height.

4. A strong growth of nitrogen fixing bacteria nodules developed on the Legume roots of all three plots.

5. The soil texture has improved from the turning under of the first planting of Oats and Austrian Peas in plot G1.

6. The Oats and Austrian Pea mix of plot G1 was the only mix that grew quickly enough to allow a second planting in one growing season.

Program for 1979

1. Seeding the remaining half of the plots in the spring of 1979.

2. Apply additional fertilizer if soil samples indicate a lack of nutrients.

3. Supply irrigation in varying amounts to determine what additional moisture is necessary to establish growth.

Objectives for 1979

To determine:

1. Which seeding program will give the best results.

2. If a cover crop is necessary to establish growth.

4. The irrigation requirements to establish permanent growth.

5. The fertilizer requirements necessary to establish growth.

The special permanent seed mix recommended by Bob Donaldson of Buckerfield's consists of 5% Alfalfa, 10% Sainfoin, 5% Cicer Milk-vetch, 25% Crested Wheatgrass, 25% Russian Wild Ryegrass, 25% Streambank Wheatgrass and 5% Troy Kentucky Bluegrass.

11a Barley Plots (Ploughed) Two - 1-acre plots

These plots were established to see if a commercial crop could be grown, to compare growth obtained by irrigation versus natural moisture conditions, and to determine if a cover crop would assist the growth of a permanent grass and legume mix. Irrigation was applied to maintain optimum moisture conditions on the one plot for the growing season.

The following sequence of work was done on each plot:

April

- 150 pounds of 13-16-10 fertilizer applied to each plot.
- The ground plowed.
- 150 pounds of 13-16-10 fertilizer again applied to each plot.
- The ground harrowed twice.
- Craigmont #5 mix seeded on half of each plot at 35 pounds per acre.
- Spring barley seeded in each plot at 75 pounds per acre.
- The ground compacted.

June

- 21-0-0 fertilizer applied at 50 pounds per acre to half of each section in both plots.

September

- Craigmont #5 mix seeded at 30 pounds per acre to the half of the plots not seeded in April with Craigmont #5 mix.

October

- Fall barley seeded at 65 pounds per acre to the half seeded with Craigmont #5 mix in September.

Observations to Date

1. Water is a major factor limiting growth in the dryland plot. The Legumes established fairly well, but the Grasses showed minimal growth.

2. The over-all Barley growth was good but could have used additional fertilizer.

3. The grass and legume mix did establish growth under dryland and irrigated conditions.

4. A stronger grass and legume growth was established with irrigation.

5. The fertilizer application and Barley seeding rate would have to be greatly increased for a commercial crop.

6. The Barley growth did provide protective cover for the seedling growth of the grass and legume mix.

11b. Barley Plots (Harrowed) Six plots totalling 7 acres

The purpose of these plots is to determine tillage requirements, optimum time of seeding, and the necessity of irrigation to establish a permanent grass and legume forage crop.

The following sequence of work has been completed on 3½ acres.

October

- 13-16-10 fertilizer applied at 300 pounds per acre
- The ground harrowed
- Craigmont # 5 mix seeded at 24 pounds per acre.
- Fall barley seeded at 65 pounds per acre.

Program for 1979

1. Fertilize, harrow and seed the remaining 3 1/2 acre test area in spring 1979.

2. Provide irrigation to approximately half of the fall 1978 and spring 1979 "harrowed" Barley plots.

3. Sub-divide the "ploughed" and "harrowed" Barley plots to test the effect on plant growth of varying amounts of fertilizer.

4. Provide irrigation to part of the "ploughed" Barley plot irrigated in 1978.

Test Program Objectives

To determine:

1. Which seeding program will give the best results.

2. The effect of tillage and fertilizer placement.

3. The amount of irrigation required.

4. The fertilizer requirements necessary.

5. If growth can be established and maintained without using "green manures".

6. The effect of the previous year's growth as a mulch.

7. If irrigation is required only for one year to establish permanent growth.

The Craigmont #5 seed mix consists of 5% Hard Fescue, 10% Tall Wheatgrass, 20% Creeping Fescue, 20% Crested Wheatgrass, 20% Alfalfa and 25% Sainfoin.

APPENDIX III

1978 RECLAMATION COST COMPARISON FOR VARIOUS SEEDING METHODS

	Helicopter	Aircraft	Dept. of Ag. Heavy Duty Range Drill	Tractor Cyclone Spreader	Tractor Cyclone Spreader & Harrow	Hand Cyclone 1 a/day	Hand Cyclone & Rake
(Seed & Fert.) Application	$19/a	$17/a	$45/a	$12.50/a	$15/a	$60/a	$120/a
Seed Rate & $	100/a $91	100/a $91	20#/a $18	20#/a $18	20#/a $18	40#/a $36	40#/a $ 36
Fert. Rate	300#/a $24	400#/a $32	100#/a $8	100#/a $8	100#/a $8	200#/a $16	200#/a $16
Total $	$134	$140	$71	$38.50	$41	$112	$172
Additional Fert. with Tractor and Cyclone Spreader	-	-	$13/a	$13/a	$13/a	-	-
TOTAL $	$134	$140	$84	$51.50	$54	$112	$172

DISCUSSION RELATED TO LLOYD GAVELIN'S PAPER

Frank Pells, Brenda Mines Ltd. Have you used any reclaim water for irrigation.

ANS. The water used for irrigation on the toe dam was the reclaim water. The water used on the test plots was the cooling water from the compressors.

Question: Have you encountered Knapweed.

ANS. Well the Nicola valley is a major Knapweed infested area of B.C. and we are surrounded with it. It is encroaching on some of the toe dams at the present time. Looking at Knapweed as a cover crop, it certainly does well on disturbed lands.

Harry Quesnel, University of British Columbia. I was wondering what frequency of irrigation you were using and approximately how much water per acre you applied.

ANS. We had six lines on the test plots and we ran them on an eight-hour cycle; however, if I felt that it was not necessary to irrigate we omitted it for a period of time. So in general, I would say that in a 10 to 14-day cycle the total water applied per acre would be about one acre-foot. I would hazard a guess that if you calculated out the moisture requirements for the area it would work out to about three acre-feet.

RECLAMATION PRACTICES AT ISLAND COPPER MINE

Paper presented

by:

R. Hillis

Utah Mines Ltd.

RECLAMATION PRACTICES AT ISLAND COPPER MINE

INTRODUCTION

Island Copper Mine is located approximately 10 miles south of Port Hardy on the north end of Vancouver Island and is the largest open pit operation located on coastal British Columbia. The mineral reserves indicate approximately 280 million tons of 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 using the conventional truck and shovel method.

The milling operation has the ability to process up to 50,000 tons of ore per day, producing 1000 tons of copper concentrate and 15 tons of molybdenum concentrate. By-products found in the concentrates are gold, silver and rhenium. The mine has its own deep sea dock and transports its copper concentrate directly to Japan.

The mining operation will develop a single pit with final dimensions of 8000 feet long x 4000 feet wide x 1200 feet deep. The estimated average stripping ratio for the twenty year operation is 2.4 tons of waste for each ton of ore.

Island Copper's low grade mining operation requires the removal and disposal of large volumes of waste material in an environmentally acceptable manner.

At Island Copper, the mill tailings are treated and subsequently discharged, 165 feet below the surface, into the adjacent marine environment (Rupert Inlet). A portion of the waste rock is deposited as a landfill along the shore contiguous to the pit and acts as a berm protecting the open pit from potential seawater inflow.

Reclamation Plan

A reclamation plan was developed at the mine with both short-term and long-term objectives. The short-term objectives of the reclamation program are to reduce erosion through soil stabilization using vegetation, and to maintain aesthetic quality around the minesite.

The long-term objectives and land use consideration for the area are wildlife habitat, recreation and forestry. The present land uses in the area other than the mine operations are wildlife habitat and forestry. The area surrounding the mine is designated as a prime forest yield region.

Before the mine operations, 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. These trees were 15 to 25 inches in diameter and 100 to 150 feet tall.

The ore body was overlain with glacial till which ranged in thickness from 15 feet in the centre of the pit to 300 feet on the east and west sides.

Research Prior to Reclamation

The initial reclamation research was to assess the materials overlaying the ore body. Precipitation of 80 inches per year and the moderate temperatures year round in the area, increases the weathering of soil materials. Research indicated that soil materials within the pit had a high calcium content coupled with a fairly alkaline pH (8.5).

The organic soils associated with the relatively flat land which has a water table at or near the surface, had an acid pH. Nutrient analysis of both types of material revealed low levels of major plant nutrients. Considerable fertility amendments would be required if these materials were to be used for reclamation purposes.

RECLAMATION OPERATION

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

In the spring of 1971, approximately 50 acres of the construction site area and 10 acres of road allowance were seeded by aircraft and hand-operated Cyclone Seeders. The areas covered did not receive any special preparation prior to the seed and fertilizer application. A mixture of grasses and legumes was applied at a rate of 60 pounds per acre. Fertilizer (20-20-10) was applied at a rate of 300 pounds per acre at the time of seeding. After one year of growth, grasses with a well developed root system were firmly established in the area.

The areas seeded in 1971 have been monitored to evaluate the success of this form of reclamation. An area above the plant site had no growth in April 1971. Two months after planting, growth to a height of 4 to 6 inches was evident. By July 1972, one year after the initial planting and after a second application of fertilizer in August 1971, the area had an excellent cover of grasses which were producing seed. In August 1976, five years after the initial seeding and with no tending, the same area was predominantly legumes. Alder seeds from the surrounding forest had germinated successfully and seedlings from 6 to 18 inches in height had developed. The most recent survey of the area in August 1978 documents extensive Alder growth with trees over eight feet tall, with Conifer Hemlock growing among the Alder. In only two years this area has demonstrated the ability of Alder to grow rapidly once it has become established.

Other areas seeded in 1971 have grown successfully. One area with a road cut has a well developed grass cover with Hemlock and Alder covering 25% of the area. Where the soils are nutrient deficient naturally seeded Hemlock and Spruce are present. Some areas have developed shrubs such as Elder and Salmonberry. These reclaimed areas have become excellent habitats for deer.

In early 1971, prestripping of the pit area started. An attempt was made at stockpiling the organic soils from the lower region of the pit. Stockpiling proved to be impractical due to the water retentive character of the material.

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 nine equal areas and treated with varying amounts of seeds and fertilizer. After 5 years and no tending, plots without fertilizer did not produce a good vegetation cover. Good plant growth was evident in plots that were fertilized.

Since organic soils cannot be stockpiled, it is the practice at Island Copper to place these materials on areas which are available for immediate reclamation. In such cases, the organic soils from the stripping operations are loaded and transported by truck to an area prepared for reclamation. The soil is then spread by bulldozer to a depth of 6 to 12 inches.

In 1975, several areas on the beach waste dump were treated in this fashion. A 6-acre plot was levelled by bulldozer and covered with a layer of overburden from a stripping operation. In June 1976 the area was treated with 50 pounds per acre of seed and 200 pounds per acre of fertilizer (20-18-9). This area was hand seeded and patchy. In the spring of 1977, the bare patches were treated with additional seed and a fertilizer. The area flourished. During the 1978 season, plant growth was reduced as the nutrients were consumed. White Dutch Clover became the dominant species by July 1978.

Another 5-acre plot was levelled and spread with overburden in 1977. This plot was planted with Rambler Alfalfa at 100 pounds per acre of seed and 400 pounds per acre of fertilizer (21-18-9). The seed germinated well. Dry weather during the summer killed off many plants and, by fall, the cover was quite sparse. The plot was untended after seeding, but by the summer of 1978 growth had improved. Samples of the Alfalfa roots were examined and found to be nodulating successfully.

In September 1976, a haul truck ramp with a side slope of up to 35° was spread with overburden. This area was treated with 100 pounds per acre of seed and 400 pounds per acre of fertilizer (27-18-9). The area was the first attempt at fall planting and was successful. In January of 1977, 100 Red Alders (Alnus rubra) were transplanted onto the slope. Survival was 78% after the first year.

The north side of the pit reached its final limits in 1978 and became available for reclamation. This area included the south side of the north waste dump and, as such, presents a challenge in terms of stabilization. The preparation of this area started in April 1978. Using a D8 bulldozer and trainee operators, unnecessary ditches were filled, roads recontoured and the area generally levelled. Soil stripped from the west side of the pit was spread 6 to 12 inches thick.

The reclamation operation using the operator trainee was quite successful in two ways: we received steady use of equipment, and the new operators who normally would be doing other work were introduced to reclamation practices.

After ground preparation, the area was hand seeded at a rate of 100 pounds per acre. Seeding was followed by application of 400 pounds per acre of fertilizer (27-18-9). The area was left untended and, by October 1978, a good cover had developed.

A major consideration of Island Copper's land reclamation policy in addition to the reclamation of the surface and slope of the land waste dump, is the development and implementation of a program to reclaim the shore of the marine landfill. In the spring of 1978, a small portion of the beach dump foreshore was set aside for the study of reclamation methods. A 200-foot wide section of the dump was resloped to establish a beach with a grade of approximately 10%. After grading, the area was left to natural colonization. The rate of colonization was monitored and both plants and animals were found on the test area seven weeks after resloping. In 1979, a research program will be initiated to determine the diversity and abundance of species on the test plot.

It has been demonstrated at Island Copper that planting grasses is an effective means of controlling erosion in the short-term, but it extends the time required for natural reforestation of an area. In time, the grasses are invaded by native species and the process of natural succession is initiated.

In summary, the objective of the reclamation program at Island Copper is to reduce erosion in the disturbed areas by stabilization with grasses followed by the promotion of native species.

DISCUSSION RELATED TO RON HILLIS'S PAPER

Ken Crane, Luscar Sterco Ltd. You have had no problems in handling the topsoil. Why couldn't you stock pile it for later use.

ANS. Well, you can't pile it. It must be spread right away, because it flows.

Neil Duncan, Energy Resources Conservation Board. You showed a very brief slide of the tailings being dumped into the bay or the sea. Oceanographer Jacques Cousteau has given a lot of bad publicity to mining operations which have done this in the tropical latitudes. Have you been visited by Cousteau or have you had divers or anyone interested in what is happening to the tailings being discharged into the bay.

ANS. No, Mr. Cousteau hasn't shown up. They wouldn't have much chance in diving anyway, because the turbidity would prevent them from seeing too much.

Bill Burge, Sage Creek Coal Limited. I would like to remark on how quickly the old ocean is recovering that beach area that Island Copper has.

ANS. There doesn't appear to be any reduction in growth rate. The test plot we have there is bounded on one side by our discharge of tailings and on the other side by our waste dumping. There is some evidence now that shows that our growth plates located there are growing better than the normal area. I don't think we are adding any nutrients there, but it does seem to be doing quite well, and we'll know better how we are doing next year when we do our program. There's going to be a large foreshore developed as a result of that marine dump and a lot of people are concerned about what's going to happen to it when we have finished our operations.

Dave Polster, Techman Ltd. Have you given any thought to adding small amounts of Alder seed to your grass and legume mix.

ANS. Yes. The first plot that we did on the beach in 1976 had Alder seeds in the mix, but they couldn't compete. It may work if we plant Alder shoots or seedlings.

Kerry Clarke, Arcon Associates. Why plant Alder. Why not Conifers.

ANS. Alders supply nitrogen to the soil.

PRESENTATION OF THE THIRD ANNUAL RECLAMATION AWARD

March 8, 1979

MINE RECLAMATION AWARDS

TERMS OF REFERENCE

Under the auspices of the British Columbia Ministry of Energy, 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. In addition to this award, two citations are given to recognize merit in mining reclamation. The guidelines for these awards are as follows:

1. Nominations will be solicited from Ministry of Energy, Mines and Petroleum Resources' 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 Energy, Mines and
   Petroleum Resources
   Minerals Resources Branch
   525 Superior Street
   Victoria, B.C.
   V8V 1T7

   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 be won in two successive years.

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

REPORT OF THE AWARDS SUBCOMMITTEE
TECHNICAL AND RESEARCH COMMITTEE
BRITISH COLUMBIA MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES

AND

THE MINING ASSOCIATION OF BRITISH COLUMBIA

This year two Citations and the Reclamation Award and a special citation were presented by the Hon. James J. Hewitt, Minister, Ministry of Energy, Mines and Petroleum Resources from the nominations received from individuals involved in the mining industry. This year the selection committee had a particularly difficult task in determining the recipients of the awards because of the number of excellent nominations. This is surely a sign that the industry is serious about its reclamation programs.

Before presenting the Citations and the Reclamation Award, honourable mention for achievements in reclamation was awarded to:

1. Bluebell Mine- for reclaiming the mine site and maintaining the Riondel community.

2. Pacific Petroleum- for an excellent reclamation program in the Northeast Coal Block.

3. Coleman Collieries - for reclamation of exploration disturbances in the Southeast Coal Block.

1978 RECLAMATION AWARD

This year the Reclamation Award was presented to Kaiser Resources Ltd., Sparwood B. C.

Kaiser Resources has continued its overall commitment to reclamation. Not only have they reclaimed large areas, but they have also increased their nursery by twenty acres for their tree and shrub programs, continued their nutrient-cycling studies, established a soil analytical facility, and are conducting wildlife studies.

Kaiser continues to produce results and lead the industry in the development of facilities and techniques for the propagation of native woody plants for operational scale reclamation.

RECLAMATION AWARD

PRESENTED TO

KAISER RESOURCES LTD.

Tony Milligan (right) and Lou Cherene (left) receive the 978 Reclamation Award, from Hon. James J. Hewitt, Minister of nergy, Mines and Petroleum Resources, on behalf of Kaiser .esources Limited.

CITATIONS

The First Citation was presented to Craigmont Mines Ltd. at Merritt, B.C. Craigmont is currently phasing out their operations and the company has filed their final reclamation plan. The mine area will be restored to a state of use and appearance that will be compatible with the surrounding environment.

The Second Citation was presented to Fording Coal Limited at Elkford, B.C. The present management and staff are dedicated to reclamation excellence. They have applied today's technology for rehabilitation of disturbed areas for fish and wildlife habitat. They are conducting research on slope stability of spoil piles, and are experimenting with seed mixtures, fertilizers and use of glacial till and other materials for ultimate reclamation applications. Their new laboratory, and their new twenty-acre nursery and greenhouse should make Fording a leader in environmental protection and reclamation.

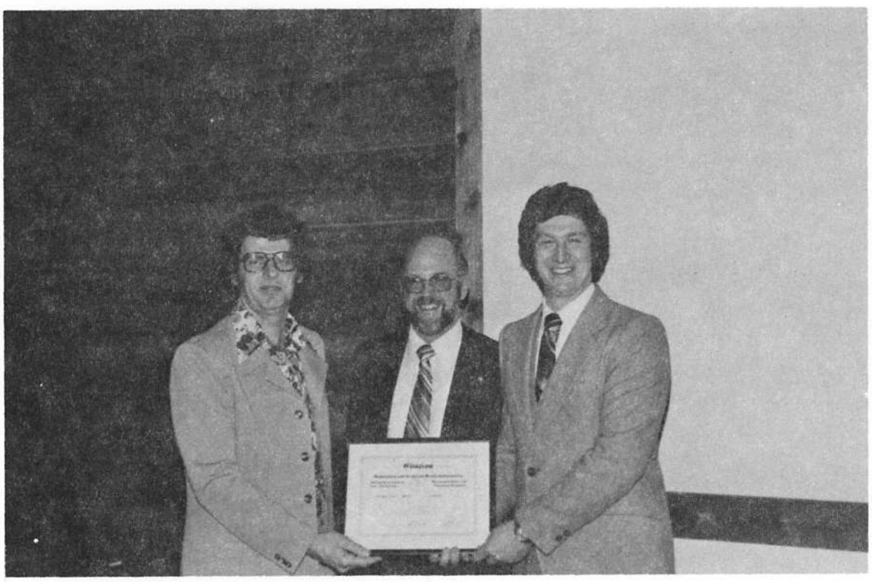
CITATIONS PRESENTED TO

CRAIGMONT MINES LTD.

Lloyd Gavelin (right) receiving Citation from Hon. James J. Hewitt, Minister of Energy, Mines and Petroleum Resources, on behalf of Craigmont Mines Ltd.

AND

FORDING COAL LTD.



Roger Berdusco (right) and Jim Popowich (left) receiving Citation from Hon. James J. Hewitt, Minister of Energy, Mines and Petroleum Resources on behalf of Fording Coal Ltd.

SPECIAL CITATION

This year a Special Citation was presented to Mr. J.D. McDonald, Senior Reclamation Inspector, Ministry of Energy, Mines and Petroleum Resources. This citation was given with unanimous support of the Technical and Research Committee on Reclamation. The Citation recognizes an individual who has demonstrated his dedication, foresight and objective assessments of mine reclamation.

SPECIAL CITATION

PRESENTED TO

JAKE McDONALD

Jake McDonald (right) receiving the special citation from the Hon. James J. Hewitt, Minister of Energy, Mines and Petroleum Resources.

RECLAMATION RESEARCH

Chairman of the Morning Session
Friday, March 9, 1979

Dr. L.M. Lavkulich
Professor, Soil Science
University of British Columbia

PHOSPHORUS REQUISITE FOR LEGUME-DOMINATED VEGETATION ON MINE WASTES

Paper Prepared Jointly
by:

R.T. Gardiner,
and
H.E. Stathers
Cominco Ltd.

PHOSPHORUS REQUISITE FOR LEGUME-DOMINATED VEGETATION ON MINE WASTES

INTRODUCTION

Two nutrients essential for sustaining plant life on mine waste are nitrogen and phosphorus. Whereas undisturbed soils generally have adequate nitrogen and phosphorus in forms used by plants to sustain life, this is not generally true for mine rock, tailings or, in some cases, overburden. In order for vegetation on mine waste to be self-sustaining and of sufficient quality and quantity to achieve revegetation objectives, nitrogen and phosphorus must be available to plants in quantities necessary to sustain growth and reproduction.

Rocks and minerals from which soils are formed, and which constitute the content of rock dumps and tailings ponds, contain very little nitrogen; so to satisfy plant requirements, nitrogen must be added; either in the form of:

a) fertilizer
b) by biological N Fixation or
c) as plant residues, with subsequent conversion of organic N to inorganic forms used by plants.

Phosphorus in soil comes largely from weathering of the mineral apatite which breaks down very slowly releasing phosphorus which subsequently forms a variety of compounds including the orthophosphate forms used by plants. Some plants develop a symbiotic association with certain soil micro-organisms which improve utilization of soil P; however, it has been our experience that the most effective method of providing phosphorus for vegetation on mine waste is by application of a phosphorus containing fertilizer.

Currently, fertilizers are the main source of N and P added during revegetation of mine waste. The usual approach is to apply fertilizer, generally containing N, P, and K at a somewhat arbitrarily selected amount prior to seeding in order to promote vegetation establishment; and, then, sustain growth by annual maintenance applications over a period of years. Once maintenance is discontinued, vegetation often deteriorates because the nutrient supplying capacity of the waste has not been increased to a level necessary to sustain growth. This is particularly true of vegetation dominated by grasses which are dependent upon maintenance applications of nitrogen to satisfy their requirements for growth and reproduction. In contrast, vegetation dominated by nitrogen-fixing legume species can sustain growth and produce substantial quantities of organic matter for several years after maintenance fertilizer has been discontinued; primarily, because of their ability to satisfy N requirements by utilizing atmospheric N. The advantages of establishing legume-dominated vegetation on mine waste are obvious; by eliminating the need for annual applications of nitrogen, maintenance costs can be reduced or even eliminated, and at the same time, substantial quantities of nitrogen can be added to the system in organic form for subsequent re-use by plants. However, phosphorus, which must be added to the system as fertilizer, must be available in sufficient quantity and in a form utilized by plants, if legume growth and N fixation are to be sustained at a level necessary to achieve revegetation objectives.

A study was initiated at Fording Coal in May 1977 to determine the phosphorus requirement of waste rock and overburden for establishing legume-dominated vegetation and for maximizing organic matter production and biological N fixation over an extended period of time, in this case a minimum of eight years. During this period, there would be no maintenance fertilizer applied. In other words, we are attempting to increase the phosphorus supplying capacity of the waste to a level necessary to sustain maximum legume growth over the long term. This would be achieved by applying the total phosphorus requirement in a single application prior to seeding and, at the same time, determine how much phosphorus fertilizer must be applied to achieve this objective. Since relatively large quantities of phosphorus fertilizer may be required, and since soluble fertilizer phosphorus reverts to less soluble forms following application, it was considered prudent to investigate various frequencies of application and the resultant effects on efficiency of phosphorus use. On adjacent areas, equivalent total amounts of phosphorus were applied in equal increments, either annually or biennially, throughout the study period.

EXPERIMENTAL DESIGN

The study is being conducted at Fording Coal, at an elevation of 1700 metres and on two types of growth media, waste rock and overburden. Waste rock is a mixture of sandstone and shale; overburden is a calcareous glacial till. Table 1 shows the chemical and physical characteristics of the waste rock and glacial till.

Phosphorus was applied at rates ranging from 0 to 1600 kilograms of P_2O_5 per hectare, and in the form of treble superphosphate. The fertilizer was broadcast prior to seeding and incorporated throughout the surface's 15 centimetres of waste using a rototiller.

Rambler Alfalfa and Boreal Creeping Red Fescue were seeded, as a mixture, at 30 kilograms per hectare. The legume comprised two-thirds of the mixture by weight and was appropriately inoculated. Nitrogen and potassium were applied at 50 kilograms per hectare each to promote seedling establishment and growth during the first growing season. We subsequently learned from another study that addition of potassium does not improve legume seedling establishment and growth on these two types of mine waste.

Two growing seasons have passed since the study was initiated. During the first growing season the effect of phosphorus on legume establishment was assessed by evaluating:

a) legume seedling populations
b) seedling height
c) seedling phosphorus content.

TABLE 1

CHEMICAL AND PHYSICAL PROPERTIES OF FORDING COAL WASTE ROCK AND GLACIAL TILL OVERBURDEN

CHARACTERISTICS	WASTE ROCK	GLACIAL TILL
1. <u>CHEMICAL PROPERTIES</u>		
$CaCO_3$ Equivalent (%)	5.3	26.0
C.E.C. (me/100g)	2.4	1.5
Exch. Cations (me/100g)		
Ca	20.2	42.8
Mg	2.6	2.0
K	0.5	0.4
Na	0.2	0.1
Fe	5.6	5.6
Total N (%)	0.4	0.1
Total P (ppm)	850	1000
Extractable P (ppm)	1	1
Non-Exch. K (ppm)	800	1120
pH	8	8
ECe (mmhos/cm)	1.8	0.5
2. <u>PHYSICAL PROPERTIES</u>		
Clay (%)	11	16
Silt (%)	25	36
Sand (%)	64	48
Texture	sl	l
Moisture Retention (%)		
1/3 atm	17	14
15 atm	4	4
A.W.S.C.	13	10

During the second growing season, the effect of phosphorus on legume growth and nitrogen fixation was assessed by evaluating:

a) legume content

b) biomass

c) nitrogen yield, and

d) phosphorus content.

Waste rock and overburden were sampled each growing season to determine extractable phosphorus levels.

RESULTS AND DISCUSSION

As indicated earlier, this study is planned to continue for a minimum of eight years. Results reported at this time will deal only with the effect of phosphorus applied over a wide range of rates on Alfalfa establishment during the first growing season, and Alfalfa and Creeping Red Fescue growth during the second growing season. The effects of varying application rates and frequency on phosphorus use efficiency will not be discussed at this time.

First Growing Season Results

Legume Seedling Populations. Phosphorus did not affect Alfalfa seedling populations on either type of waste (Figure 1). However, seedling populations were significantly higher on waste rock than on overburden. Overburden forms a hard surface crust on drying and this may account for reduced seedling emergence.

A minimum of 10 seedlings per 0.1 square metres has been suggested as necessary for optimum forage production in agriculture; our experience suggests 3 to 5 legume seedlings per 0.1 square metres will generally produce a satisfactory stand on mine waste. Although these numbers will vary with the plant species, it would appear that Alfalfa seedling

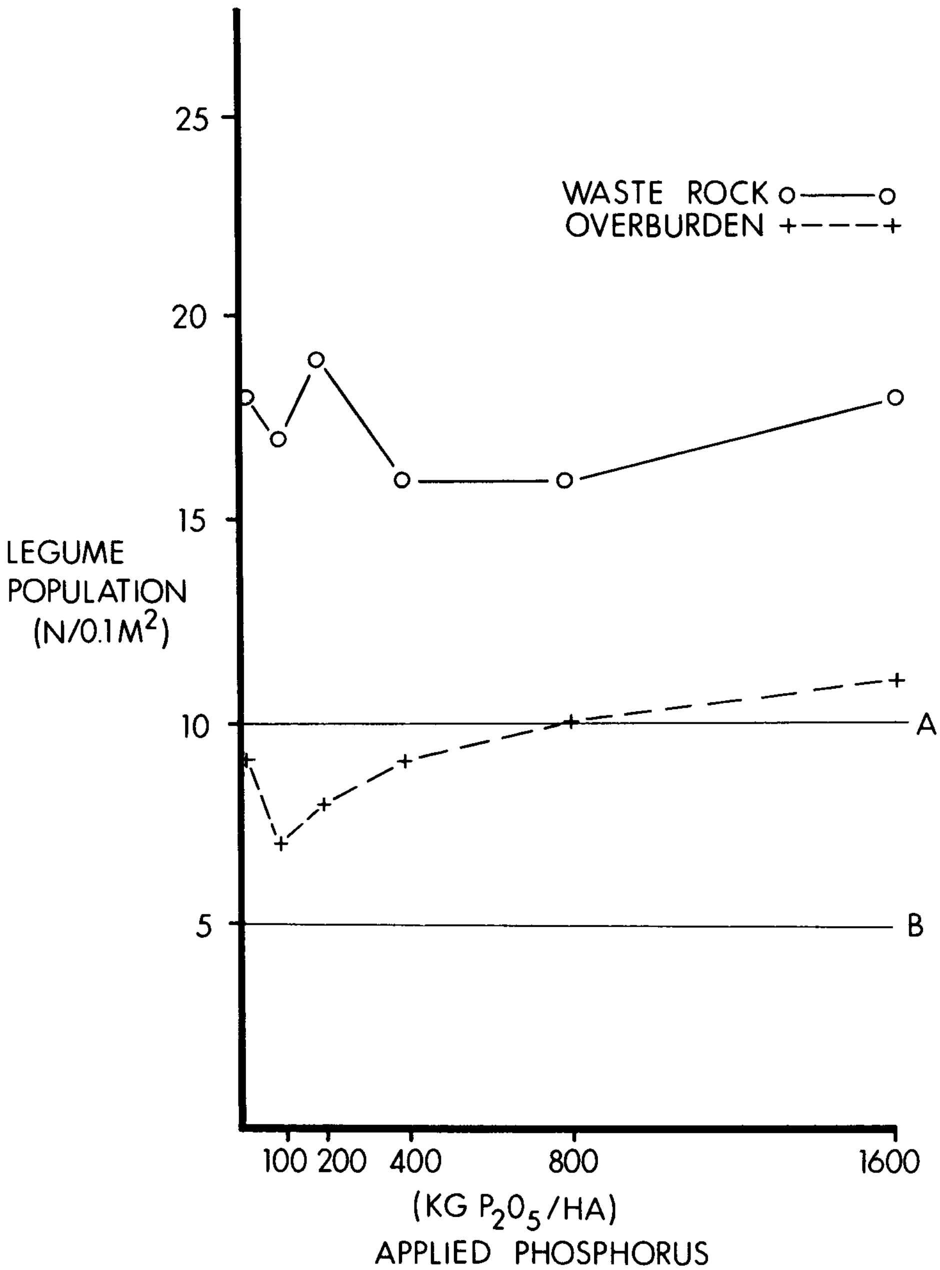


Figure 1: Effect of Phosphorus on Legume Seedling Population

populations were adequate on both types of mine waste without addition of phosphorus.

Legume Seedling Growth. The effect of phosphorus is more evident when related to Alfalfa seedling growth (Figure 2). Seedling height was increased significantly by addition of phosphorus. On waste rock, near maximum height was produced by 400 kilograms of P_2O_5 per hectare. At the lower phosphorus rates, seedlings were significantly taller on waste rock than on overburden.

In regions of severe climate, seedling height has been correlated with winter survival and seed production during the second growing season.

Legume Seedling Phosphorus Content. The phosphorus content of Alfalfa seedlings was increased significantly by phosphorus fertilizer, and was significantly higher in seedlings grown on waste rock than on overburden (Figure 3). One hundred kilograms of P_2O_5 per hectare added to waste rock, increased phosphorus content of seedlings to within the "critical P range" for Alfalfa (1); while 400 kilograms of P_2O_5 per hectare increased phosphorus content to 0.26%, a level reported necessary for maximum Alfalfa yield. On overburden, however, 800 kilograms of P_2O_5 per hectare was required to increase seedling phosphorus content to within the critical range. The term critical level is referred to as the plant composition below which growth may be expected to be limited by a low supply of a nutrient (1).

Second Growing Season Results

Legume Content. Legume content describes the percentage of the total vegetative cover of a grass-legume stand which was due to the legume

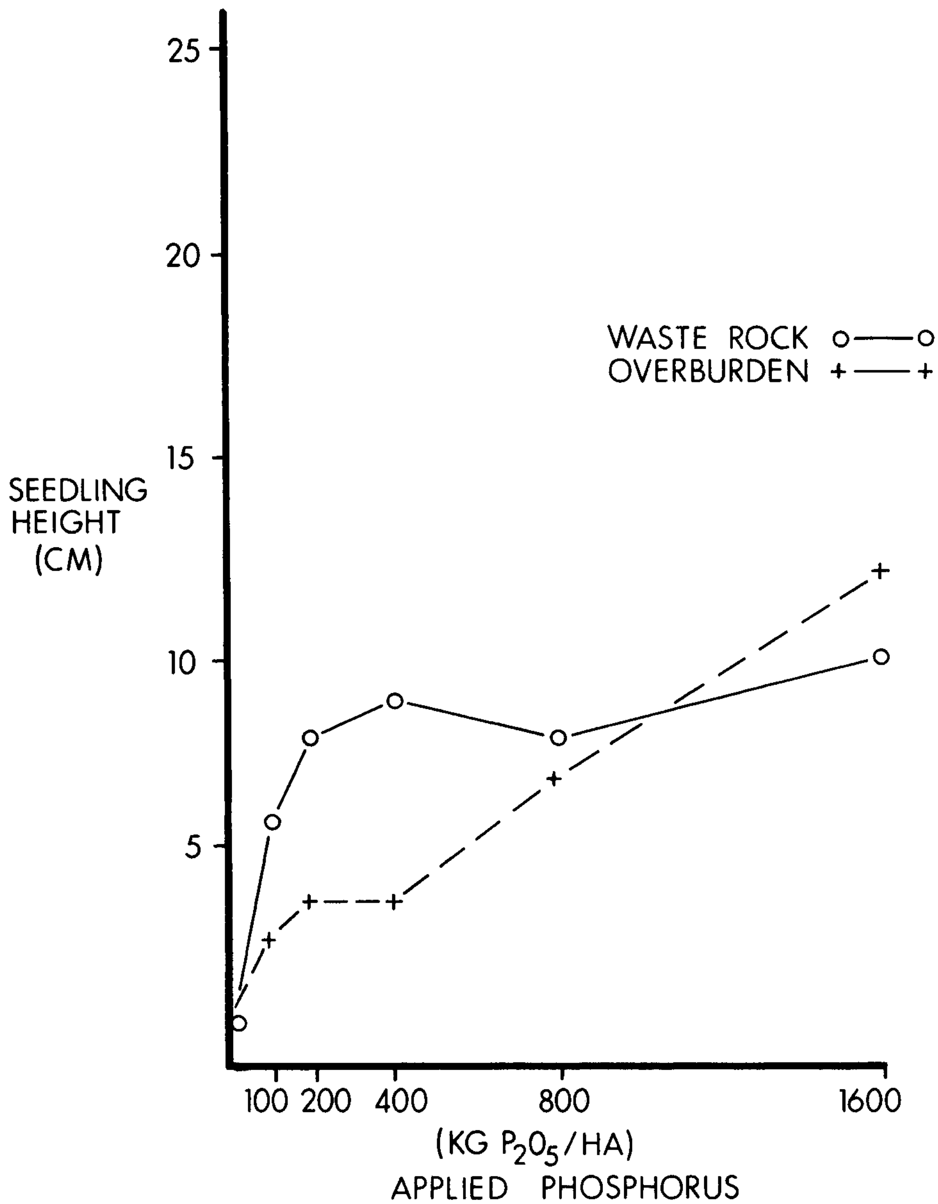


Figure 2: Effect of Phosphorus on Legume Seedling Growth

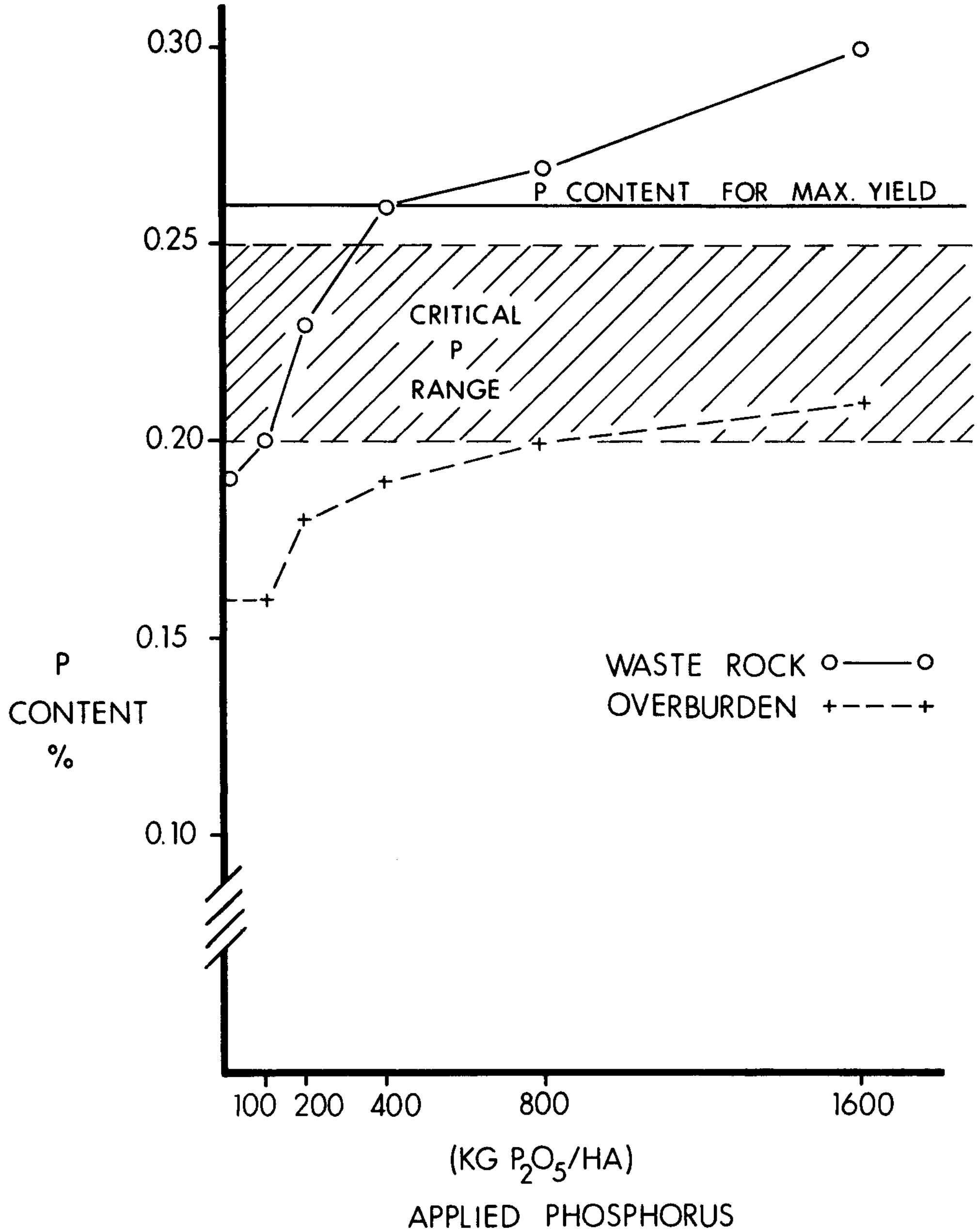


Figure 3: Effect of Phosphorus on P Content of Legume Seedlings

species present. To have a legume-dominated stand, the legume content should exceed 50%.

Phosphorus was essential for establishment of legume-dominated vegetation on both waste rock and overburden (Figure 4). However, substantially more phosphorus was required to achieve legume dominance on overburden than on waste rock.

As you will recall from our discussion of first growing season results, Alfalfa seedlings growing on overburden fertilized with 400 kilograms of P_2O_5 per hectare and less, were small relative to those growing on waste rock, and contained less than the critical level of phosphorus for Alfalfa. Alfalfa seedlings on overburden may have suffered a higher mortality during the first winter than did the larger, more vigorous seedlings growing on waste rock.

Organic Matter Production. As indicated earlier, one objective of revegetation was to produce organic matter. A significant correlation was observed between biomass, expressed as tonnes per hectare, and phosphorus applied on both waste rock and overburden (Figure 5). Biomass ranged from 0.2 tonnes per hectare with no phosphorus, to between 4 and 5 tonnes per hectare with 800 kilograms of P_2O_5 per hectare.

The difference in biomass between waste rock and overburden was less than might be anticipated if the much wider differences in legume content are considered, particularly at phosphorus rates of 800 kilograms per hectare and less. The growth response to phosphorus by Creeping Red Fescue, which dominated vegetation on overburden fertilized with less than 800 kilograms of P_2O_5 per hectare, accounted for the relatively high production of organic matter on overburden.

Biological Nitrogen Fixation. Nitrogen yield was used as an indicator of biological nitrogen fixation (Figure 6). Nitrogen yield, expressed as kilograms of N per hectare, is the product of biomass times the nitrogen content of the vegetation. Significant correlations were observed between

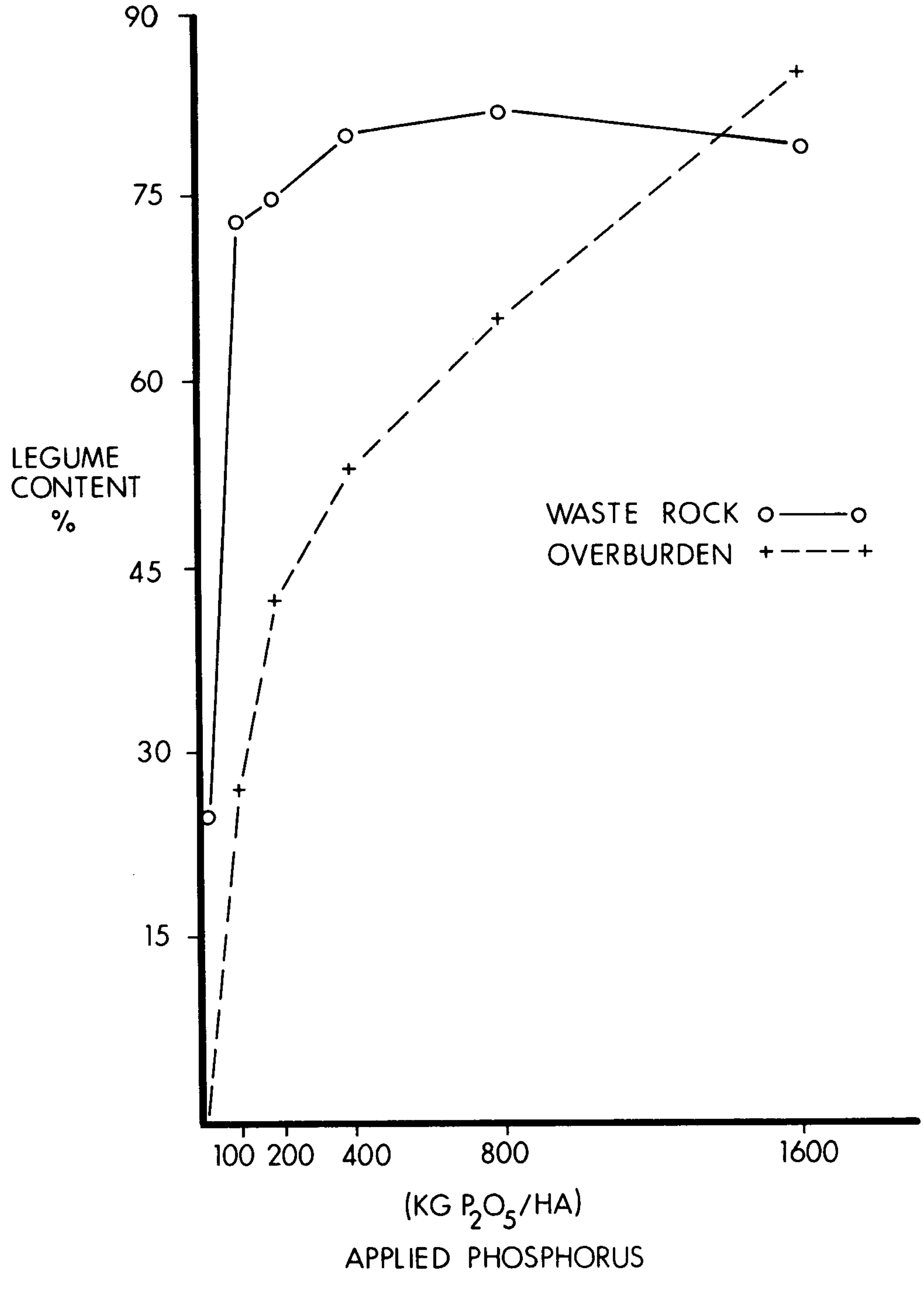


Figure 4 : Effect of Phosphorus on Legume Content

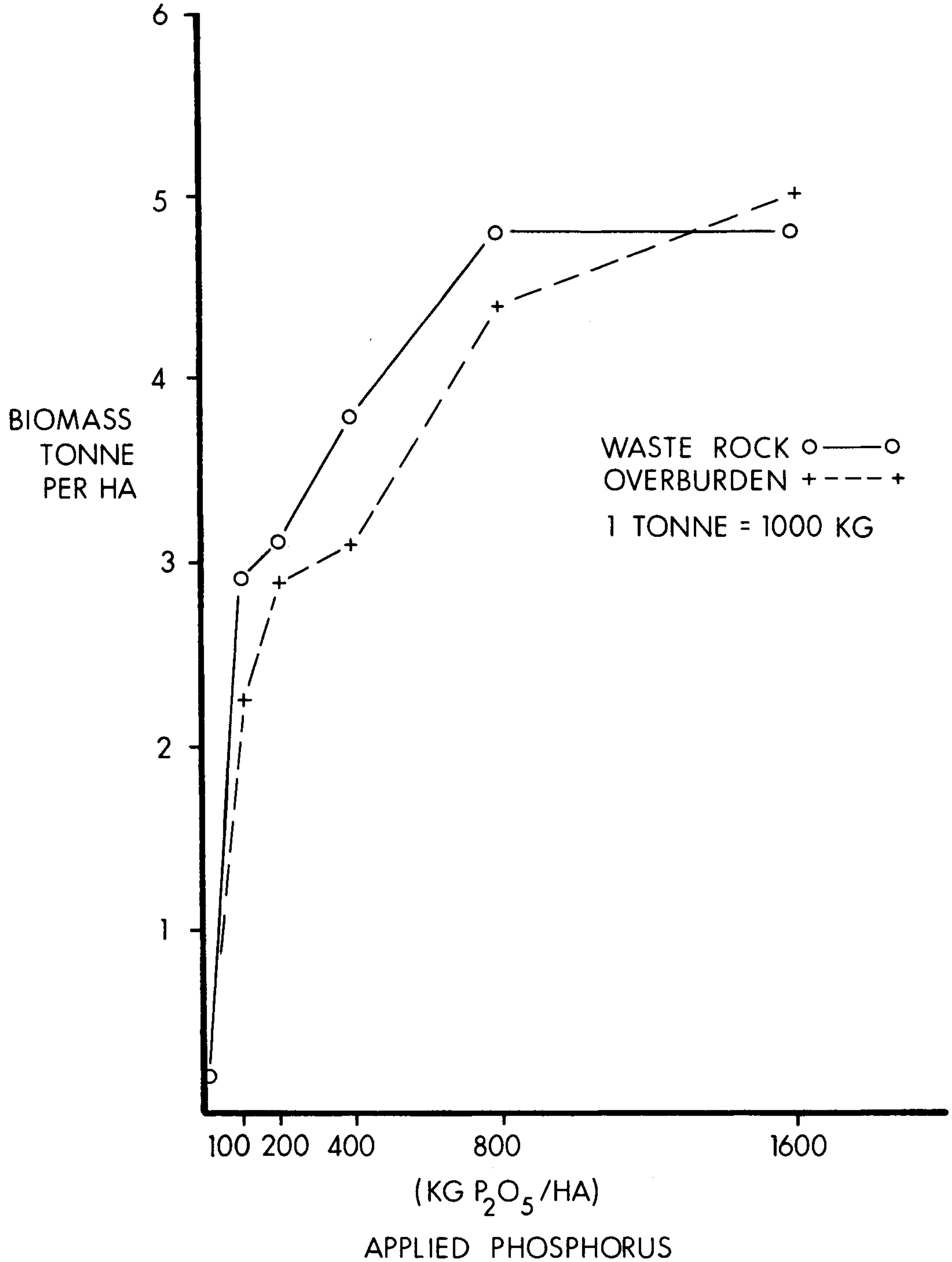


Figure 5: Effect of Phosphorus on Organic Matter Production

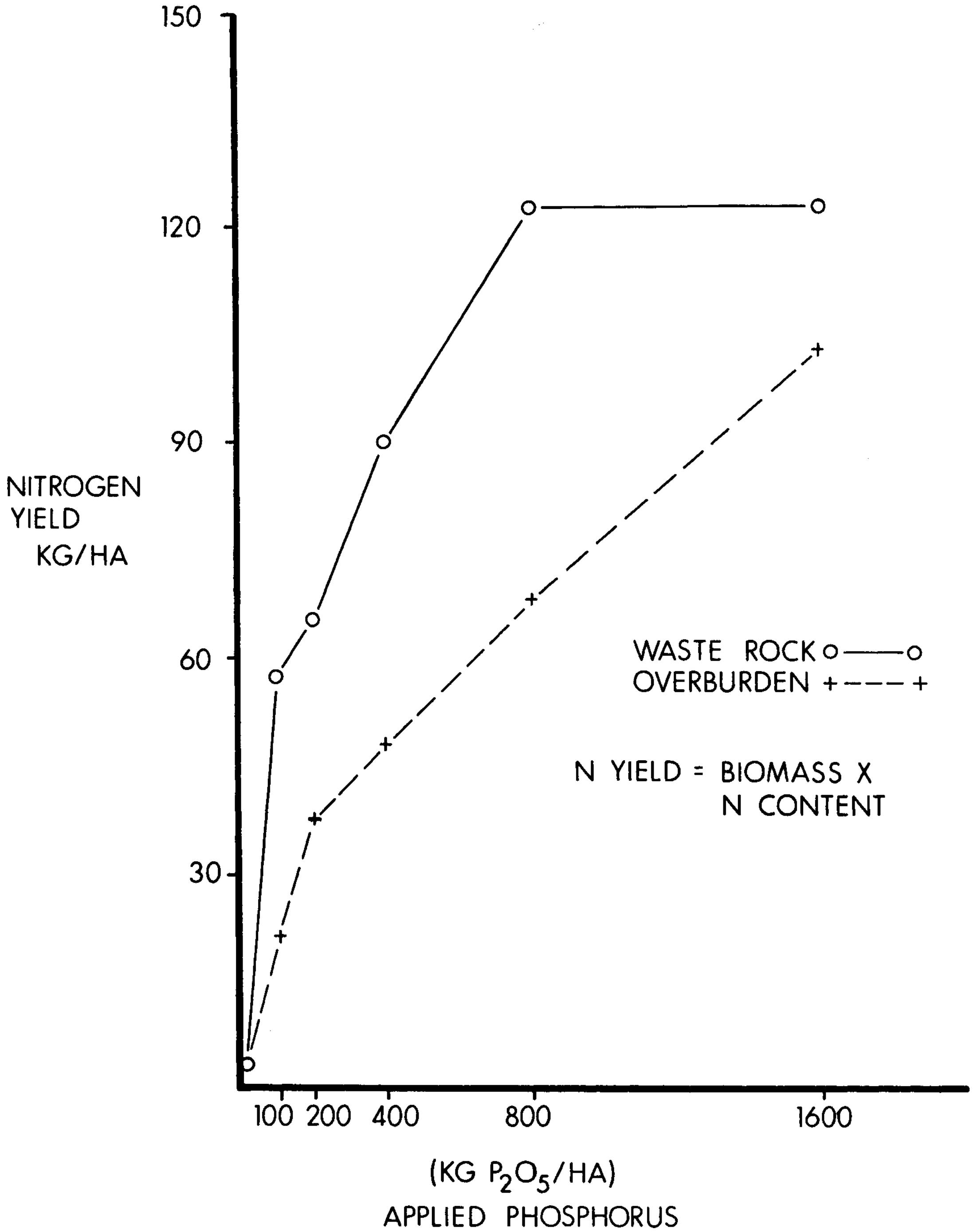


Figure 6: Effect of Phosphorus on Biological Nitrogen Fixation

N yield and applied phosphorus for both types of mine waste. Biological N fixation was significantly higher on waste rock than on overburden and is a reflection of both a higher legume content and higher organic matter production.

On waste rock N yield ranged from 3 kilograms of N per hectare with no phosphorus, to 123 kilograms of N per hectare with 800 kilograms of P_2O_5 per hectare, a difference of 120 kilograms per hectare of nitrogen. Current retail price for nitrogen fertilizer is in the order of 41 cents per kilogram of N; therefore, the value of nitrogen fixed during one growing season ranged from 23 dollars per hectare (9 dollars per acre) at the 100 kilograms per hectare phosphorus rate, to 49 dollars per hectare (20 dollars per acre) at the 800 kilograms per hectare phosphorus rate. I might add that transportation and application costs were not included in the above. Depending on how remote a mine is relative to a fertilizer dealer, transportation costs can be significant, as much as 24 cents per kilogram of N, which would increase the value of biologically fixed nitrogen by another 60%.

Phosphorus Content of Vegetation. As suggested earlier the critical phosphorus content for Alfalfa is in the range of 0.2% to 0.25%, and at levels below 0.2% Alfalfa growth and reproduction would be limited because of an insufficient supply of phospherus. In addition to optimizing growth and reproduction, the phosphorus content of plant residues is considered an important factor in determining whether net mineralization or immobilization of phosphorus occurs during decomposition of residues by micro-organisms. The critical level above which mineralization or the release of organic P in a form which can be utilized by plants takes place is above 0.2% (2). On waste rock, these critical P levels in vegetation were not achieved until 800 kilograms of P_2O_5 per hectare was applied (Figure 7). On overburden, 1600 kilograms of P_2O_5 per hectare was required to produce vegetation with 0.2% phosphorus.

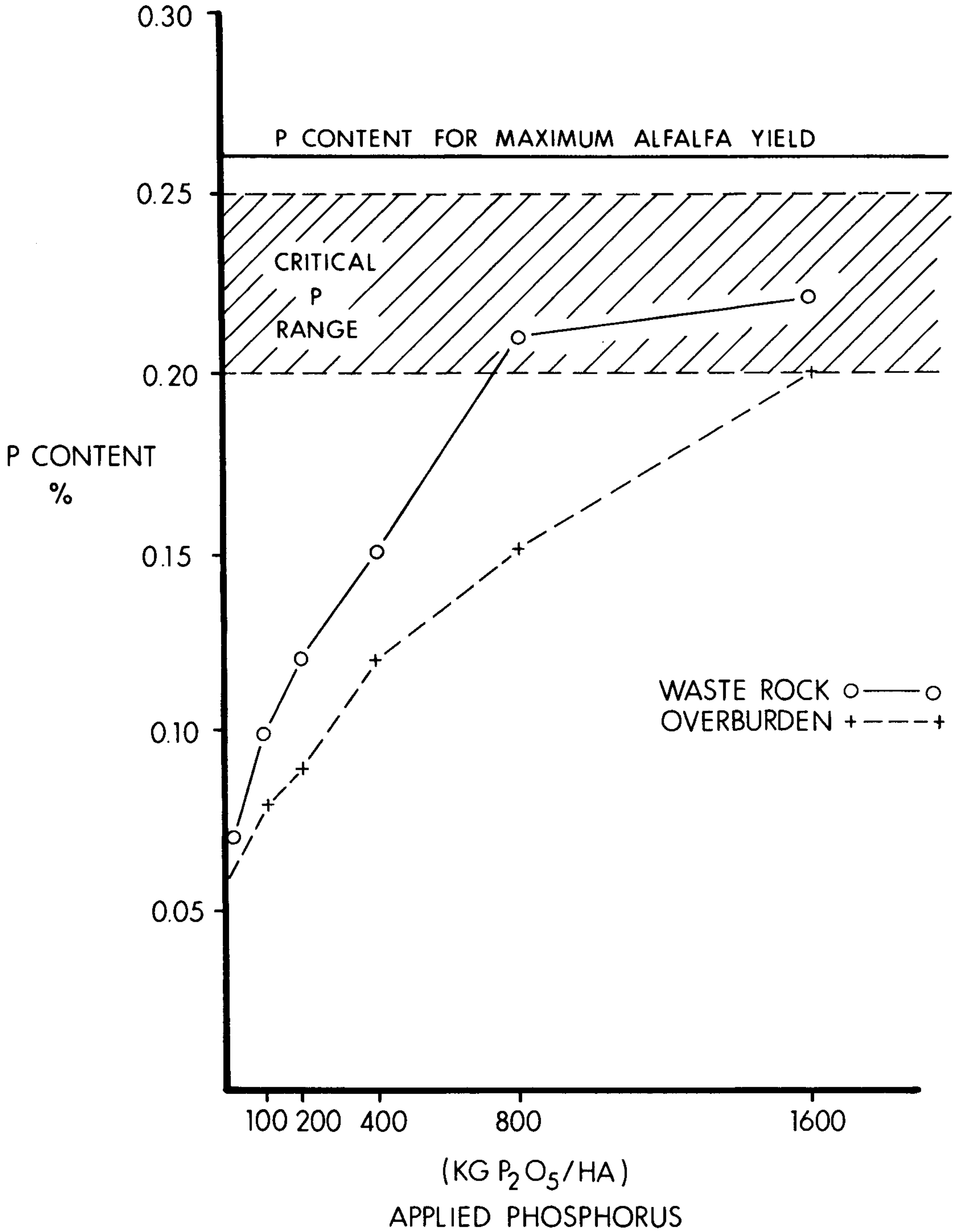


Figure 7: Effect of Phosphorus on P Content of Vegetation

SUMMARY AND CONCLUSIONS

The principle objective of this study was to determine if a maintenance-free plant community can be established on mine waste. Experimentation included using legume species to add nitrogen to the system, and increasing the phosphorus supplying capacity of the waste to a level capable of sustaining growth and reproduction over the long term, by applying the total phosphorus requirement as fertilizer prior to seeding. Other important objectives include determining the phosphorus requirement of two types of mine waste at Fording Coal and the most efficient method for applying phosphorus to these mine wastes.

The study will be monitored for a minimum of eight growing seasons during which period no maintenance fertilizer will be applied. Preliminary results after two growing seasons were reported.

Phosphorus has been confirmed as the only nutrient which limits the growth of nitrogen-fixing legume species on mine rock and overburden at Fording Coal. By supplying adequate phosphorus, legume-dominated vegetation produced large quantitities of plant residues, in the order of 4 to 5 tonnes per hectare, and fixed significant amounts of nitrogen, up to 125 kilograms of N per hectare per year.

To achieve the above levels of organic matter and nitrogen production, large quantities of phosphorus were required, in the order of 800 kilograms of P_2O_5 per hectare for waste rock and 1600 kilograms of P_2O_5 per hectare for glacial till overburden.

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2. Dalal, A.C. 1977. Soil Organic Phosphorus. Advances in Agronomy 29: 83-118. Academic Press. New York.

HAT CREEK RECLAMATION STUDIES
RESULTS OF THE FIRST YEAR PROGRAM

Paper Prepared Jointly
by:

F.G. Hathorn,
B.C. Hydro and Power Authority

and

R.L. Docksteader and D.K. McQueen
Acres Consulting Services Limited

HAT CREEK RECLAMATION STUDIES
RESULTS OF THE FIRST YEAR PROGRAM

SUMMARY

Test plots to evaluate the revegetation of waste materials expected from the proposed Hat Creek coal mine and powerplant have been established in the Hat Creek Valley. These plots were seeded with three different seed mixes of four species each during the fall of 1977. At the same time two additional tests were undertaken to evaluate the revegetation of typical waste embankments at slopes of 22^{o}, 26^{o} and 30^{o}.

During the late summer of 1978 the vegetation on these test plots was counted and harvested to determine the progress of the experiments in the first year following seeding. This paper describes the sampling program and presents and discusses the results in the context of short-term revegetation goals, namely the establishment of vegetation for the prevention of wind and waterborne erosion.

The principal conclusions are as follows:

- Revegetation of surficial materials such as colluvium, gravel and till was readily achieved. The sodic materials, gritstone and bentonitic clay proved more difficult to revegetate. The carbonaceous wastes would require a cover of suitable material in order to be revegetated in the first year. Fly ash, because of its fine and uniform texture would likewise benefit from a thin surface cover if vegetation for erosion control is to be established in the short term.

- The effect of topsoil was to increase emergence success and biomass on carbonaceous soils, gritstone and bentonitic clay, while on colluvinm and gravel a decrease was observed. It is suggested that the retention of surficial materials such as

colluvium and gravel with topsoil for the future surfacing of waste dumps would be beneficial.

- Several vegetation species suitable for short-term revegetation practices have been identified. Of the grasses, Fall Ryegrass, Streambank and Slender Wheatgrasses performed particularly well while Sainfoin was the most successful legume.

- Revegetation of 15 metre high embankments with up to 30° slopes constructed of till or gravel was readily achieved. Erosion in the first year was not apparent.

INTRODUCTION

Over the past several years B.C. Hydro has been examining the possibilities of developing the Hat Creek coal deposits to fuel a coal-fired powerplant. As part of the environmental planning for this project, a program was undertaken to examine the reclamation potential of the various waste materials expected from the proposed open pit mine, and to determine suitable vegetation species for this purpose. Details of the rationale for this program, preparation of test sites and species used, have been described previously (1).

In the summer of 1977, following the extraction of a bulk sample of coal, seven different waste materials, typical of those expected from a full-scale mine, were selected for reclamation testing. In addition, a bulk sample of fly-ash was returned from a large-scale combustion test. These eight materials were arranged in field test plots located in an open area near Aleece Lake at Hat Creek. Half of each plot was capped with a thin layer of topsoil. Three different seed mixes of four species each were sown on each plot in the fall of 1977.

Additional testing of revegetation practices was undertaken at two other locations at Hat Creek, where typical waste retaining embankments were constructed and reclamation at slopes of 22°, 26° and 30° was examined.

In July and August of 1978, a counting and harvesting program was undertaken to determine the progress of these experiments. This paper describes the methods of sampling and analysis and discusses the results obtained within the context of short-term revegetation goals.

SAMPLING PROGRAM

Aleece Lake

The waste material test plots at Aleece Lake measured approximately 15 metres square by 1 metre deep. Half of each plot was covered with a layer of topsoil about 5 centimetres deep. Three seed mixes (Table 1) were used, such that each mix was applied to equal areas of both the topsoiled and non-topsoiled portions of each plot. Two seed mixes only, were used on the fly-ash plot since it was smaller and could not accommodate all three. Thus there were 46 vegetation populations at the Aleece Lake test area made up of seven materials with two surface treatments and three seed mixes, plus the fly-ash plot with two surface treatments and two seed mixes. Each material plot had six populations except the smaller fly-ash plot, which had four.

Sample Locations. Each population was sampled at eighteen locations, selected as follows:

Three transects, 1 metre apart, were marked lengthwise across each population (Figure 1). Twenty equidistant points, 31.7 centimetres apart, were set out along each transect, an allowance being made for edge effects. Thus sixty potential sampling points were located on each population. Of these, 18 were randomly selected using the method described by Zar (2).

A wooden quadrat 31.7 centimetres x 31.7 centimetres (0.1 square metres) within which all samplings were carried out, was centred on each

TABLE 1

SEED MIXES USED AT ALEECE LAKE

GRASS OR LEGUME (VARIETY)	% BY NUMBER OF SEEDS	
SEED MIX I		
CRESTED WHEATGRASS (NORDAN)	41	
CANADA BLUEGRASS	29	
ALFALFA (DRYLANDER)	26	
FALL RYEGRASS	4	
	APPLICATION RATE	5 KG/HA
SEED MIX II		
RUSSIAN WILD RYEGRASS	39	
SLENDER WHEATGRASS	18	
SAINFOIN (MELROSE)	25	
SWEET CLOVER	18	
	APPLICATION RATE	108 KG/HA
SEED MIX III		
SMOOTH BROMEGRASS (MANCHAR)	19	
STREAMBRANK WHEATGRASS	39	
CANADA BLUEGRASS (RUBENS)	14	
DOUBLE CUT RED CLOVER	28	
	APPLICATION RATE	48 KG/HA

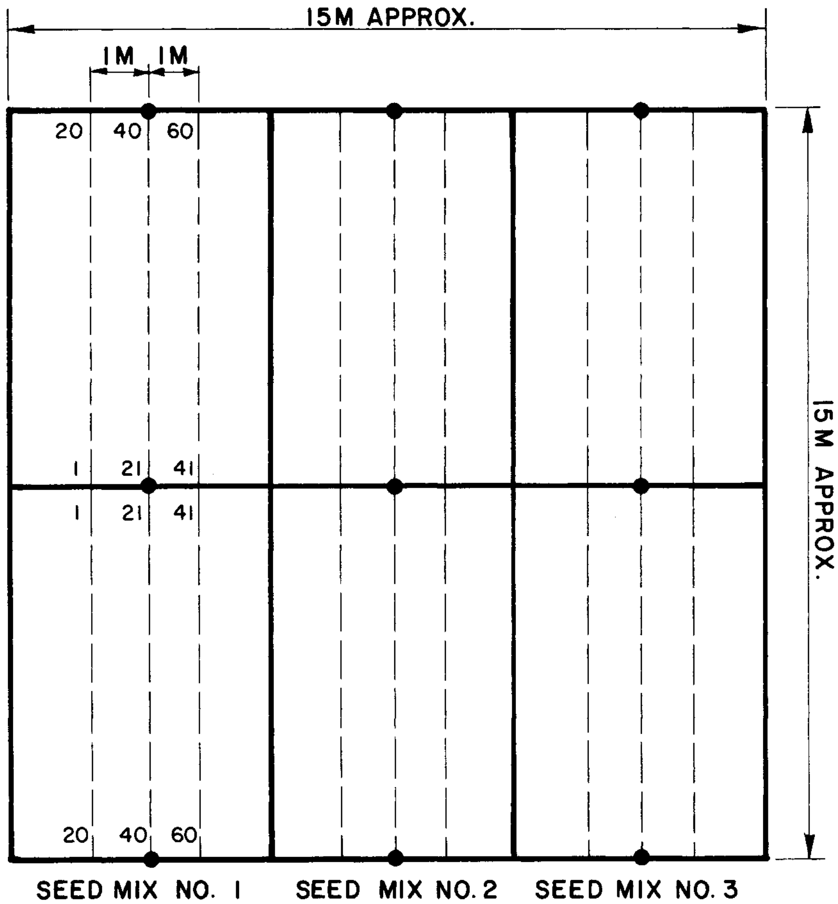

FIGURE I

LEGEND

——— *Population boundaries*

– – – *Transect line*

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY		
HAT CREEK PROJECT **ALEECE LAKE PLOTS** **TRANSECT & SAMPLING POINT LOCATIONS**		
DATE FEB 1979	FIG. I	R
DWN CY	DWG No.	

REPORT No.

of the selected sampling points. The area covered in sampling each population was therefore approximately five percent of the total area of that population.

Sampling Method. Data recorded at each quadrat included: the total number of each vegetation species present, their approximate height and the percent ground cover. A general note on the condition of the vegetation was also made. Vegetation was harvested for biomass production analysis. Samplers wearing plastic gloves clipped vegetation at ground level (i.e. only the aerial portion was collected) using acid-washed (10% HNO_3) stainless steel scissors. Each of the agronomic species collected was bagged separately in bleached white paper bags. Sampling was carried out when the plants were relatively dry. Native species (invaders) were identified and collectively bagged in one bag per population.

Biomass production was determined by drying and weighing the bagged samples at B.C. Hydro Research and Development Laboratories. Drying was carried out in a forced circulation oven at $100^{\circ}C$ for 24 hours.

Slope Test Plots

Test slopes at Houth Meadows and Medicine Creek were approximately 15 metres wide and varied in length depending on the slope angle. Half the width of each plot at Houth Meadows was covered with approximately 5 centimetres of topsoil. The upper and lower halves of each test plot were sampled, thus 12 populations existed at Houth Meadows and 6 at Medicine Creek.

Two transect lines were run across each slope, one was a quarter of the slope length from the top, and the other a quarter of the slope length from the bottom (see Figure 2). Five sampling points were arbitrarily located at approximately equal distances along each transect line, care being exercised to avoid areas previously disturbed.

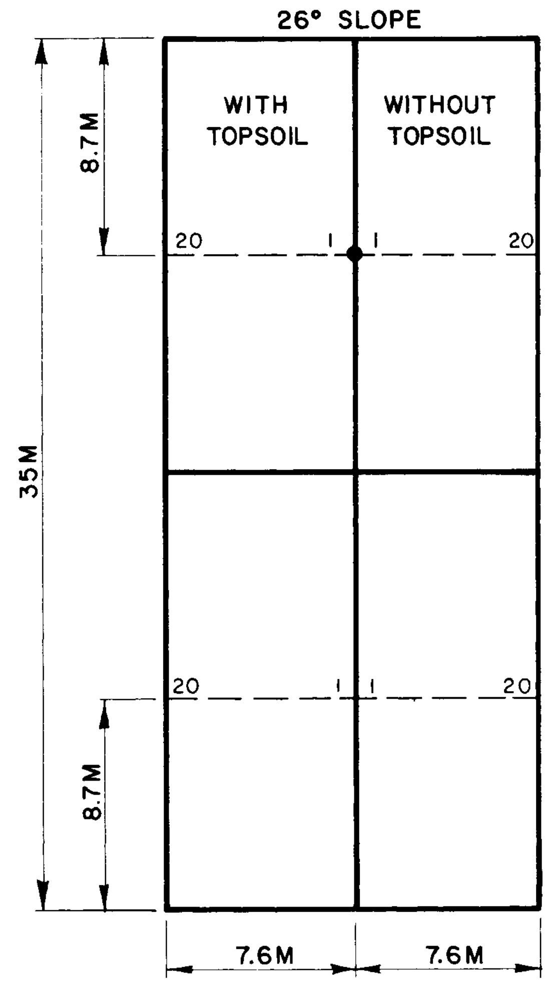

FIGURE 2

LEGEND

——— *Population boundaries*

- - - - *Transect line*

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

TYPICAL SLOPED PLOTS TRANSECT & SAMPLING POINT LOCATIONS

DATE FEB 1979	FIG. 2	R
DWN CY	DWG No.	

REPORT No.

Sampling was carried out as indicated previously for the Aleece Lake plots except at Medicine Creek, where the vegetation was not retained for biomass determination.

RESULTS FROM ALEECE LAKE PLOTS

Soil characteristics of the eight waste materials at Aleece Lake exhibited a wide variation. The success of the revegetation trials is discussed in the light of these characteristics. The performance of the twelve vegetation species tested is discussed separately.

Soils as Growth Media

Based on their chemical and physical properties (Table 2) the eight waste materials may conveniently be grouped into four categories: carbonaceous, sodic, alkaline and fly-ash materials. Results of biomass and plants produced per unit area are given in Tables 3 and 4.

Carbonaceous Materials. Both the coaly waste and carbonaceous shale exhibited low pH and a moderately high soluble boron concentration. Their dark colour would be expected to cause high surface temperatures and surface drying. In addition, the shale is somewhat water repellent and moisture does not easily penetrate the surface.

In terms of biomass produced and seedling emergence, neither material proved to be a successful growth medium (Tables 3 and 4). The chemical characteristics of the materials appear to be less deterrent to plant growth than do their physical properties, particularly their dark colour and the hydrophobic nature of the shale. The poor plant emergence on these materials may be attributed to unsuitably low soil moisture conditions during the period of potential germination. Average biomass production per plant was low compared with that in other soils (Table 5). Plants rarely progressed beyond the seedling stage.

TABLE 2

ANALYSIS OF SOIL MATERIALS AT ALEECE LAKE

	Texture		Organic Matter %	pH	Conductivity mmho/cm	Available Plant Nutrients kg/ha					S (ppm)	B (ppm)	Na (ppm)
	>2mm %	<2mm Class				N	P	K	Ca	Mg			
Carbonaceous Shale	18	N.D.	18.0	4.5	3.70	93	22	365	6,882	1,120+	30+	1.44	70
Coal Waste	N.D.	Clay	30+	4.0	5.00	8	19	318	4,463	1,120+	30+	3.50	90
Bentonitic Clay	N.D.	Clay	0.7	8.1	3.80	8	53	870	10,000+	1,120+	30+	-	2,050
Gritstone	4	Loam	2.3	8.7	1.30	39	90	844	5,776	1,120+	30+	-	980
Colluvium	39	Sandy Clay Loam	3.0	7.9	3.50	21	63	631	10,000+	1,120+	30+	0.30	140
Baked Clay	44	Sandy Loam	0.7	8.0	0.90	3	49	812	10,000+	1,120+	30+	<0.20	150
Glacial Gravel	67	Silt Loam	2.0	8.3	0.56	53	80	507	10,000+	1,120+	5.0	0.38	50
Fly Ash	0	Silt Loam	1.2	9.1	0.32	9	43	124	3,471	239	17.6	11.09	20

Sampled: 25/26 April 1978
Analyzed: B.C. Department of Agricultural Soil Testing Laboratory, Kelowna.
N.D. - No Data.

TABLE 3

TOTAL BIOMASS PRODUCED ON ALEECE LAKE PLOTS

Plot	Biomass Produced In g/m^2							
	Seed Mix 1		Seed Mix 2		Seed Mix 3		Average	
	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil
Carbonaceous Shale	5	81	0	22	0	23	1.7	42
Coal Waste	6	71	3	17	6	29	5	39
Bentonitic Clay	41	120	20	35	11	41	24	65
Gritstone	56	152	21	33	16	32	31	72
Colluvium	506	486	139	125	171	127	272	246
Baked Clay	320	322	104	74	88	52	171	149
Glacial Gravels	260	236	62	62	67	32	130	110
Fly-Ash	142	144	4	103	-	-	73	124
Average	167	202	44	59	51	48		

TABLE 4

NUMBER OF PLANTS PRODUCED ON ALEECE LAKE PLOTS

Plot	Average Number of Plants Per m^2							
	Seed Mix 1		Seed Mix 2		Seed Mix 3		Average	
	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil
Carbonaceous Shale	30	380	0	400	20	360	17	380
Coal Waste	120	240	110	490	210	270	147	333
Bentonitic Clay	140	230	400	530	270	330	270	363
Gritstone	190	390	430	510	260	240	293	380
Colluvium	310	240	600	450	650	520	520	403
Baked Clay	170	230	520	480	360	520	350	410
Glacial Gravels	300	270	490	490	390	190	393	317
Fly-Ash	310	140	370	500	-	-	340	320
Average	200	270	370	480	310	350		

TABLE 5

NUMBER OF PLANTS AND BIOMASS PRODUCTION AT ALEECE LAKE PLOTS

Material	Without Topsoil			With Topsoil		
	Number of Plants/m^2	Biomass g/m^2	Biomass g/Plant	Biomass g/Plant	Biomass g/m^2	Number of Plants/m^2
Carbonaceous shale	17	1.7	0.10	0.11	42	380
Coal Waste	147	5	0.03	0.12	39	333
Bentonitic Clay	270	24	0.09	0.18	65	363
Gritstone	293	31	0.11	0.19	72	380
Colluvium	520	272	0.52	0.56	224	403
Baked Clay	350	171	0.49	0.36	149	410
Glacial Gravel	393	130	0.33	0.35	110	317
Fly-Ash	340	73	0.21	0.39	124	320

The addition of topsoil markedly increased the emergence success and total biomass production. Biomass per plant increased sharply for the coal waste, but remained essentially unchanged on the shale.

In general terms, plants appeared stunted (Table 5) and suffered from chlorosis. Most of the grasses showed only limited spike development while the legumes were devoid of any signs of maturity.

Sodic Materials. The materials in this category, bentonitic clay and gritstone, exhibited high concentrations of sodium. Field observations indicated that the soil structure was poor under extreme conditions of moisture, that is gel-like and swollen when saturated, and severely shrunken and cracked when dry.

Results (Tables 3 and 4) indicated that those soils were moderately successful in terms of seedling emergence but biomass production was relatively low. This may have been due to the high concentration of sodium which contributed to poor soil structure and nutrient imbalances.

The effect of topsoil was to increase substantially the emergence success and to double the individual plant size.

Plants on the bentonitic clay and gritstone were stunted (Table 5) and generally exhibited leaf tip chlorosis. Grasses showed up to 20% inflorescence formation except for Fall Ryegrass which exhibited a greater, almost 100%, degree of maturity. None of the legumes showed flower development.

Alkaline Materials. These materials, colluvium, baked clay and glacial gravels, exhibited moderately good soil characteristics. There did not appear to be any potentially adverse constituents to inhibit plant growth although, as with most other materials tested, they were low in nitrogen. Physically they were relatively coarse. Their water holding capacity would therefore be low and thus they were expected to be dry during periods of low rainfall.

Biomass production and seedling emergence confirmed the good soil characteristics of these materials as growth media (Tables 3 and 4). Although quantitative data showed less overall vegetative growth on baked clay and glacial gravel as compared to the colluvium plot, qualitatively they appeared similar (Table 5). Growth in all three cases was most abundant. Plants appeared healthy with little sign of chlorosis.

The effect of topsoil on these materials was inconsistent. The glacial gravels and colluvium exhibited similar results in that overall emergence success and biomass production decreased with topsoil. The baked clay did not show a consistent trend; whilst a greater emergence success yielded more plants per square metre with topsoil, they were smaller in size resulting in a decrease in overall biomass production.

Fly-Ash. The fly-ash is discussed separately because it is anthropogenic. It exhibits a high pH and a high soluble boron concentration which might be sufficient to be detrimental to plant growth. This material was a uniform silty loam which makes it susceptible to wind erosion in the absence of a vegetation cover.

The plant emergence data suggests that the fly-ash provided a good environment for seed germination. However, total biomass production was low and individual plants were stunted (Tables 3 and 4). It is suggested that metabolic interference due to boron may have occurred. Plants appeared dried out and exhibited chlorotic conditions.

The topsoil treatment had a positive effect on average plant size. Biomass production was approximately doubled yet the number of plants that emerged was approximately the same.

Effect of Topsoil

The practice of stripping and stockpiling topsoil or other suitable surface material during initial mining for subsequent surfacing of waste materials is being widely recommended as a method of improving the success of revegetation programs. As a preliminary examination of this practice, half of each plot at Aleece Lake was covered with a 5 centimetre layer of topsoil. Results of plant emergence and biomass production are given in Tables 3 and 4 for both topsoiled and non-topsoiled portions of the plots.

Considering first the effect of topsoil on plant emergence: On the least successful materials, the carbonaceous soils, the presence of topsoil dramatically increased the number of plants per square metre. A smaller but nevertheless substantial increase also occurred with the gritstone and bentonitic clay materials, whereas, there was a marked decrease in overall emergence success on the colluvium and glacial gravels. The baked clay and fly-ash showed variable responses among the seed mixes with the former showing a net increase and the latter a slight overall decrease.

Emergence on the topsoiled portions of the plots showed an average value of 363 plants per square metre over all materials, with a range of values from 317 to 410 plants per square metre. This consistency would be expected for vegetation germinating in the same medium. The micro-environment presented to the seeds was clearly improved in the topsoil as compared with the carbonaceous materials, bentonitic clay and gritstone, where such adverse factors as soil pH, and soil structure as it affects the movement of gases and moisture, and salinity existed.

Surprisingly, the glacial gravel and colluvium provided a more suitable micro-environment than the topsoil. It would appear that the separate stripping and stockpiling of only topsoil horizons at Hat Creek need to be evaluated further. It may be beneficial to include suitable subsurface materials such as gravels and colluvium, if soil for future surfacing of dumps is to be retained.

Biomass results and emergence data showed similar trends (Tables 3 and 5). However, although major improvements were noted on the coal waste, carbonaceous shale, bentonitic clay and gritstone, the yields were substantially less than those obtained on other materials at Aleece Lake. The reasons for these effects cannot be defined precisely with data presently available. Nevertheless, it seems clear that the plant seedling, as its root system penetrated the thin topsoil layer, encountered the poorer material where further root development was inhibited. Thus the continued uptake of nutrients and consequently, plant growth, was retarded. The net result was that plants were stunted with a higher incidence of chlorosis than those grown on the better materials (Table 5). It did not appear that acute toxic conditions, e.g. due to boron, existed, since vegetation continued to develop on the topsoil-treated side throughout the first year of growth.

Invader Species. Invader (weed) species were identified, counted and their biomass determined from all plots at Aleece Lake. These data are shown in Table 6.

As may be seen, there were substantially more invaders present on the topsoiled portions of the plots than on the non-topsoiled areas. From this it may be inferred that the seeds of these species were transported to the test site in the topsoil.

Comparisons between the total numbers of weeds produced and the numbers of agronomic species present would indicate that, for all but the fly-ash and gritstone plots, the invaders did not present a threat. On the gritstone and particularly the fly-ash where invaders amounted to approximately 36% of the total plants produced, competition probably occurred to a limited extent.

TABLE 6

AVERAGE NUMBERS AND BIOMASS OF INVADERS AT ALEECE LAKE TEST PLOTS

	With Topsoil				Without Topsoil			
	Average Number of Invaders/m^2	% of Total Plants	Average Invader Biomass g/m^2	% of Total Biomass	Average Number of Invaders/m^2	% of Total Plants	Average Invader Biomass g/m^2	% of Total Biomass
Carbonaceous Shale	14	4	6	13	0	0	0	0
Coal Waste	12	3	5	11	2	1	0.4	6
Bentonitic Clay	14	3	12	16	3	1	0.6	2
Gritstone	41	10	17	19	4	1	3	9
Colluvium	6	1	16	7	3	< 1	8	3
Baked Clay	10	2	9	6	2	< 1	1	<1
Glacial Gravel	9	3	11	9	3	< 1	3	2
Fly Ash	70	36	69	36	19	21	5	6

The invader species were generally quite large compared to the agronomics planted. The invaders exhibited rapid early growth and matured earlier than the agronomics. This behaviour is presumably indicative of their adaption to the climatic conditions at Hat Creek.

The most prevalent weed species were Flixweed (Descurainia sophia), Prostrate Knotweed (Polygonum aviculare), Downy Bromegrass (Bromus tectorum) and Blueburr (Lappula echinata). These accounted for 70% of the weeds present. None of the invaders were toxic to either wildlife or other vegetation. However, Foxtail Barley when young does exhibit very sharp spikes which have been known to lacerate the mouths of cattle. In total this species represented only 1% of the weed population.

Individual Vegetation Species

Twelve plant species were tested at Aleece Lake; eight grasses and four legumes. These species were originally selected on the basis of their suitability for use on the soil materials available and their adaption to the climate of the Hat Creek Valley. Individual species were examined, counted and their biomass production determined. These are reported in Tables 7 and 8. Results are discussed for each species and collectively for the three seed mixes.

Seed Mix I. This mixture comprised Crested Wheatgrass, Fall Ryegrass, Canada Bluegrass, and Alfalfa. Each species is discussed below.

Crested Wheatgrass showed an overall emergence success of 17% on untreated soils and ranked fifth among the eight grasses. Its performance on the carbonaceous materials was relatively good. Although it showed consistent results on the other materials its performance was not particularly noteworthy. The plants showed varied spike development depending on the soil material. Little or no development was evident on

TABLE 7

EMERGENCE SUCCESS RATIO - AVERAGE NUMBER OF PLANTS PRODUCED AS A PERCENT OF SEED SOWN

PLANT	CARBONACEOUS SHALE		COAL WASTE		BENTONITIC CLAY		GRITSTONE		COLLUVIUM		BAKED CLAY		GLACIAL GRAVELS		FLY ASH		AVERAGE	
	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T
GRASSES																		
Crested Wheatgrass	3	36	11	21	12	20	18	37	26	21	12	18	24	24	29	11	17	24
Canada Bluegrass	0	0	0	0	0	0	0	0.5	1	0	0	0	1	0	0	0	0	0
Fall Ryegrass	4	45	23	42	15	24	26	38	36	38	58	42	53	36	39	14	32	35
Russian Wild Ryegrass	0	30	8	27	34	39	33	40	43	30	33	35	38	35	40	34	29	34
Slender Wheatgrass	0	16	9	49	14	16	22	17	33	21	27	9	21	22	5	21	16	21
Smooth Bromegrass	0	23	9	22	16	27	16	22	62	45	34	48	40	15	-	-	25	29
Streambank Wheatgrass	2	30	20	21	25	22	24	16	41	35	19	32	18	12	-	-	21	24
Canada Bluegrass (Rubens)	0	2	0	1	0	3	0	3	1	4	8	5	6	4	-	-	2	3
LEGUMES																		
Drylander Alfalfa	0	4	0	4	4	7	2	7	9	5	2	6	8	5	3	5	4	5
Sainfoin	0	13	1	12	10	21	12	16	16	20	20	25	14	16	2	21	9	18
Sweet Clover	0	2	1	2	2	4	1	5	4	3	7	3	5	6	0	4	2	4
Red Clover	0	1	0	1	0	4	0	1	9	6	6	8	9	3	-	-	3	3

NT - No Topsoil
T - With Topsoil

TABLE 8

AVERAGE SIZE OF PLANTS PRODUCED IN GRAMS/PLANT

Plant	Carbonaceous Shale		Coal Waste		Bentonitic Clay		Gritstone		Colluvium		Baked Clay		Glacial Gravels		Fly Ash		Average	
	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T
GRASSES																		
Crested Wheatgrass	0.02	0.02	0.01	0.04	0.05	0.13	0.3	0.7	0.24	0.20	0.11	0.12	0.08	0.12	0.13	0.18	0.084	0.110
Canada Bluegrass	0	0.01	0	0	0	0.02	0	0.11	0.02	0	0	0	0.03	0.07	0	0	0.006	0.026
Fall Rye	1.17	1.82	0.27	1.67	2.73	4.64	2.25	3.77	14.1	15.2	5.90	8.12	5.12	6.67	3.10	9.08	4.33	6.37
Russian Wild Ryegrass	0	0.01	0.02	0.02	0.02	0.04	0.02	0.04	0.12	0.13	0.11	0.08	0.08	0.07	0.01	0.13	0.048	0.065
Slender Wheatgrass	0	0.21	0.04	0.12	0.18	0.22	0.11	0.16	0.66	0.90	0.52	0.84	0.34	0.35	0.02	0.44	0.233	0.405
Smooth Bromegrass	0	0.09	0.03	0.21	0.04	0.14	0.04	0.14	0.20	0.19	0.22	0.20	0.18	0.18	-	-	0.101	0.114
Streambank Wheatgrass	0	0.06	0.03	0.06	0.04	0.13	0.07	0.14	0.35	0.31	0.30	0.22	0.22	0.19	-	-	0.144	0.160
Canada Bluegrass (Rubens)	0	0.03	0	0.07	0	0.07	0	0.04	0.03	0.08	0.27	0.11	0.04	0.05	-	-	0.049	0.064
LEGUMES																		
Drylander Alfalfa	0	0.03	0	0.01	0.02	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.01	0.01	0.02	0.06	0.011	0.025
Sainfoin	0	0.08	0.03	0.05	0.05	0.06	0.07	0.08	0.09	0.13	0.16	0.13	0.11	0.11	0.02	0.23	0.066	0.109
Sweet Clover	0	0.02	0.01	0.02	0.07	0.03	0.05	0.04	0.10	0.18	0.13	0.13	0.07	0.08	0	0.29	0.054	0.099
Red Clover	0	0.03	0	0.02	0.04	0.06	0.02	0.05	0.03	0.08	0.07	0.15	0.09	0.04	-	-	0.036	0.061

NT - No Topsoil
T - With Topsoil

the untreated carbonaceous and bentonitic clay materials; maximum inflorescence (20 to 25%) was noted on the glacial gravels. Toward the edge of the plots the Crested Wheatgrass appeared to be more fully developed due to less competition from Fall Ryegrass.

Fall Ryegrass is a vigorous, tall-growing annual which developed rapidly. In overall emergence success it was superior to all other species. The presence of Fall Ryegrass may have contributed to the reduced growth of other species sown with it in Seed Mix I by outcompeting them for the available moisture, sunlight and nutrients. Biomass production per plant was far in excess of other species tested. Spike development was apparent on all plots with between 90 - 100% of plants having spikes. The spikes ranged from 8 to 12 centimetres in length on carbonaceous shale and baked clay, respectively. Although lodging was common on all plots it was noted that the root systems were still intact with the soil, allowing growth to continue. From these results it appeared the Fall Ryegrass would be most useful in short-term reclamation activities such as erosion control on temporary stockpiles.

Canada Bluegrass had the poorest emergence success of all species studied, failing to appear on three of the untreated soils. Plants that did exist showed only rudimentary development, and few possessed panicles. The presence of topsoil generally improved success though it remained very low. These results are surprising since this species is widely recommended for revegetation on poor soils and in dry climates. Whilst it is speculated that either low seed viability or lack of compatibility with the other species with which it was sown may be responsible for its poor performance, it will continue to be monitored to see if it develops in subsequent years.

Alfalfa showed only a 4% emergence success. Plants were generally stunted and exhibited rudimentary, i.e. no flower, development. Seedlings never attained a height of greater than about 9 centimetres, consequently biomass production was low. Alfalfa was seeded with Fall Ryegrass which appeared to outcompete other species in the mix for available moisture and/or nutrients. There is evidence elsewhere that when competition is reduced the Alfalfa was much more successful.

Seed Mix I (Table 1) produced the greatest quantity of biomass, primarily as a result of the Fall Ryegrass. This species was included to provide early revegetation. However, its size and vigour is suspected to have inhibited the development of at least two of the other species, Alfalfa and Crested Wheatgrass, by outcompeting them for the available moisture and nutrients. The Canada Bluegrass performed so poorly, it is suspected that, in addition to any competition effects, the seed itself may not have been viable. The competition provided by Fall Ryegrass notwithstanding, it would obviously be of considerable value in any short-term revegetation program.

Seed Mix II. This seed mixture comprised Russian Wild Ryegrass, Slender Wheatgrass, Sainfoin, and Sweet Clover. Each species is discussed below.

Russian Wild Ryegrass with its overall emergence success of 29% on untreated soils showed excellent results on all but the carbonaceous materials. Of particular note is its performance on the bentonitic clay and gritstone soils where it would appear to be a most useful species. Whilst the number of plants per square metre was high, the plants themselves were small and did not show any signs of spike development. This species is characteristically slow to develop which would explain the observations. It remains to be seen whether it will continue to develop into large plants and thus fulfill, in the long term, its short-term promise.

The average emergence success of Slender Wheatgrass was similar to that of Crested Wheatgrass, but a substantially greater percentage of plants showed spike development. The plants themselves were generally quite large, as shown by the high biomass production and thus the species should be useful in short-term revegetation programs designed for erosion control. The high emergence success on topsoiled coaly waste is noteworthy.

Sainfoin showed good emergence success on all materials except the carbonaceous soils and fly-ash. It clearly outperformed all other legume species tested. On average, about 5% of the plants were mature. The addition of topsoil improved both emergence success and plant size substantially.

The overall germination success of Sweet Clover was lowest of all legumes. Sweet Clover is a biennial which was expected to develop rapidly in the first year. This did not occur except along the periphery of the plot where, presumably, competition from other species was less.

Seed Mix II (Table 1) produced the greatest number of plants per square metre overall even though its performance on the carbonaceous materials was poor. The species in the mix appeared to be compatible. Neither of the grasses provide Sainfoin with excessive competition. The Sweet Clover did appear to suffer competition from the other species, collectively, since it was found to do well only along the periphery of the plots where competition was least.

Seed Mix III. This seed mixture comprised Smooth Bromegrass, Streambank Wheatgrass, Canada Bluegrass (Rubens), and Double Cut Red Clover. Each species is discussed below.

Overall, the Smooth Bromegrass, a long-lived sod grass, ranked third in emergence success on untreated soils. However, its average success was enhanced by a particularly good showing on the "better" soils, colluvium, baked clay and glacial gravels. It showed only average success on the bentonitic clay and gritstone. The particularly good productivity on the topsoiled coaly waste is noteworthy. Plants generally had not reached the reproductive stage at the time of sampling in early August.

Although Streambank Wheatgrass ranked only fourth overall, its emergence success on the carbonaceous materials, bentonitic clay and gritstone suggested that it is a valuable species for reclamation. Second and subsequent years growth needs to be followed carefully before this is clearly established, since the plants on these plots had not progressed beyond the seedling stage. It is interesting to note that on the coaly waste, bentonitic clay and gritstone, the addition of topsoil had little effect on emergence success while the biomass produced per plant always showed an increase. Characteristically it has a vigorous rhizomatous rooting system which should enable the grass to spread rapidly in subsequent years to form a good ground cover and enhancing soil stabilization.

Canada Bluegrass (Rubens) showed very poor success and was only marginally better than the common variety. It may yet develop in subsequent years; however, it does not appear suitable for short-term revegetation programs in the present seed mix.

Double Cut Red Clover showed approximately the same germination success as Alfalfa. Growth was particularly successful around the perimeter of the plot where plants became quite large. Flower development was evident on approximately 5% of those species within the plot proper, while those plants along the perimeter were more prolific.

Seed Mix III (Table 1) had an overall biomass production similar to that of Seed Mix II. However, the average number of plants per square metre produced was slightly lower, due mainly to the poor emergence success of

Rubens and Red Clover. Although the Streambank Wheatgrass has a characteristically vigorous rooting system, this did not appear to have any effect on the performance of the Smooth Bromegrass. The Red Clover would seem to have suffered some competition since it was found mostly along the edges of the plots.

Additional Factors in Plant Growth

Climate. The Hat Creek region receives on average 317 millimetres of precipitation annually, about half falling in the form of snow. Summers are typically hot and dry resulting in a short growing period when moisture is available. This low rainfall is a major factor in revegetation. The effect of a lack of moisture is noted in those areas where shallow pools of water collected; the vegetation is markedly more successful both in abundance and size compared with adjacent areas outside the "pools". Surface preparations designed to retain surface moisture should be beneficial and are being studied further.

A greater than average rainfall during the growing season (May - September), 157 millimetres compared with 139 millimetres average, was precipitated in 1977. The results presented here should be viewed in this light. The greater than average rainfall was partially offset by the greater than average daily temperatures.

RESULTS FROM SLOPE TEST PLOTS

Slope plots of 22^{o}, 26^{o} and 30^{o} were prepared at two locations, Houth Meadows and Medicine Creek, to examine the relationship between slope and revegetation success. At Houth Meadows, half the plots were covered with topsoil. Seed Mix I was used on all plots. Results of plant counts and biomass production are given in Tables 9, 10 and 11.

Considering first the data for the upper and lower slopes at Houth Meadows

(Table 9), the number of plants per square metre on the upper slopes was consistently less than on the lower slopes. These plots were hydroseeded using a truck-mounted sprayer from the base of the plots. These plots were all 15 metres high and varied in length between 30.5 and 40.5 metres, depending on slope angle. It is suspected that because of the rather long distances over which the seed/fertilizer/mulch was sprayed, the upper slopes received less than the lower areas. This suspicion is borne out by qualitative field observations which indicated that mulch density at the top of the plots was less than on the lower portions. At Medicine Creek where hydroseeding was carried out from a truck located at the top of the plots and on foot, using a hose, the upper and lower slopes show approximately the same catch (Table 11).

Comparing the number of plants produced on plots of different slope angle, Tables 9 and 11 show that the greatest number of plants per square metre were located on the steepest slope, 30°. At Medicine Creek, the average difference between the 22° and 26° slopes and the 30° slope amounted to a factor of 2. At Houth Meadows, the difference is not as great but the 30° is still the most successful. As mentioned above it is difficult to obtain consistent application rates when hydroseeding. It may be that the 30° slopes received a greater seed application than other plots. In any event it would be unwise to infer from these data that slopes of 30° are actually more suitable for plant growth than those less steep. However, it would seem reasonable to conclude that there are no major deterrents to growth at slopes as steep as 30°. Examination of the slopes indicated that waterborne erosion was minimal in the first year. This is noteworthy since rainfall received at Hat Creek during 1977 was above the average.

Effect of Topsoil

Half of each plot at Houth Meadows was covered with approximately 5 centimetres of topsoil. Results of plant counts and biomass production are shown in Tables 9 and 10. As found on the glacial gravel at

TABLE 9

AVERAGE NUMBER OF PLANTS PRODUCED AT HOUTH MEADOWS

Plot		Average Number of Plants per m^2				
		Upper Slope		Lower Slope		Average
		No Topsoil	Topsoil	No Topsoil	Topsoil	
22^o	Agronomic	100	28	223	174	131
	Invaders	0	84	0	40	
26^o	Agronomic	94	106	214	130	136
	Invaders	0	40	0	22	
30^o	Agronomic	168	138	212	200	180
	Invaders	0	28	0	40	
Average	Agronomic	121	91	216	168	
	Invaders	0	51	0	34	

TABLE 10

TOTAL BIOMASS PRODUCED AT HOUTH MEADOWS (g/m^2)

Plot		Upper Slope		Lower Slope		Average
		No Topsoil	Topsoil	No Topsoil	Topsoil	
22^o	Agronomic	83	54	245	249	158
	Invaders	0	47	0	59	n/a
26^o	Agronomic	65	161	327	202	189
	Invaders	0	22	0	15	n/a
30^o	Agronomic	208	442	306	144	275
	Invaders	0	56	0	15	n/a
Average	Agronomic	119	219	293	198	
	Invaders	0	42	0	30	

TABLE 11

AVERAGE NUMBER OF PLANTS PRODUCED AT MEDICINE CREEK

Plot	Upper Slope Number Of Plants $/m^2$	Lower Slope Number Of Plants $/m^2$	Average Number Of Plants $/m^2$
22^o	138	60	99
26^o	76	100	88
30^o	176	186	181
Average	130	115	

Aleece Lake, there was a reduction in plants per square metre on the topsoiled portions of the plots. The topsoil in this case came from a different location from that used at Aleece Lake and contained greater quantities of weed seeds. The number of invaders on topsoiled portions of the Houth Meadows plots was appreciable and, as a result, may have caused competition contributing to the lower number of plants per square metre. On average, 42 invaders per square metre were found on the Houth Meadows plots compared to 9 per square metre on the gravel plot at Aleece Lake.

Weed species diversity was not as great as at Aleece Lake. Three species, Flixweed (Descurainia sophia), Blueburr (Lappula echinata) and Stinkweed (Thalspi arvense) made up 86% of all invaders.

CONCLUSIONS

The revegetation test results presented here relate only to vegetation success in the first season following a fall seeding. The detailed examinations have been carried out to determine the degree to which vegetation may he established on the waste materials in the short-term. This aspect refers to B.C. Hydro's major short-term goal in the overall reclamation effort, namely the rapid establishment of vegetation to prevent wind and/or waterborne erosion. The primary conclusions of these studies may be summarized as follows:

1. Vegetation is readily established on surficial materials, colluvium, glacial and recent gravels and baked clay.

2. Although vegetation cover on the bentonitic clay and gritstone was substantially less than on the surficials, the effect was most noticeable in terms of plant size rather than seedling abundance. The nature of these clayey materials in forming a surface crust when dry would mitigate against wind erosion even in the absence of vegetation.

3. The carbonaceous materials would be the most difficult to revegetate of all materials examined. A surface capping would be necessary if successful revegetation is required in the short-term.

4. Plant growth on fly-ash was stunted although there were a large number of individual seedlings. Some problems due to the relatively high boron content may be expected. A surface capping of surficial soil would be beneficial if vegetation for short-term erosion control is to be established.

5. The addition of topsoil to the carbonaceous materials, bentonitic clay and gritstone resulted in improved seedling emergence and biomass production. On the colluvium and gravels the converse was observed. These results indicated that the materials selected for stripping and stockpiling as surface growth media, may comprise gravel, colluvium, till and topsoil either separately or in combination.

6. Short-term revegetation of dump faces comprised of either colluvium/till or gravel with an overall height of 15 metres and with slopes up to 30^{o} was readily achieved without serious waterborne erosion problems during the first year.

7. Several grass and legume species suitable for short-term revegetation of waste materials at Hat Creek have been identified. Among the grasses Fall Ryegrass, Streambank Wheatgrass and Slender Wheatgrass were of particular note, while Sainfoin was the most successful legume.

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NATURAL REVEGETATION OF DISTURBANCES IN THE PEACE RIVER COALFIELD

Paper presented

by:

D.V. Meidinger
Dept. of Biology
University of Victoria

NATURAL REVEGETATION OF DISTURBANCES IN THE PEACE RIVER COALFIELD

INTRODUCTION

Knowledge of the environmental factors influencing the natural revegetation of man-made disturbances can provide valuable information which can be applied to reclamation procedures. The environmental factors influencing natural revegetation were examined on areas disturbed by coal exploration in the Peace River Coalfield. The factors found to be significantly correlated with the total vascular plant cover on a site (used as a measure of revegetation success) are discussed and suggestions are made regarding how this information may be of use to those responsible for reclamation.

DESCRIPTION OF STUDY AREA

The Peace River Coal Block is located on the eastern slope of the Rocky Mountains and runs in a northwest to southeast band within the Rocky Mountain Foothills Physiographic Region (Vold, 1977) and extends from Williston Lake in the north to the Alberta border in the south. The topographic relief within this region ranges from about 600 metres in some valley bottoms, to approximately 1900 metres at the top of some foothills. The foothills are underlain by faulted and folded sandstones, shales, conglomerates, and of course, coal.

Natural vegetation in the area can be classified into four biogeoclimatic zones (Krajina, 1965). The Boreal White and Black Spruce Zone to the west and the Subboreal Spruce Zone to the east occur in the valley bottoms and extend in height to approximately 1,000 metres. The Engelmann Spruce - Sub-alpine Fir Zone is located between about 1,000 metres and 1,600 metres, while the Alpine Tundra Zone occurs at highest elevations. At the upper levels of the treeline, where the Engelmann Spruce - Sub-alpine Fir Zone meets the Alpine Tundra Zone, there is an area where stunted Engelmann

Spruce and/or Sub-alpine Fir patches are found in mosaic with alpine vegetation. This area is referred to as the krummholz, due to the straggling, krummholz form of the trees, and is given a subzone designation by Harcombe (1978) in his biophysical treatment of the vegetation in the area. Coal exploration has occurred in all four biogeoclimatic zones, but has been concentrated in the Englemann Spruce - Sub-alpine Fir Zone and the Alpine Tundra Zone. Thus, the sampling sites were concentrated in these two zones.

STUDY METHODS

Data Collection

Data for this study were collected during the summers of 1977 and 1978 in conjunction with a study of the native species invasion of disturbances in the Peace River Coalfield. The main sampling areas were Bullmoose Mountain, Mount Chamberlain, Babcock Mountain, McAllister Creek - Carbon Creek, and Mount Johnson, which were selected because of the wide range of disturbances found in these areas and their relative ease of access.

Sampling sites were chosen on disturbances that had been left to revegetate naturally. Plots were located in sections of disturbances where there was uniformity in species composition, community physiognomy, parent material, and adjacent vegetation, as well as consistency in such physical factors as slope and aspect. Plot size varied from 25 to 40 square metres depending upon the site dimensions. For each plot, in addition to an estimate of the total vascular plant cover, a list of all species with an estimate of their individual cover was made. Information recorded included the date of the observation; plot location; year of site abandonment; and the physical environmental parameters such as slope, aspect, elevation, moisture condition, microrelief, exposure type and magnitude, and position on slope. In addition features of the soil such as texture, colour, pH, drainage, compaction, degree of erosion and origin of surficial material were noted, as were the features of the adjacent undisturbed vegetation community including slope, aspect, dominant plants in each layer, and the biogeoclimatic zone. At all sites during 1978, a soil sample was collected which was analyzed to determine the levels of nitrate, phosphorus, potassium, magnesium and calcium concentration, per cent organic matter and electrical conductivity by the B.C. Ministry of Agriculture, Soils Lab, Kelowna.

Data Analysis

Total vascular plant cover in a plot was used as a measure of the "revegetation success" on a particular site which within the age range of the sites sampled, was considered to be a valid approach. The relationship of the environmental variables to the "revegetation success" on a site was determined by calculating correlation coefficients between each of the environmental variables and the total vascular plant cover (expressed as per cent cover).

Product-moment correlation coefficients (Zar, 1974) were calculated to determine the relationship between total cover and the continuous variables of age, elevation, site slope, adjacent site slope, site exposure, adjacent site exposure, pH, nitrates, phosphorus, potassium, calcium, magnesium, organic matter content, salt level per cent erosion, compaction, and the texture of coarse fragments (Table 1).

Spearman rank correlation coefficients (Zar, 1974) were calculated to determine the relationship between total cover and the ordinal variables of magnitude of wind exposure, heat index, site moisture regime, degrees of compaction, erosion intensity index, extent erosion, texture index, and soil colour (Table 2).

To determine if there were any different factors affecting revegetation above and below the treeline, the data set was divided into two subsets and the previously described analysis was performed on each subset.

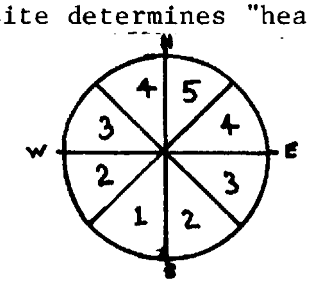
The rates of revegetation on identifiable subsets of the data were determined by performing linear regression analysis (Zar, 1974) using the variable of age versus cover for each subset. The subsets chosen were similar to the vegetation units described in the British Columbia Ministry of Mines and Petroleum Resources, Reclamation Program,

TABLE 1

EXPLANATION OF CONTINUOUS VARIABLES MEASURED

Variable	Units of Measurement	Explanation
Age	Years	Years since site was abandoned
Elevation	metres	Elevation above sea level.
Site slope	degrees	Slope of road or drill site sampled.
Adjacent site slope	degrees	Slope of natural site adjacent to the disturbance.
Site exposure	degrees	Exposure of road or drill site measured as 180^{o} - (exposure ^{o}true)
Adjacent site exposure	degrees	Exposure of natural site adjacent to its disturbance measured as above.
pH		Soil reaction using Hellige-Truog Soil Reaction Kit.
Nitrates	pounds/acre	Measured using colorimetric method utilizing phenoldisulfonic acid.
Phosphorus	pounds/acre	Measured using Bray P-1 colorimetric method.
Potassium	pounds/acre	Measured using atomic absorption spectrophotometer.
Calcium	pounds/acre	Measured using atomic absorption spectrophotometer.
Magnesium	pounds/acre	Measured using atomic absorption spectrophotometer.
Salts	Mmhos/ centimetre	Electrical conductance.
Organic Matter Content	per cent	Measured using modified Wakely Black Method.
Per centerosion	per cent	Visual estimate of per cent of plot eroded.
Compaction	kilogrammes/ $centimetre^2$	Estimated using pocket penetrometer (Soil Test Inc., Chicago)
Texture of coarse fragments	per cent	Volume of coarse fragments (<72mm) in soil profile

TABLE 2: EXPLANATION OF CODING OF ORDINAL VARIABLES

VARIABLE	EXPLANATION
Wind exposure magnitude	0 - Wind exposure not important 1 - strong wind exposure 2 - very strong wind exposure 3 - extreme wind exposure
Heat index	Exposure of site determines "heat index" as follows: 
Site moisture regime	1 - very xeric 2 - xeric 3 - subxeric 4 - submesic 5 - mesic 6 - subhygric 7 - hygric 8 - subhygric 9 - hygric
Compaction magnitude	0 - material on site less compacted than adjacent natural site 1 - material on site compacted about the same as adjacent site 2 - moderately compacted relative to adjacent site 3 - highly compacted relative to adjacent site
Erosion intensity index	Number of channels in plot times the depth of the channels in centimetres
Erosion magnitude	0 - no visible erosion 1 - sheet erosion 2 - rill erosion 3 - gully erosion
Texture index	1 - sand, loamy-sand 2 - sandy-loam 3 - loam, silt-loam 4 - silt, sandy-clay-loam, clay-loam, silty-clay-loam 5 - sandy-clay, clay, silty-clay, heavy clay 6 - organic
Soil colour	Value plus chroma using 10YR Munsell Colour Chart

Northeast Coal Block, 1977 report. The units are based on broad physiognomic and edaphic criteria, and include Dry Alpine, Mesic Alpine, Wet Alpine, Dry Forest, Mesic Forest, and Wet Forest. The regressions were forced through zero, as there was not adequate sampling on the young sites, and it was assumed that the cover would be zero at time zero.

RESULTS

Environmental Factors Affecting Natural Revegetation

Summary statistics for both the continuous and ordinal variables are shown in Tables 3 and 4, respectively. The maximum and minimum values recorded for the continuous variables give some idea of the range of sites sampled. As can be seen, cover varied from 0 to 100% on sites ranging in age from one to nine years. Almost the entire possible range for the variables of slope, exposure, compaction, and texture of coarse fragments were sampled. The elevation of the sites sampled ranged from 632 metres to 1935 metres. Although the erosion on a site varied from 0 to 35%, the mean value was quite low (2.6%), as most sites had very little erosion. All of the macronutrients sampled covered a good range of possible values from low to high except the nitrate concentration, which was very low at all sites. The variables of pH, compaction, and organic matter content cover a wide range of possible values. All the measured values for electrical conductivity (salts) were quite low.

All of the ordinal variables covered the full range of possible values with the exception of the Erosion Intensity Index. Since most sites had no rill or gully erosion, there were a lot of zeros for this measure. The maximum value was ninety-nine.

The correlation coefficients for the relationship between total

TABLE 3

SUMMARY STATISTICS FOR CONTINUOUS VARIABLES MEASURED AT ALL SITES

VARIABLE	SAMPLE SIZE	MEAN	STANDARD DEVIATION	MIN.	MAX.	COEFFICIENT OF VARIATION %
Cover (%)	141	41.1	27.55	0.0	100	67.09
Age (years)	141	6.1	1.78	1.0	9	29.03
Elevation (metres)	141	1423.2	290.87	632.0	1935	20.44
Site Slope (degrees)	141	7.4	6.87	0.0	39	93.11
Adjacent Site Exposure (degrees)	141	12.6	9.23	0.0	38	73.20
Site Exposure (degrees)	141	88.0	55.00	0.0	180	62.52
Adjacent Site Exposure (degrees	141	92.0	53.01	0.0	180	57.63
pH	141	6.3	1.22	4.5	8	19.32
Nitrate (pounds/acre)	103	2.0	1.34	1.0	9	65.84
Phosphorus (pounds/acre)	103	36.3	43.74	2.0	258	120.45
Potassium (pounds/acre)	103	53.5	43.16	25.0	335	80.65
Calcium (pounds/acre)	103	2881.4	2532.99	500.0	10,000	87.91
Magnesium (pounds/acre)	103	346.7	255.78	25.0	1,000	73.77
Salts (mmhos/centimetre)	103	0.1	0.07	0.1	0.3	58.67
Organic Matter (%)	103	4.9	5.09	0.5	30	103.10
Erosion (%)	103	2.6	5.64	0.0	35	215.86
Compaction (Kilograms/centimetre^2)	103	1.9	1.11	0.1	4.5	57.87
Coarse Fragment Texture (%)	141	31.1	18.89	0.0	95	60.68

TABLE 4

SUMMARY STATISTICS FOR ORDINAL VARIABLES
MEASURED AT ALL SITES

VARIABLE	SAMPLES SIZE	MEAN	STANDARD DEVIATION
Wind Exposure Magnitude	141	0.61	0.87
Heat Index	141	2.9	1.30
Site Moisture Regime	141	4.8	1.12
Compacting Magnitude	141	1.8	0.76
Erosion Intensity Index	141	5.7	15.06
Erosion Magnitude	141	0.8	0.89
Texture Index	141	2.8	0.84
Soil Colour	141	7.6	1.95

vascular plant cover and the continuous and ordinal environmental variables are given in Tables 5 and 6. These are the correlation coefficients for the maximum number of sites sampled for each variable. Significant positive correlations, at the 99% level of significance occur with the variables of age, site moisture, and texture. Negative correlations are significant with the variables of elevation, texture of coarse fragments, wind exposure, and compaction as measured by two methods.

Due to the major macroclimatic difference between the forested zones and the alpine zone, the data were divided into these two categories to determine if the environmental factors influencing natural revegetation would be the same.

Forested Zones. The summary statistics for the continuous and ordinal variables measured from sites in the forested zones are shown in Tables 7 and 8, respectively. The range of values measured for each variable was very close to the ranges found when all the sites sampled were included in the analysis. The main differences occurred with elevation, which now ranged from 632 metres to only 1745 metres and site slope, which had a maximum of 24°. The mean values were very similar, except for elevation and wind exposure, which were both lower in the forested zones.

The correlation coefficients for total cover versus the various environmental variables are shown in Tables 9 and 10. Highly significant positive correlations occur with the variables age, magnesium concentration, site moisture and texture and negative correlations are found with the variables compaction, compaction magnitude and texture of coarse fragments.

Alpine Zone. The statistics for the continuous and ordinal variables measured from sites sampled in the Alpine Zone are summarized in Tables 11 and 12. The mean cover was much lower in the Alpine Zone and, as expected, the mean elevation was higher. Of the nutrients sampled, the

TABLE 5

CORRELATION COEFFICIENTS FOR TOTAL COVER
VERSUS CONTINUOUS ENVIRONMENTAL
VARIABLES AT ALL SITES MEASURED

VARIABLE	PRODUCT-MOMENT CORRELATION COEFFICIENT	DEGREES OF FREEDOM	SIGNIFICANCE
Age (years)	0.331	140	*
Elevation (metres)	-0.247	140	*
Site Slope (degrees)	0.072	140	N.S.
Adjacent Site Slope (degrees)	0.076	140	N.S.
Site Exposure (degrees)	-0.005	140	N.S.
Adjacent Site Exposure (degrees)	0.035	140	N.S.
pH	0.145	140	N.S.
Nitrates (pounds/acre)	-0.050	102	N.S.
Phosphorus (pounds/acre)	-0.120	102	N.S.
Potassium (pounds/acre)	0.075	102	N.S.
Calcium (pounds/acre)	0.095	102	N.S.
Magnesium (pounds/acre)	0.187	102	N.S.
Salts (mmhos/centimetre)	0.091	102	N.S.
Organic Matter (%)	0.207	102	N.S.
Erosion (%)	-0.041	102	N.S.
Compaction (Kilograms/centimetre^2)	-0.299	102	*
Coarse Fragment Texture (%)	-0.261	140	*

* correlation significant at probability < 0.01
N.S. not significant

TABLE 6

CORRELATION COEFFICIENTS FOR TOTAL COVER
VERSUS ORDINAL ENVIRONMENTAL VARIABLES
MEASURED AT ALL SITES

VARIABLE	SAMPLES SIZE	SPEARMAN RANK CORRELATION COEFFICIENT	SIGNIFICANCE
Wind Exposure Magnitude	141	-0.304	*
Heat Index	141	-0.002	N.S.
Site Moisture Regime	141	0.574	*
Compaction Magnitude	141	-0.331	*
Erosion Intensity Index	141	-0.003	N.S.
Erosion Magnitude	141	-0.096	N.S.
Texture Index	141	0.379	*
Soil Colour	141	0.147	N.S.

* correlation significant at Probability < 0.01
N.S. not significant

TABLE 7

SUMMARY STATISTICS FOR CONTINUOUS VARIABLES
MEASURED AT SITES IN FORESTED ZONES

VARIABLE	SAMPLE SIZE	MEAN	STANDARD DEVIATION	MIN.	MAX.	COEFFICIENT OF VARIATION (%)
Cover (%)	102	45.0	27.63	0	100	61.39
Age (years)	102	6.3	1.68	2	9	26.81
Elevation (metres)	102	1328.1	281.85	632	1745	21.22
Site Slope (degrees)	102	6.8	5.15	0	24	75.56
Adjacent Site Slope (degrees)	102	11.6	8.54	0	37	73.91
Site Exposure (degrees)	102	87.6	55.43	0	180	63.27
Adjacent Site Exposure (degrees)	102	88.5	55.10	0	180	62.24
pH	102	6.1	1.18	4.5	8.0	19.17
Nitrates (pounds/acre)	78	1.7	0.95	1.0	6.0	54.82
Phosphorus (pounds/acre)	78	42.2	47.84	2.0	258.0	113.39
Potassium (pounds/acre)	78	53.0	47.20	25.0	335.0	89.08
Calcium (pounds/acre)	78	2482.2	2245.19	500.0	10,000	90.45
Magnesium (pounds/acre)	78	290.3	213.79	25.0	1000	73.65
Salts (mmhos/centimetre)	78	0.11	0.07	0.1	0.32	62.12
Organic Matter (%)	78	4.2	3.99	0.5	30	94.73
Erosion (%)	78	2.7	5.98	0.0	35	225.24
Compaction (Kilograms/centimetre^2)	78	2.0	1.10	0.1	4.5	54.65
Coarse Fragment Texture (%)	102	31.2	19.62	0	95	62.83

TABLE 8

SUMMARY STATISTICS FOR ORDINAL VARIABLES
MEASURED AT SITES IN FOREST ZONES

VARIABLES	MEAN	STANDARD DEVIATION	N
Wind Exposure Magnitude	0.2	0.515	102
Heat Index	3.0	1.27	102
Site Moisture Regime	4.9	1.05	102
Compaction Magnitude	1.8	0.75	102
Erosion Intensity Index	5.0	13.95	102
Erosion Magnitude	0.8	0.92	102
Texture	2.9	0.89	102
Soil Colour	7.9	1.85	102

TABLE 9

CORRELATION COEFFICIENTS FOR TOTAL COVER
VERSUS CONTINUOUS ENVIRONMENTAL VARIABLES
MEASURED AT SITES IN FORESTED ZONES

VARIABLE	PRODUCT-MOMENT CORRELATION COEFFICIENT	DEGREES OF FREEDOM	SIGNIFICANCE
Age (years)	0.283	101	*
Elevation (metres)	-0.147	101	N.S.
Site Slope (degrees)	0.026	101	N.S.
Adjacent Site Slope			N.S.
(degrees)	0.048	101	N.S.
Site Exposure (degrees)	0.008	101	N.S.
Adjacent Site Exposure (degrees)	0.098	101	N.S.
pH	0.201	101	N.S.
Nitrates (pounds/acre)	-0.124	77	N.S.
Phosphorus (pounds/acre)	-0.223	77	N.S.
Potassium (pounds/acre)	0.096	77	N.S.
Calcium (pounds/acre)	0.156	77	N.S.
Magnesium (pounds/acre)	0.299	77	*
Salts (mmhos/centimetre)	0.126	77	N.S.
Organic Matter (%)	0.212	77	N.S.
Erosion (%)	0.011	77	N.S.
Compaction (Kilograms/centimetre^2)	-0.325	77	*
Coarse Fragment Texture (%)	0.299	101	*

* correlation significant at $p < 0.01$

N.S. not significant

TABLE 10

CORRELATION COEFFICIENTS FOR TOTAL COVER
VERSUS ORDINAL ENVIRONMENTAL VARIABLES
MEASURED AT SITES IN THE FORESTED ZONES

VARIABLE	SAMPLES SIZE	SPEARMAN RANK CORRELATION COEFFICIENT	SIGNIFICANCE
Wind Exposure Magnitude	102	-0.167	N.S.
Heat Index	102	0.008	N.S.
Site Moisture Regime	102	0.602	*
Compaction Magnitude	102	-0.326	*
Erosion Intensity Index	102	-0.191	N.S.
Erosion Magnitude	102	0.023	N.S.
Texture Index	102	0.412	*
Soil Colour	102	0.241	N.S.

* correlation significant at $p < 0.01$
N.S. not significant

TABLE 11

SUMMARY STATISTICS FOR CONTINUOUS VARIABLES
MEASURED AT SITES IN THE ALPINE ZONE

VARIABLE	SAMPLE SIZE	MEAN	STANDARD DEVIATION	MIN.	MAX.	COEFFICIENT OF VARIATION (%)
Cover (%)	39	30.8	24.87	3	80	80.75
Age (years)		5.8	2.00	1	9	34.54
Elevation (metres)	39	1672.0	112.81	1480	1935	6.75
Site Slope (degrees)	39	8.9	10.02	0	39	112.99
Adjacent Site Slope (degrees)	39	15.3	10.44	3	38	68.10
Site Exposure (degrees)	39	88.9	54.70	8	180	61.52
Adjacent Site Exposure (degrees)	39	101.0	46.57	10	180	46.11
pH	39	6.7	1.24	4.5	8.0	18.59
Nitrates (pounds/acre)	25	3.0	1.87	1.0	9	62.36
Phosphorus (pounds/acre)	25	18.0	17.99	2	68	100.19
Potassium (pounds/acre)	25	55.2	27.67	25	112	50.16
Calcium (pounds/acre)	25	4127.2	2993.45	500	9728	72.53
Magnesium (pounds/acre)	25	522.8	297.94	25	1000	56.99
Salts (mmhos/centimetre)	25	0.1	0.06	0.1	0.26	48.46
Organic Matter (%)	25	7.2	7.21	1.5	29	100.14
Erosion (%)	25	2.5	4.52	0	15	182.24
Compaction (Kilograms/ centimetre^2)	25	1.6	1.10	0.2	4.2	68.27
Coarse Fragment Texture (%)	39	30.9	17.09	5	80	55.30

TABLE 12

SUMMARY STATISTICS FOR ORDINAL VARIABLES
MEASURED AT ALL SITES
(Alpine Zone)

VARIABLE	SAMPLES SIZE	MEAN	STANDARD DEVIATION
Wind Exposure Magnitude	39	1.5	0.82
Heat Index	39	2.9	1.38
Site Moisture Regime	39	4.3	1.18
Compaction Magnitude	39	1.8	0.78
Erosion Intensity Index	39	7.6	17.70
Erosion Magnitude	39	0.9	0.83
Texture Index	39	2.7	0.686
Soil Colour	39	6.9	2.04

mean phosphorus concentration was much lower in the alpine, whereas the calcium and magnesium mean concentrations were higher than in the forested zones. The range of values was less for potassium, although the mean was about the same. The mean values for nitrates concentration and organic matter content were slightly higher in the alpine. Of course, the mean value for the wind exposure was much higher in the Alpine Zone. The other variables showed similar trends to those observed in the forested zones.

The correlation coefficients shown in Tables 13 and 14 are for the relationship between total cover and the environmental variables measured. In the Alpine Zone, only the variables of age and site moisture showed siginificant positive correlations, and the Erosion Intensity Index was the only variable displaying a significant negative correlation.

Rates of Revegetation

The linear regressions showing the rate of revegetation in the different broad vegetation units are shown in Figures 1 to 6. Figures 1, 2 and 3 show the revegetation rate for the first nine years in the Dry Forest, Mesic Forest, and Wet Forest units respectively, and Figures 4, 5 and 6 show the same for the Dry Alpine, Mesic Alpine and Wet Alpine units. All regressions were significant at $P < 0.001$.

A comparison of the regression coefficients gave some idea of the relative rates of revegetation, for example, the regression coefficient for Dry Forest was 4.283, compared to 6.111 in the Mesic Forest unit. A ranking of the regression coefficients in order of increasing magnitude would put the vegetation units in the following order of increasing rate of revegetation: Dry Alpine, Dry Forest, Mesic Alpine, Mesic Forest, Wet Alpine, and Wet Forest. From this ranking, it appears that moisture is more important than elevation in the areas sampled.

TABLE 13

CORRELATION COEFFICIENTS FOR TOTAL COVER
VERSUS CONTINUOUS ENVIRONMENTAL VARIABLES
MEASURED AT SITES IN THE ALPINE ZONE

VARIABLE	PRODUCT-MOMENT CORRELATION COEFFICIENT	DEGREES OF FREEDOM	SIGNIFICANCE
Age (years)	0.391	38	*
Elevation (metres)	-0.222	38	N.S.
Site Slope (degrees)	0.250	38	N.S.
Adjacent Site Slope (degrees)	0.311	38	N.S.
Site Exposure (degrees)	0.013	38	N.S.
Adjacent Site Exposure (degrees)	-0.065	38	N.S.
pH	0.204	38	N.S.
Nitrates (pounds/acre)	0.325	24	N.S.
Phosphorus (pounds/acre)	0.215	24	N.S.
Potassium (pounds/acre)	0.001	24	N.S.
Calcium (pounds/acre)	0.176	24	N.S.
Magnesium (pounds/acre)	0.296	24	N.S.
Salts (mmhos/centimetre)	0.072	24	N.S.
Organic Matter (%)	0.430	24	N.S.
Erosion (%)	-0.302	24	N.S.
Compaction (Kilograms/ centimetre^2)	-0.396	24	N.S.
Coarse Fragment Texture (%)	-0.173	38	N.S.

* correlation significant at $P < 0.001$
N.S. not significant

TABLE 14

CORRELATION COEFFICIENTS FOR TOTAL COVER
VERSUS ORDINAL ENVIRONMENTAL VARIABLES
MEASURED AT SITES IN
THE ALPINE ZONE

VARIABLE	SAMPLE SIZE	SPEARMAN RANK CORRELATION COEFFICIENT	SIGNIFICANCE
Wind Exposure Magnitude	39	−0.277	N.S.
Heat Index	39	−0.048	N.S.
Site Moisture Regime	39	0.418	*
Compaction Magnitude	39	−0.389	N.S.
Erosion Intensity Index	39	−0.420	*
Erosion Magnitude	39	−0.391	N.S.
Texture Index	39	0.238	N.S.
Soil Colour	39	−0.145	N.S.

* correlation significant at Probability <0.01
N.S. not significant

FIGURE 1

REVEGETATION RATE – DRY FOREST

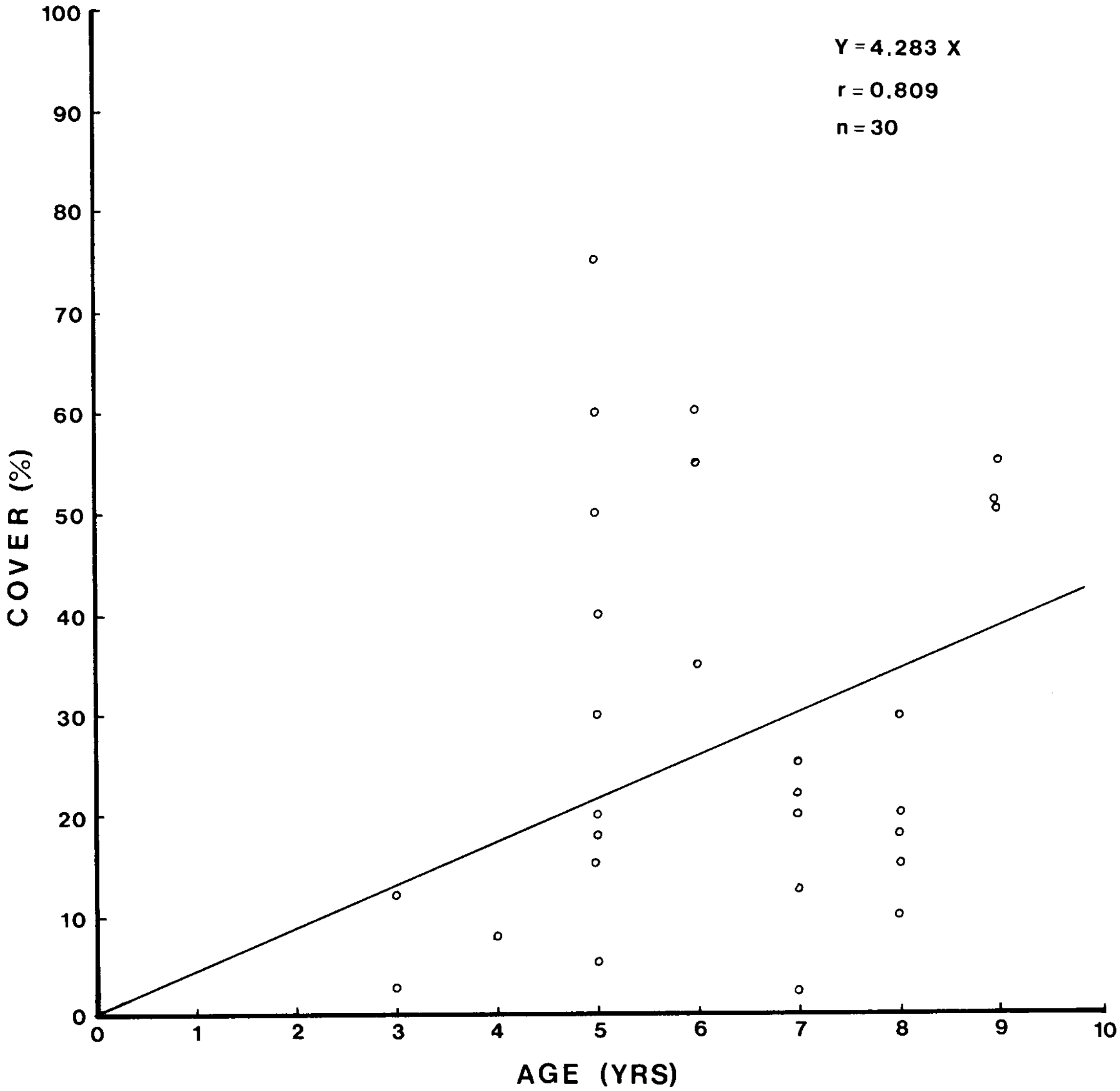


FIGURE 2

REVEGETATION RATE - MESIC FOREST

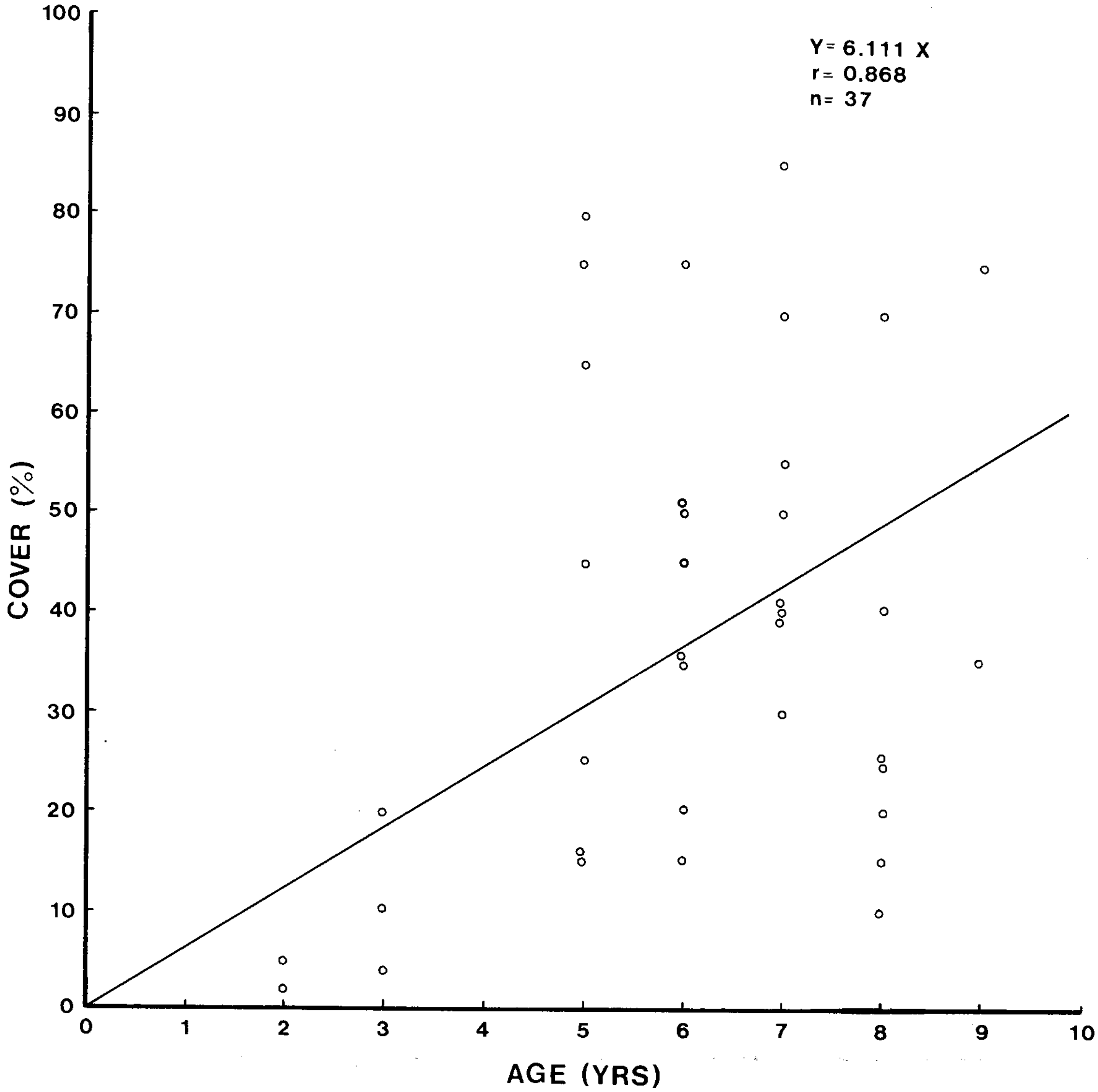


FIGURE 3

REVEGETATION RATE — WET FOREST

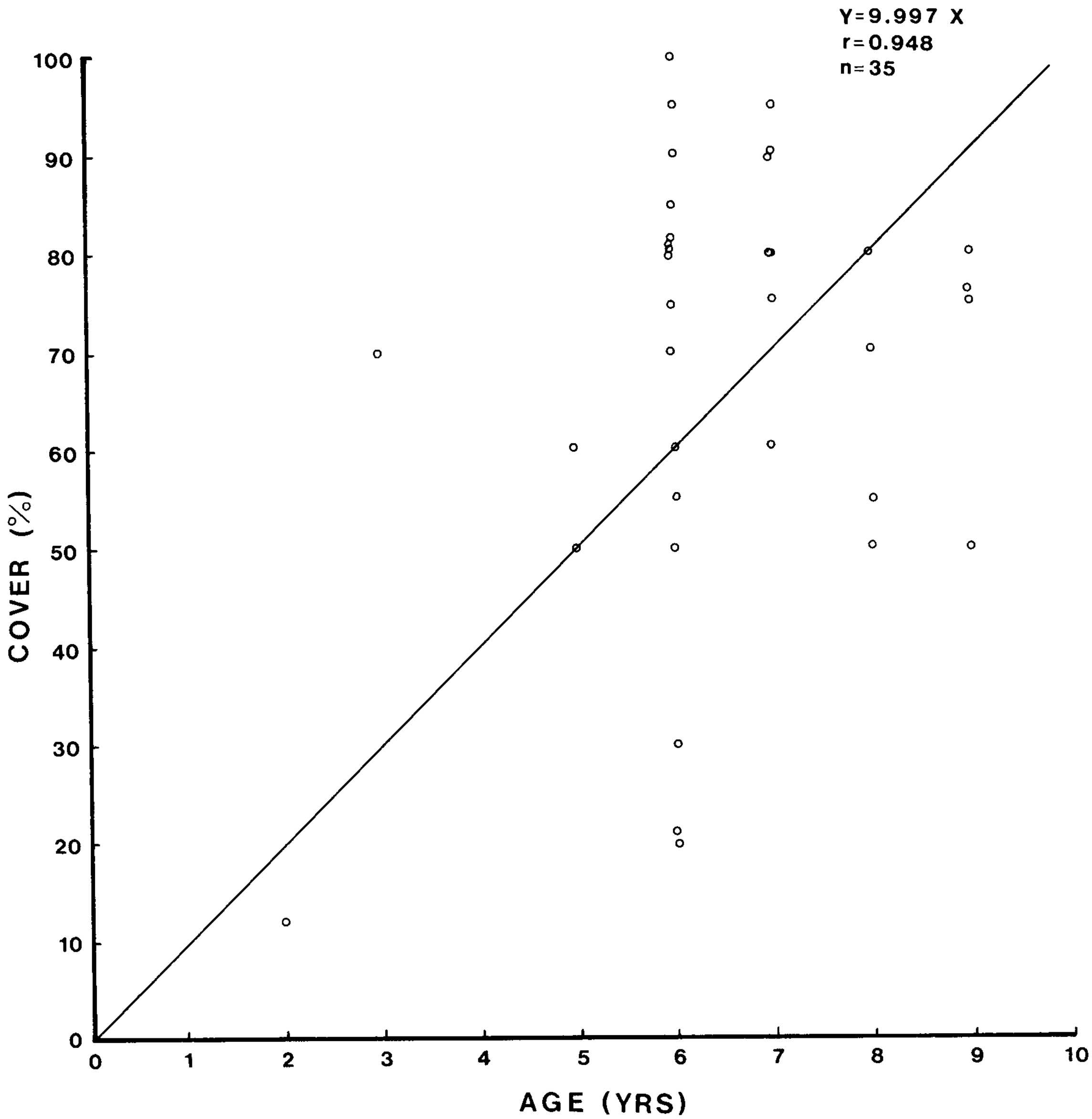


FIGURE 4

REVEGETATION RATE — DRY ALPINE

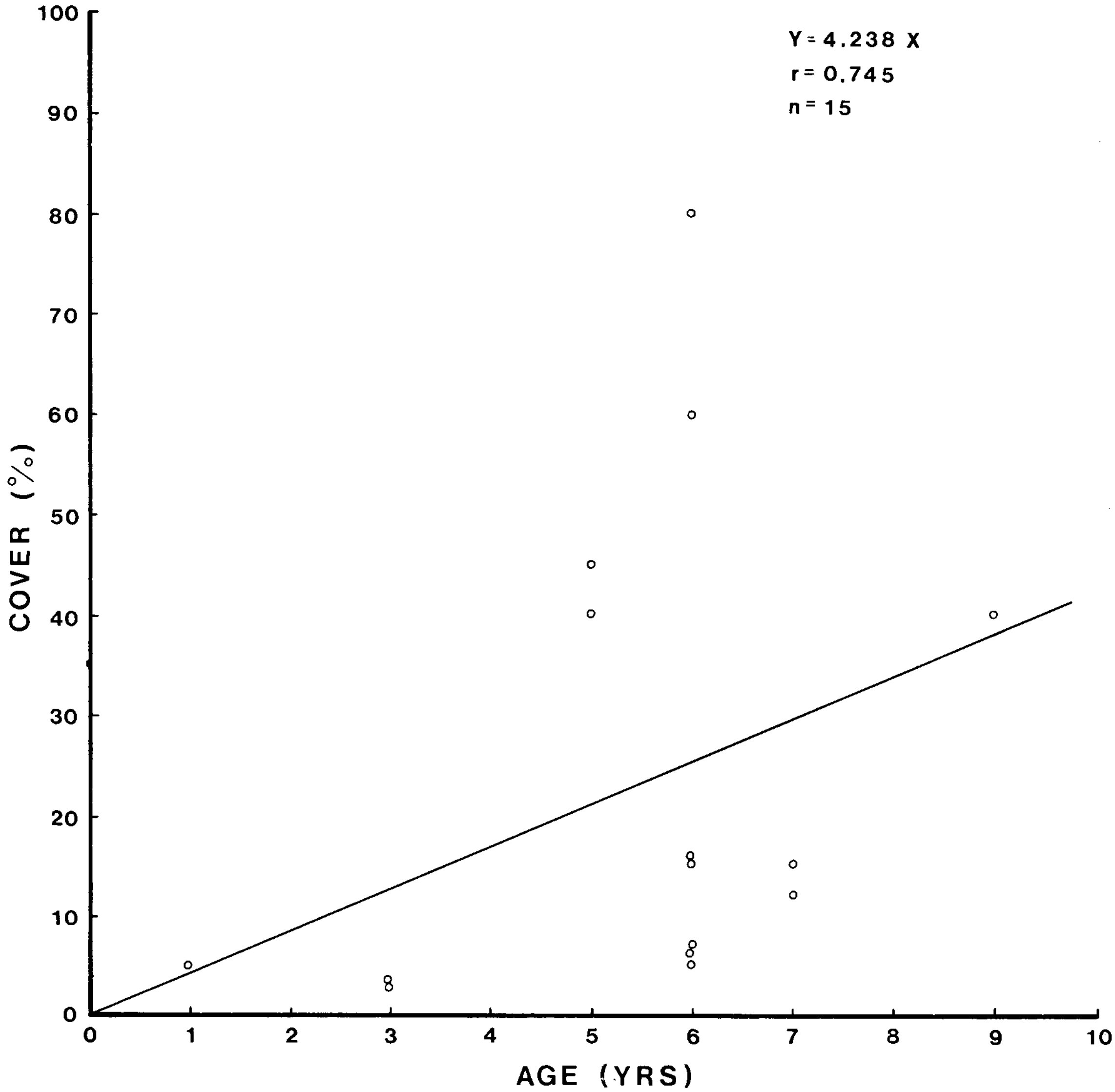


FIGURE 5

REVEGETATION RATE – MESIC ALPINE

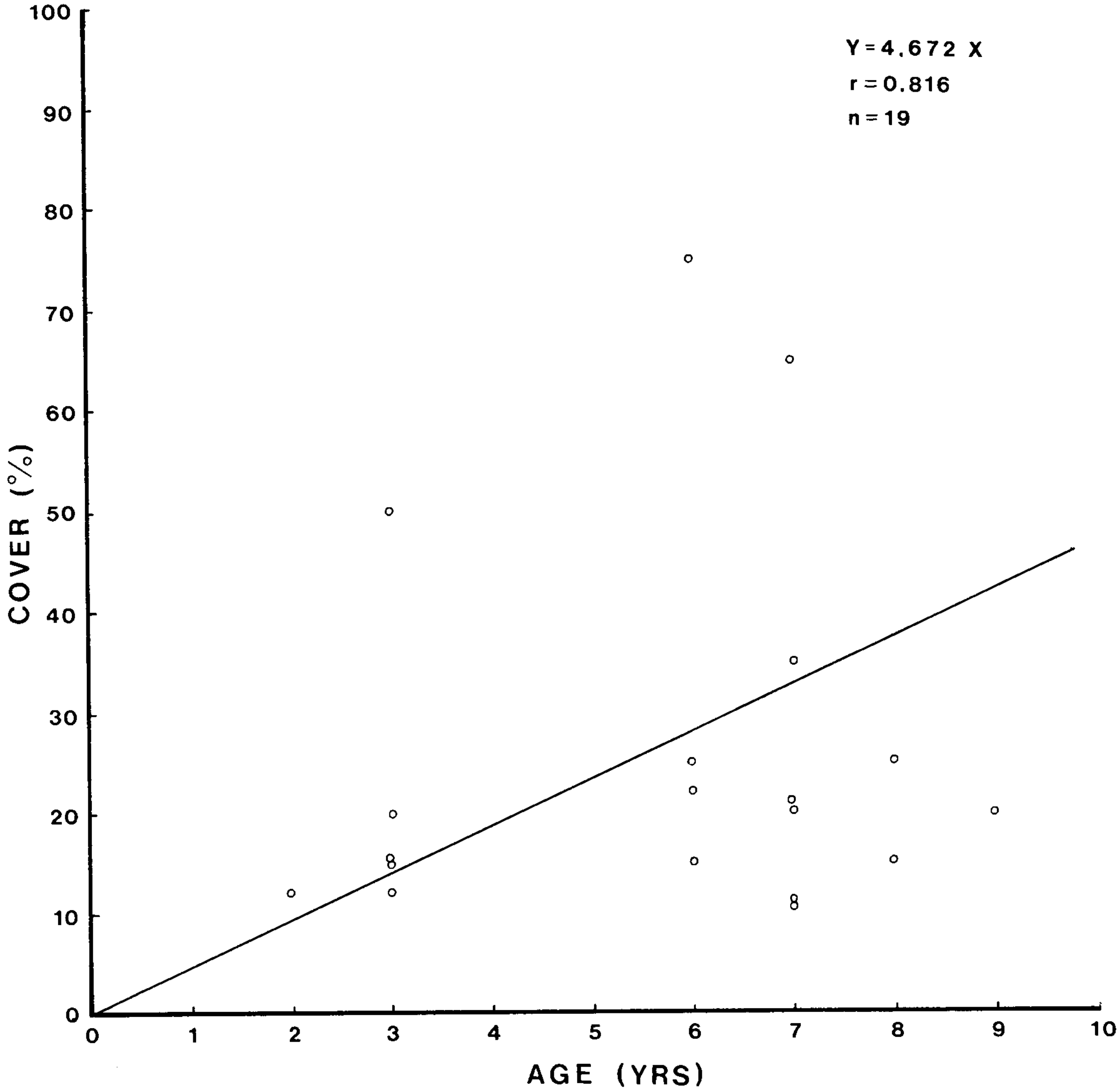
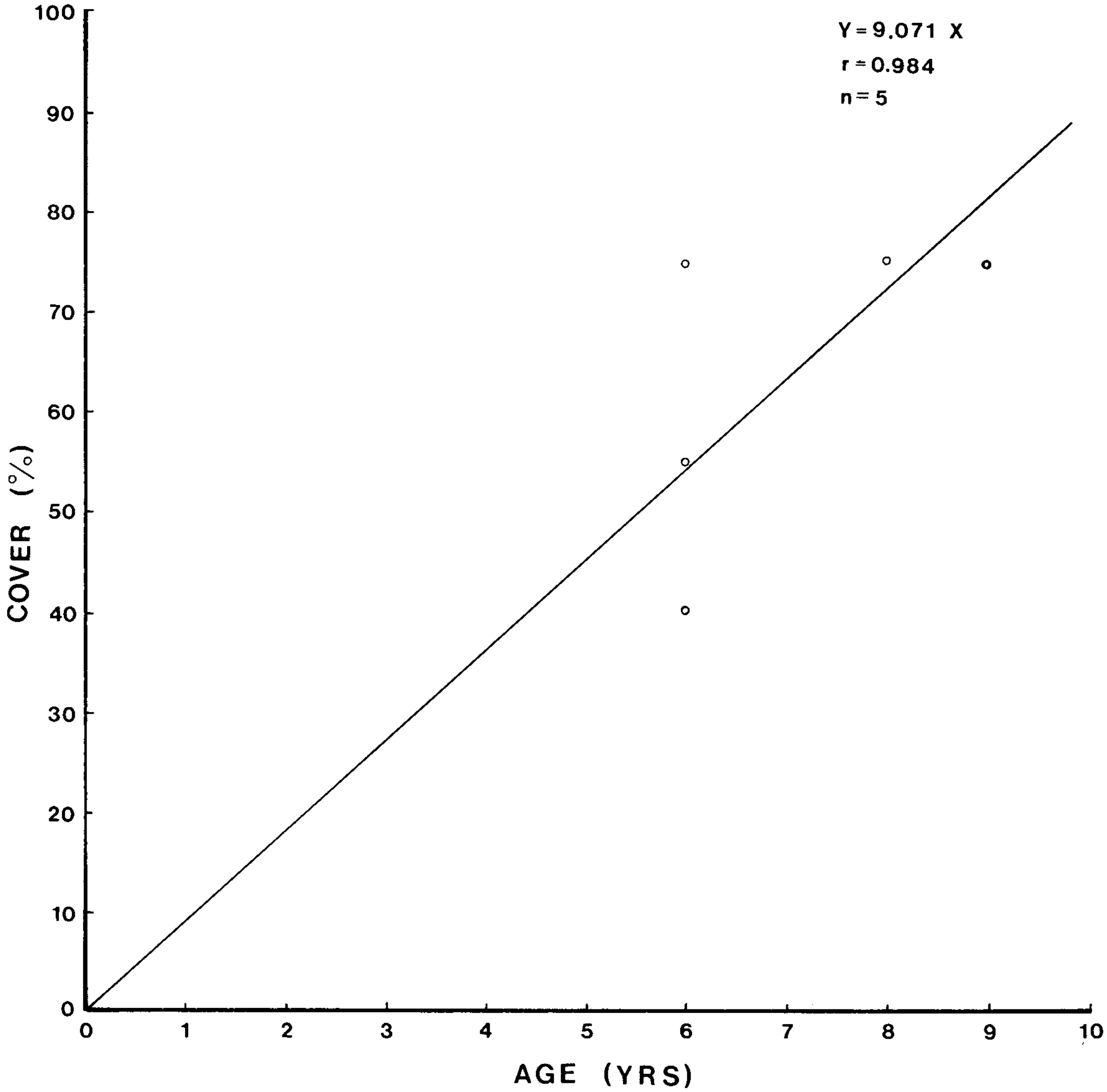


FIGURE 6

REVEGETATION RATE — WET ALPINE



DISCUSSION

Environmental Factors Affecting Natural Revegetation

Table 15 provides a summary of the significant correlations found between total cover on a site and the measured environmental variables. Age of a site was found to be positively correlated with total cover in all three analysis. This result was expected and has been confirmed. Increasing elevation results in decreasing cover when all sites are considered, but when the data set is divided into the two zones, the relationship is not significant. Therefore, elevation is not as important a factor within a zone as it is between the two zones.

Magnesium was the only macronutrient measured which showed a significant relationship with cover. This occurred only in the forested zones, such that increasing magnesium concentrations correlated with increasing cover. The reason that none of the other nutrients showed a relationship with cover may have been due to the very low nitrate concentrations in the soils, in conjunction with the principle of limiting factors. That is, the other nutrients were not allowed to "express" themselves because of the very low nitrate levels limiting the growth.

Increasing compaction of a site was correlated with decreasing cover both when all sites were considered and when only sites in the forested zone were analyzed. There was also a fairly strong negative correlation between compaction and total cover for the Alpine Zone, but it was only significant at the 95% level, consequently it was not included in the summary table. Highly compacted soils would primarily influence plant establishment by inhibiting root penetration. Compaction also results in decreased pore space for a particular soil, and this decreases the porosity of the soil to air and water, which could also affect growth.

TABLE 15

SUMMARY TABLE OF SIGNIFICANT CORRELATIONS*

VARIABLE	ALL SITES	FORESTED ZONES	ALPINE ZONES
Age	+	+	+
Elevation	-		
Magnesium		+	
Compaction	-	-	
Compaction Magnitude	-	-	
Texture of coarse fragments	-	-	
Texture Index	+	+	
Wind Exposure Magnitude	-		
Site Moisture Regime	+	+	+
Erosion Intensity Index			-

* Only variables with at least one significant correlation are summarized in this table.

\+ Significant positive correlation ($P < 0.001$)

\- Significant negative correlation ($P < 0.001$)

Both the texture of the coarse fragments (2 millimetres) and the fine fragments were significantly correlated with cover. As the volume of coarse fragments in a soil increased, the cover decreased. As the texture of the fine fragments changed from coarse to fine textured materials, the cover increased. Therefore, in both cases, the coarse textured soils were correlated with lower cover. Coarse textured soils have a relatively low water holding capability and do not have the capacity to absorb nutrients as well as finer textured soils. Thus, they tend to show reduced potential for plant growth compared to finer soils.

Magnitude of wind exposure was only significant when all the sites were considered. It was thought that this factor would be important within the Alpine Zone even if elevation was not important, but apparently it is not. When all the sites are pooled together, this variable could be considered as just another measure of elevation.

Site moisture regime was consistently and significantly correlated with the total cover on a site. Moisture regime is a composite index which takes into account a number of site factors such as the position on slope, drainage characteristics, texture and depth of the parent material, and the slope and exposure. Increasing moisture is highly correlated with increasing cover in all cases. This would indicate that moisture is a limiting factor for revegetation on some sites in the Peace River Coalfield.

Although three different measurements of erosion on a site were used in this study, only the Erosion Intensity Index showed any significant correlation. As erosion increased in the Alpine Zone, as measured by the index, the cover increased. This resulted basically from the direct removal of a "habitable" ground. In rills and gullies it is very difficult for young plants to become established after they have formed, due to the continuous erosion which occurs in such topography. The lack of any relationship between erosion and cover in the forested regions was probably because very few sites had a large amount of erosion. Most of the road samples had erosion bars installed, even though they had not been seeded.

All the other variables measured did not show a significant correlation with the cover on a site. In some cases, this could have been the result of only a narrow range of possible values being sampled due to the geographical area of the study and the nature of the sites, but in other cases, there may not be a simple relationship between the variables and total cover.

In considering the variables found to be correlated with cover, only two can be practicably managed in the reclamation of coal-exploration disturbances in the Peace River Coalfield. These are the compaction magnitude and the magnesium levels. By "ripping" any roads or drill sites that have become compacted after abandoning an area, the success of revegetation on that site can be enhanced. Also, if soil samples are taken on some of the disturbances in the forested zones, those sites which have low magnesium levels may be identified and then limed using a dolomitic limestone. Organic matter content on a site was also very important.[1] The methods and problems of adding organic matter to a site are too numerous to be expanded upon in this paper, but they could include adding wood chips or wood fibre to large areas, or sewage sludge or manure to smaller areas.

Rates of Revegetation

The rates of revegetation of the broad vegetation units sampled during the first nine years following abandonment of the site, showed that moisture seemed to be more important than elevation. The regression coefficient for Mesic Alpine was less than that for the Mesic Forest - Wet Alpine pairs were very close. It may be that revegetation occurs at about the same rate in the Alpine Zone as it does in the forested zones on sites having similar moisture conditions.

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[1] Organic matter content was consistent significantly at the 95% level of significance, but the 99% level was chosen for this study in order to reduce the alpha- error (Zar, 1074).

The revegetation rates for the Alpine units were based on small samples - very small in the case of the Wet Alpine unit - so more data will be required before a strong conclusion can be made. Also, a close inspection of the Dry Alpine and Mesic Alpine graphs showed that there were more points clustered below the line than above, so that if more sampling is undertaken the rates could be somewhat lower than that determined during this study. Therefore, these results must be considered preliminary.

Two more observations must be made regarding the revegetation graphs. The wide scatter of points about the line in all of the graphs is a result of the nature of the areas sampled. As discussed previously, moisture, age and elevation are not the only factors that influence revegetation on a site. For example, variations in compaction and texture of the sites within a broad vegetation unit are also going to influence revegetation. The rates of revegetation in these graphs may be considered as representative of the "average" site, with considerable variability occurring on individual sites. Also, no attempt has been made to predict when 100% cover would occur on the "average" site in each unit. A prediction of cover beyond the range of ages which were measurable would produce invalid results, as the relationship between total cover and age may change. The total cover predicted at the end of nine years for the "average" site within each broad vegetation unit is summarized in Table 16. As the table indicates, the "average" Wet Forest and Wet Alpine sites were almost totally revegetated after nine years of growth. An inspection of Figure 3 shows that some Wet Forest sites had greater than 90% cover as early as six years after site abandonment, and that some sites had a cover of only 50% after nine years. Therefore, although the revegetation graphs now approximate relative rates of revegetation on different sites, it should be recognized that the rate of revegetation on an individual site can vary considerably, depending on the growth limiting factors of a particular site.

TABLE 16

PREDICTED TOTAL COVER ON "AVERAGE" SITE AFTER NINE YEARS GROWTH

BROAD VEGETATION UNIT	REGRESSION EQUATION	TOTAL COVER (%) IN NINE YEARS ON "AVERAGE" SITE
Dry Forest	Y = 4.283 X	39
Mesic Forest	Y = 6.111 X	55
Wet Forest	Y = 9.997 X	90
Dry Alpine	Y = 4.238 X	38
Mesic Alpine	Y = 4.672 X	42
Wet Alpine	Y = 9.071 X	82

CONCLUSION

The results of this study indicate that a number of factors are important influences on the potential success of revegetation on a particular site. The most important factors include elevation, age, moisture, texture and compaction of the site. Of the site factors found to be significantly correlated with cover, only the compaction and the magnesium level can be modified easily. Although the rate of revegetation of an individual site may vary, these relative rates of revegetation within broad vegetation units may be compared. From the comparisons, it appears that moisture is more important than elevation in determining the revegetation rate.

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MIGRATION OF ACID SUBSTANCES IN SULLIVAN TAILINGS
A COLUMN STUDY

Paper presented
by:

S. Ames
Dept. of Soil Science
University of British Columbia

MIGRATION OF ACID SUBSTANCES IN SULLIVAN TAILINGS - A COLUMN STUDY

INTRODUCTION

Reclamation of the tailings pond at the Sullivan Mine, at Kimberley, British Columbia, involves some unique problems. Although the pond is still active, procedures are being developed for the ultimate reclamation of the pond. Attempts at establishing vegetation directly on the tailings pond have met with little success because of the high acid production potential and the high salt content of the soil. This is because the reduced pyritic tailings are weathered in an oxidizing environment which converts sulfides to sulfates.

Several procedures for reclamation have been considered. One procedure involved covering the tailings with overburden or soil to some depth and the establishment of vegetative cover on this material. The question raised is: Will the acid produced by the oxidizing tailings slowly rise through the overburden and, with time, contaminate the overburden with acids, soluble salts and heavy metals to make the overburden ultimately ineffective? To test this, a laboratory study was initiated in co-operation with Cominco Ltd. at the Department of Soil Science, University of British Columbia.

The objectives of the study were:

(1) To test whether an overburden that is applied directly onto the surface of the Sullivan Mine iron tailings would become severely contaminated with time, contamination occurring as a function of the potential upward migration of acids and toxic materials from the tailings, and

(2) To test whether a barrier, in this case a layer of gravel, would provide "insulation" to the overburden from the iron tailings, thus inhibiting potential contamination.

METHODS AND MATERIALS

The oxidized iron tailings used in the study were collected from the surface of the iron tailings pond at Sullivan Mine. The tailings were taken to the laboratory, dried, and crushed for uniform packing in plexi-glass columns. The chemical composition of the reduced tailings (unoxidized) is given in Table 1. Some chemical and physical properties for the unoxidized and oxidized tailings are given in Table 2.

Overburden (glacial till) was removed from a ditch north of the iron tailings pond. The overburden was felt to be representative of the type of material that would be used if overburden were to be placed over the tailings. Routine chemical and physical analyses were conducted on the tailings material and overburden.

The study was designed as a nine-month project which consisted of two treatments. Nine plexi-glass columns, 190 centimetres in height, with an inside diameter of approximately 15 centimetres were constructed for each treatment. Treatment 1 consisted of 45 centimetres of overburden placed directly onto the surface of a 30 centimetre deep layer of iron tailings (Figure 1). Treatment 2 consisted of 45 centimetres of overburden separated from a 30 centimetre deep layer of tailings by a 5 centimetre layer of coarse gravel. The gravel layer had two functions in this study:

(1) To provide a hydrologic barrier between the tailings and the overburden from the tailings. The upward movement of acids and toxic materials was considered to be a function of capillary rise through a uniform pore continuum. The gravel would break this continuum and therefore effectively act as a barrier under unsaturated water flow conditions, and

TABLE 1

Chemical composition of Unoxidized Iron Tailings[a]

Mineral	%	Chemical Formula
Pyrrhotite	85	$Fe_7 S_8$
Pyrite	5	$Fe S_2$
Sphalerite	1	Zn S
Galena	1	Pb S
Quartz	5	$Si O_2$

[a]From Gardiner and Stathers (3).

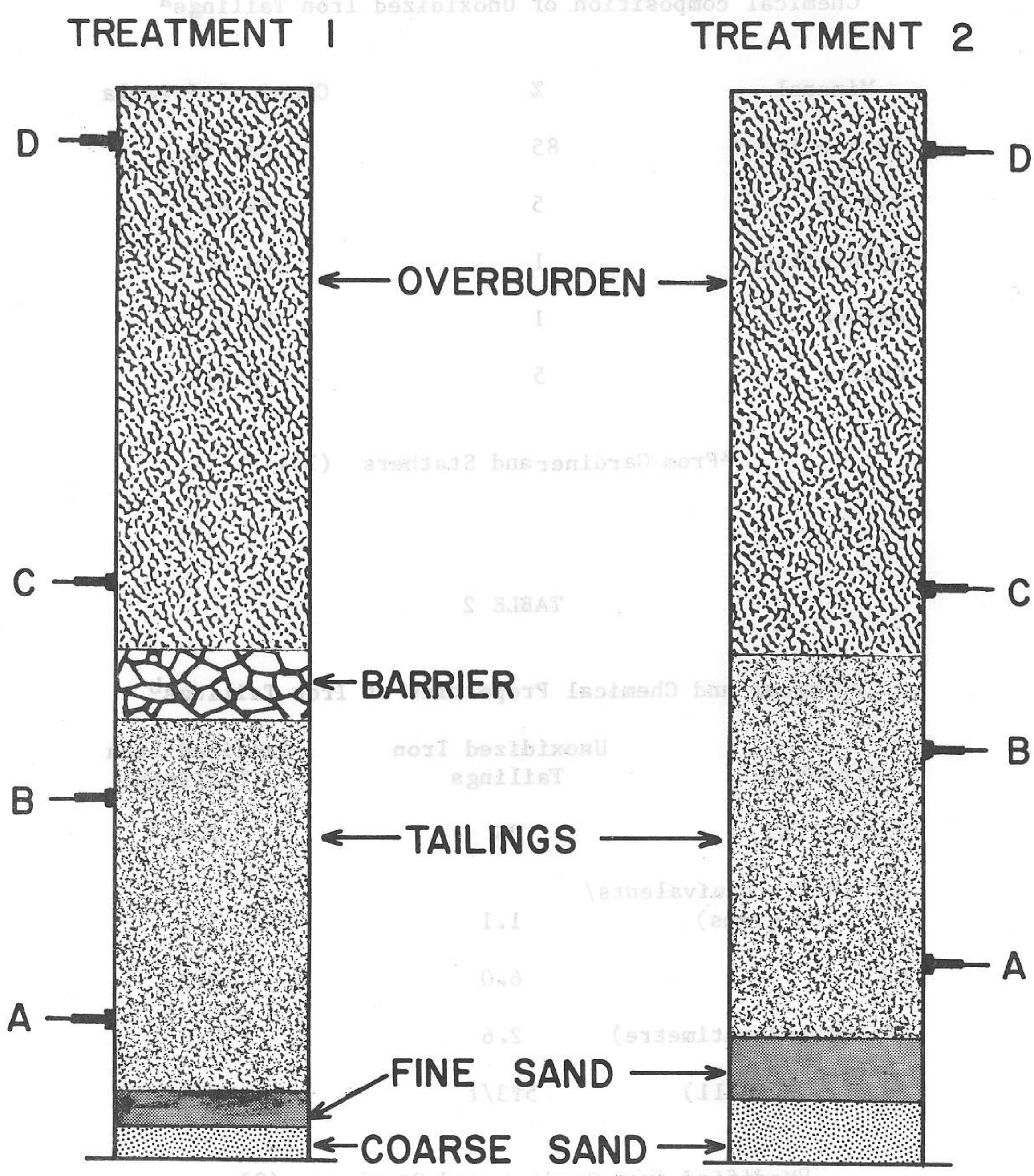
TABLE 2

Physical and Chemical Properties of Iron Tailings[b]

Property	Unoxidized Iron Tailings	Oxidized Iron Tailings
Total S(%)	34	7.3
CEC (Milli equivalents/ 100 grams)	1.1	5.1
pH	6.0	2.2
EC (mmhos/centimetre)	2.6	18.0
Colour (Munsell)	5Y3/1	10YR5/6

[b]Modified from Gardiner and Stathers (3).

FIGURE 1
COLUMN DESIGN



(2) To provide a means of reclaiming the waste rock dump. The mining process at Sullivan Mine produces waste rock. This could be used as a source of coarse material for the hydrologic barrier.

In order for upward migration to occur, water must move up through the columns by capillary rise. Thus, each column is equipped with a water table located at a height halfway up in the tailings material. Four sampling portals are specifically located to include sampling areas below and above the water table in the tailings material, at levels A and B, respectively; and, a sampling area in the overburden fairly proximate to the tailings overburden boundary at level C. A fourth portal is located near the top of the columns in the overburden, at level D (Figure 1). Solutions were extracted each month from each sampling portal for chemical analyses.

The upward movement of acids and toxic materials was promoted by accelerating evaporation at the surface of the columns. This accelerated evaporation was imposed by placing the columns in a wooden growth chamber constructed in the laboratory. The wooden structure is approximately 1.8 metres x 2.1 metres and is roughly 2.5 metres in height. It was equipped with a heater, insulation and a thermostat. The temperature was maintained at approximately 32°C. Arid conditions were mandatory for the success of this project. In an environment of room temperature and pressure the rate of reaction would be minimal.

The experimental approach of evaporation processes as opposed to leaching processes is justified by considering the climatic zone in which the mine site is located. Kimberley has been described as in the 'dry belt' of British Columbia. It receives approximately 378 millimetres of precipitation annually of which roughly 229 millimetres are allocated to rainfall. The climatic data for Kimberley is given in Table 3. With summer temperatures reaching a maximum of 32°C and a relatively long (181 day) growing season, evaporation is considered to be the dominant process as opposed to leaching.

TABLE 3

Climatic Data for the Kimberley Area[c]

Precipitation (mm)		
Mean annual	377.6	
Mean annual rainfall	228.8	
Maximum rainfall	51.8	(June)
Mean annual snowfall	154.5	
Maximum snowfall	42.4	(December)
Temperatures (°C)		
Maximum	32	(August)
Minimum	-21.1	(March)
Growing Season (days)	181	
Frost free	95	

[c]From Canada Dept. of Transport (1) and (2).

Chemical Analyses

Standard pH measurements were carried out on the solutions to monitor changes in acidity. Electrical conductivity is important as it indicates soluble salt content. Iron, aluminum, zinc, and copper were analysed by atomic absorption spectrophotometry as these elements were in relatively high concentrations in the iron tailings and were considered toxic to vegetation when in large amounts. Data is presented for the solutions extracted from the overburden at levels C and D. The experiment has been in operation for six months.

RESULTS AND DICUSSION

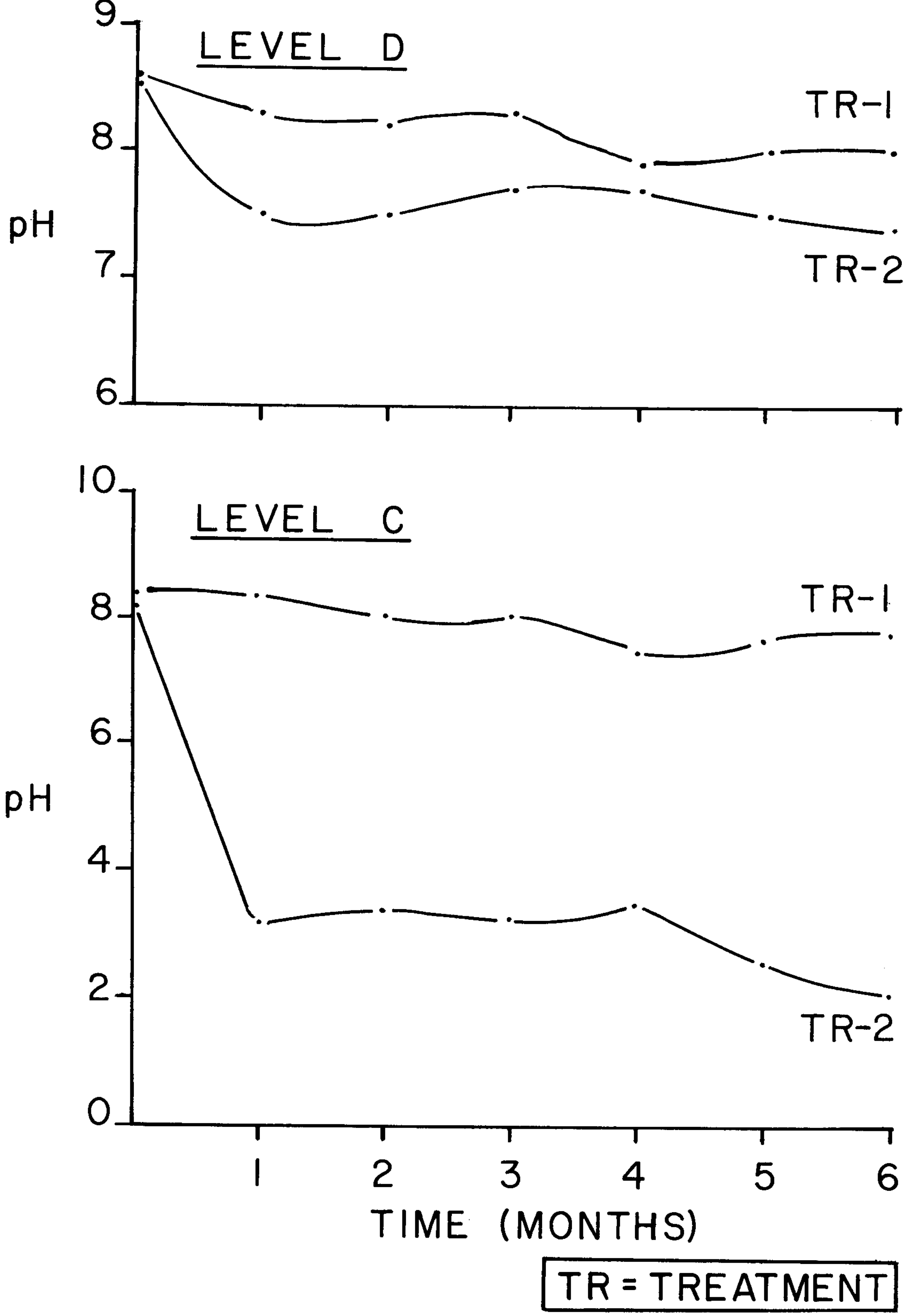
Preliminary analyses indicated that the gravel barrier was effective in preventing the upward movement of salts, acids, and other toxic materials into the overburden from the tailings material. The overburden material placed in direct contact with the tailings became contaminated by these substances. The extent of the chemical changes occurring in Treatment 2 in comparison to Treatment 1 can be effectively discussed if each type of analysis is considered separately.

Analysis of pH

As noted previously the most intense reactions were predicted to occur at level C in the columns. The barrier in Treatment 1 was effective in preventing acid movement (Figure 2). Changes in pH did not occur in this treatment during the experimental period. However changes in pH occurred in Treatment 2. The pH dropped from an initial basic reaction to a very acid condition at level C. The absence of a barrier resulted in a pore continuum between the tailings and overburden providing a direct path into the overburden. Indications that acids moved up to the D level in the columns became apparent as measurements decreased 1 pH unit during the sampling period. The reaction was much more extreme at level C, as movement to the sampling portal at level C took place over a distance of 7 centimetres (from the tailings-overburden

FIGURE 2

pH vs TIME



boundary). The optional pH range for vegetation success is roughly pH 6.5-7.0. The levels of acidity persisting at level C in Treatment 2 would pose serious problems to the growth and maintenance of vegetation.

Variation in pH measurements in the overburden at time "0", between the two treatments, was the result of rapid migration of some acid substances immediately after the columns had been packed.

Soluble Salts

Electrical conductivity measurements reflecting soluble salts are plotted in Figure 3. Treatment 1 proved to be a successful means of preventing the movement of salts. Measurements of soluble salts fall below those levels considered deleterious to vegetation-set at 4 millimhos per centimetre or lower. Unsuitably high concentrations of salts moved into the overburden at level C in Treatment 2. The short distance of 7 centimetres from the tailings boundary resulted in "rapid" contamination of the overburden at this level. Such high salt levels persisted in the overburden, illustrating the potential source of salts from the tailings.

The salts in Treatment 2 migrated in a linear manner due to the greater distance (roughly 40 centimetres) before reaching the sampling portal at level D. High salt contents appeared to be "long-term". Future analysis will verify this.

Elemental Analysis

Elemental analysis was carried out in the solutions extracted from the overburden at level C, which indicated that the acids and salts moving into the overburden in Treatment 2 were accompanied by concentrations of iron, aluminum, zinc, and copper (Figures 4 and 5). Therefore, elements did not migrate into the overburden in Treatment 1. The barrier resulted in effectively insulating the overburden from the tailings

FIGURE 3

ELECTRICAL CONDUCTIVITY vs TIME

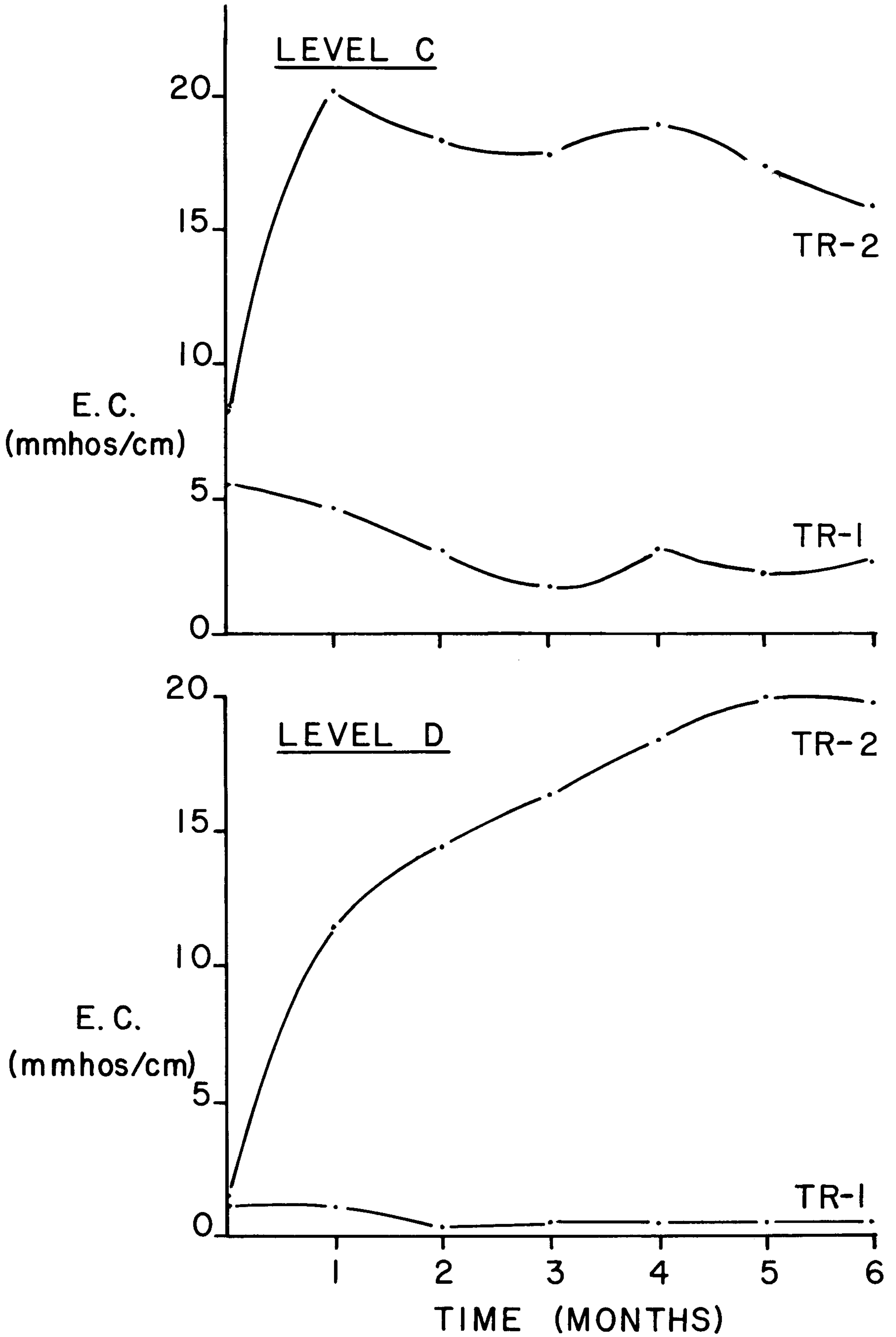
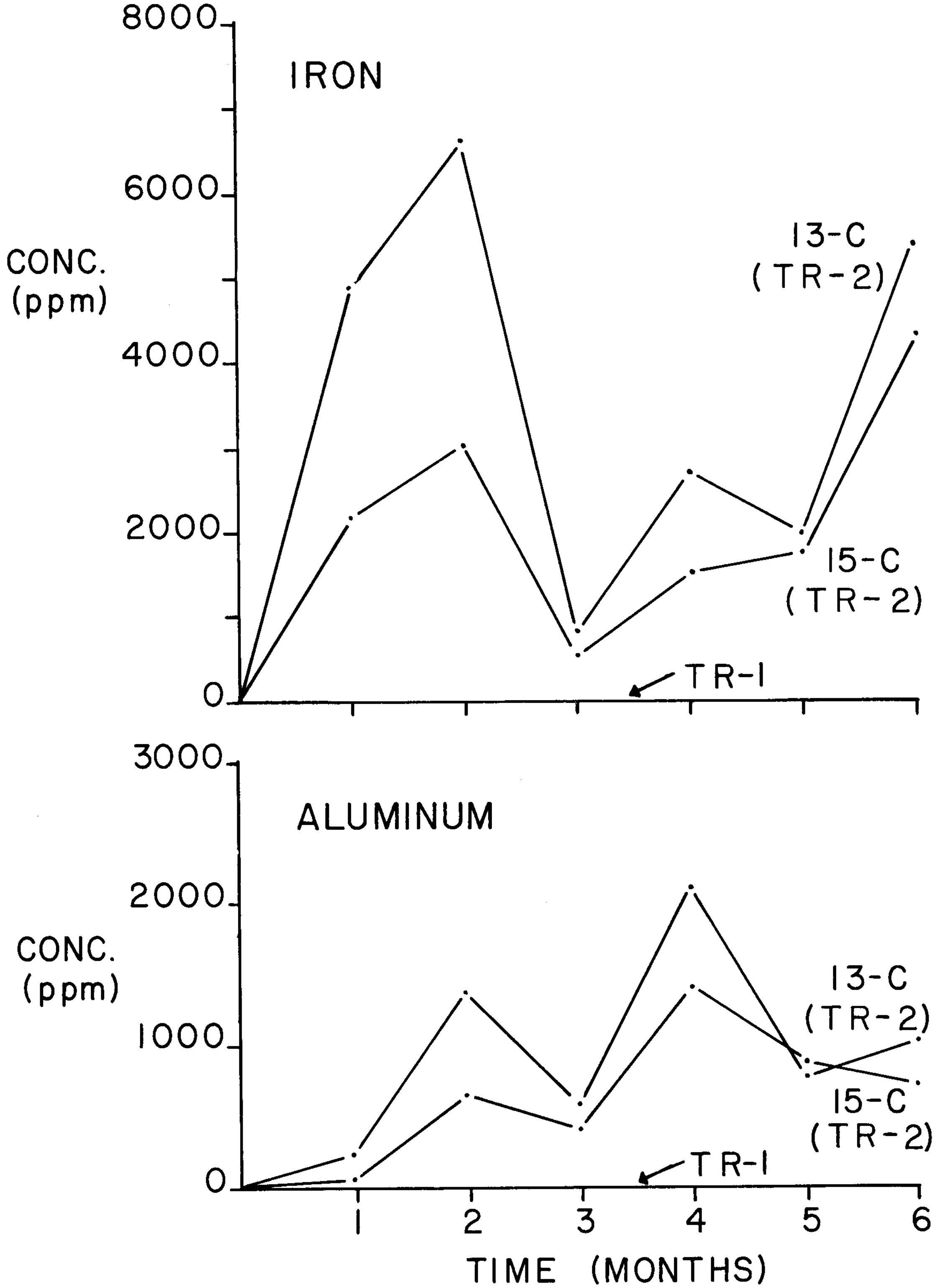


FIGURE 4

ELEMENTAL CONCENTRATION vs TIME



material. However, Treatment 2 was not effective as a reclamation procedure, as the overburden was contaminated. Relatively high concentrations of iron migrated upwards (Figure 4). This was attributed to the formation of soluble iron salts in the tailings when oxidation of the iron pyrite occurred. Data from two columns, arbitrarily numbered 13 and 15, indicated differential movement. This may give an indication of the kinds of variation that may occur in a field situation. The concentrations of iron, aluminum and zinc, rise and fall through the sampling period. This was attributed to precipitation and dissolution of precipitates under extreme acid conditions. Total analysis carried out on the overburden will verify this, or provide an alternate explanation for this pattern. As noted, this data is plotted from solutions extracted from the columns.

Aluminum and zinc concentrations were also relatively high. These high concentrations are prediatable if a source is available, as these metals are soluble under acid conditions. On completion of the experiment, total analysis on the overburden will indicate whether the concentrations of these elements will be at a level toxic to vegetation.

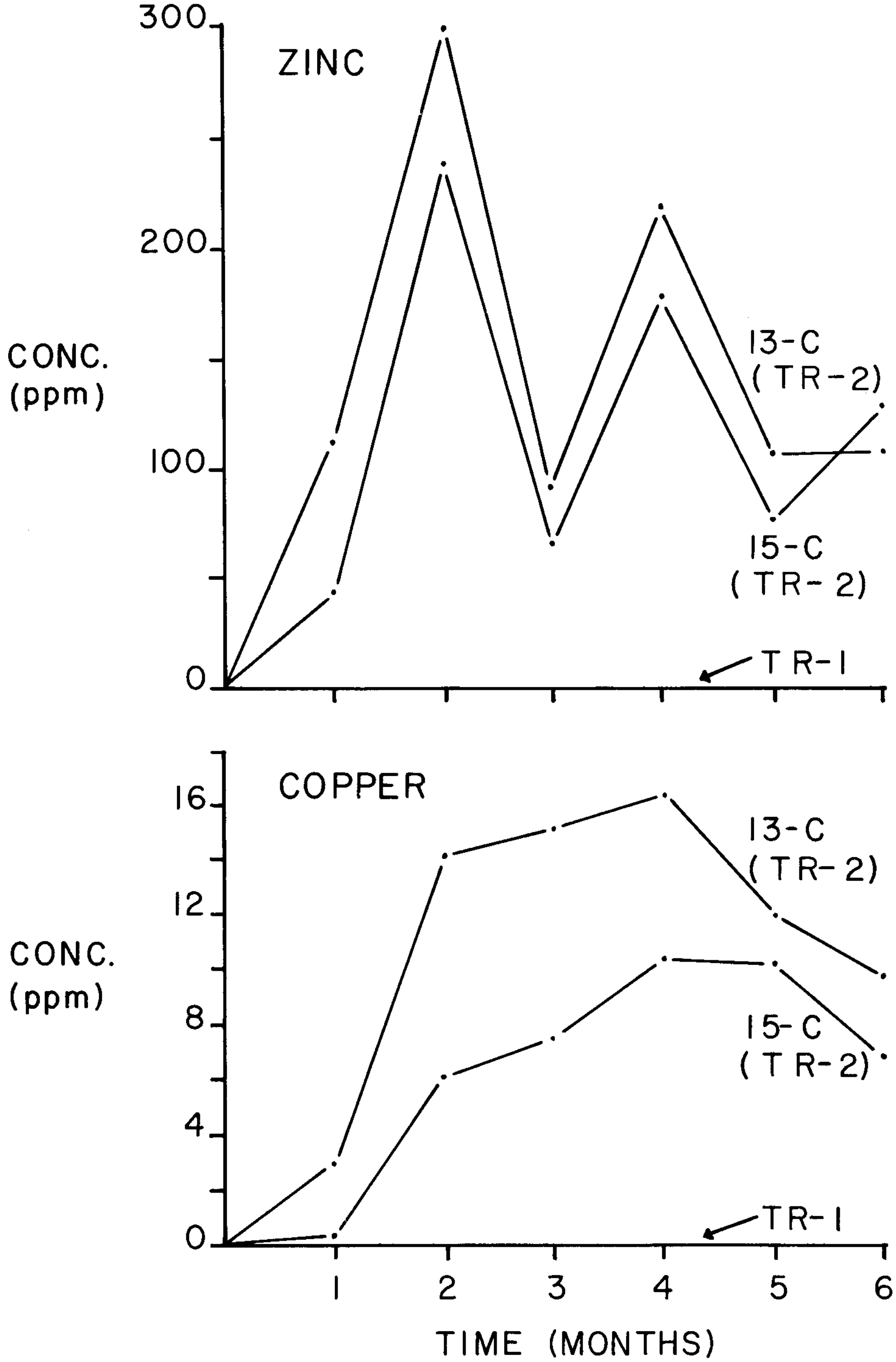
Copper concentrations did not follow the same peak-depression pattern as the other three metals, iron, aluminum, and zinc. Explanation for this change in pattern may be attributed to the comparatively low concentrations of this element in the tailings. Higher concentrations may be required for precipitation.

CONCLUSIONS

The results of this study indicated that the overburden in Treatment 2 was contaminated by the migration of acids, soluble salts, iron, aluminum, zinc and copper. The barrier in Treatment 1 was effective because the pH remained high and the electrical conductivity remained low. Detectable iron, aluminum, zinc, and copper did not migrate up into the overburden. This data indicates the progress of the experiment to date. As was formerly noted, this data was plotted from analysis of solutions extracted from the overburden material. It is predicted that total analysis on the

FIGURE 5

ELEMENTAL CONCENTRATION vs TIME



overburden will confirm that the reclamation of Sullivan Mine iron tailings may be successful if a barrier is placed between the tailings material and the overburden. It is also predicted that overburden if placed directly onto the tailings pond may become contaminated in time.

ACKNOWLEDGMENT

The author wishes to thank Cominco Ltd. for providing a Grant-in-Aid for this research.

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MAINTENANCE FERTILIZER RESEARCH AT KAISER RESOURCES LTD.

Paper presented

by:

J.W. Fyles

Department of Biology

University of Victoria

MAINTENANCE FERTILIZER RESEARCH AT KAISER RESOURCES LTD.

INTRODUCTION

Research into the use of maintenance fertilization in operational reclamation at Kaiser Resources Ltd. has, over the past few years, centered on the following questions. What application rate should be used to obtain optimum growth per kilogramme of fertilizer? What combination of elements in the fertilizer should be used to obtain best results? How many years should maintenance fertilization continue to ensure a self-sustaining cover of vegetation on reclaimed areas? During 1978, fertilizer trials were established on two sites near Sparwood to investigate the first two of these questions. Phosphorus requirements were of specific interest because of the high cost of phosphorus fertilizers in comparison to nitrogen fertilizer, which, because of its use in blasting operations, is readily available.

METHODS

Two study sites were located on reclaimed areas which supported a high cover of vegetation. Both sites had received maintenance fertilizer for several years, with the latest application taking place several weeks before the initiation of the study. The Harmer study area, at an elevation of approximately 2,000 metres, and representative of many high elevation reclaimed sites, was dominated by Orchardgrass, Timothy and Creeping Red Fescue. The Erickson study area (elevation 1,500 metres) was dominated by Intermediate and Crested Wheatgrasses and Canada Bluegrass and is typical of many dry reclaimed areas at low elevation.

Four levels each of urea and treble superphosphate yielded sixteen treatments which were randomly arrayed in treatment blocks prior to on-site layout. Three replicate blocks were established on each site. The details of each treatment are given in Table 1. Block and treatment layout at each site are given in Figures 1 and 2.

TABLE 1

FERTILIZER TREATMENTS

Treatment No.	N	P_2O_5	46-0-0	0-45-0
	Kilogram/hectare		Kilogram/hectare	
1	0	0	0	0
2	28	0	61	0
3	56	0	122	0
4	112	0	243	0
5	0	56	0	124
6	28	56	61	124
7	56	56	122	124
8	112	56	243	124
9	0	112	0	248
10	28	112	61	248
11	56	112	122	248
12	112	112	243	248
13	0	224	0	496
14	28	224	61	496
15	56	224	122	496
16	112	224	234	496

FIGURE 1

ERICKSON REPLICATE BLOCK AND TREATMENT LAYOUT

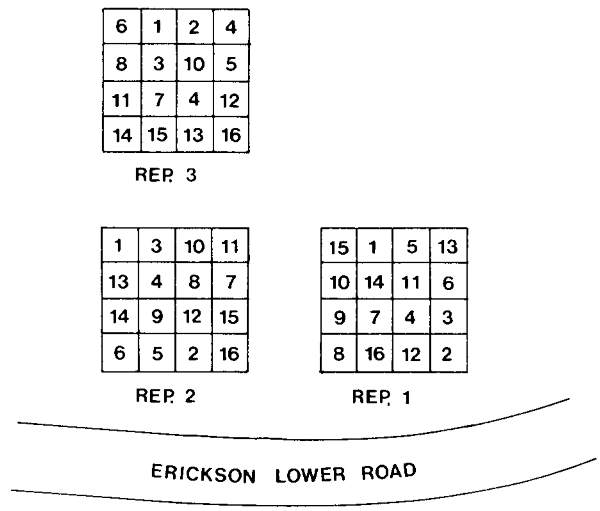
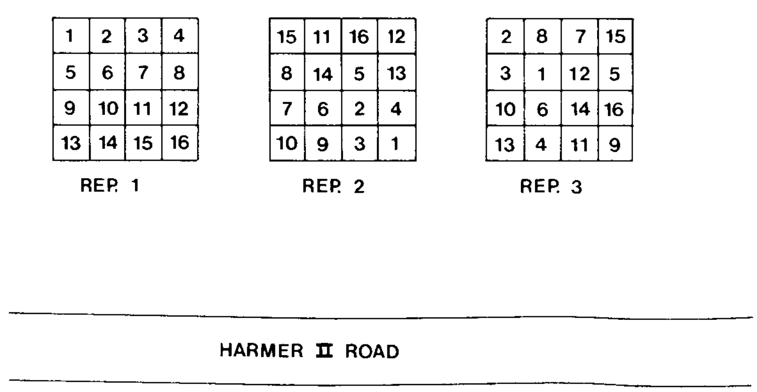


FIGURE 2

HARMER II REPLICATE BLOCK AND TREATMENT LAYOUT



Treatments were evaluated in late August according to the dry weight of aerial biomass clipped from 50 centimetre square frames. Two samples were clipped from each treatment. The data were analysed using standard Analysis of Variance methods to evaluate the effect of nitrogen and phosphorus levels (fixed treatments) and site differences reflected in the three replicate blocks (random treatment). In all analyses, significance was tested using an alpha level of 0.05.

RESULTS

The results of the analysis of the data obtained from the Erickson trials are given in Table 2. Since all of the probabilities derived are greater than 0.05 it can be concluded that none of the factors tested had a significant effect on growth. This conclusion is somewhat surprising because of the general belief that reclaimed areas are very nutrient deficient and require fertilization to support growth. The observed results can, however, be explained in two ways. Firstly, it is possible that, through previous maintenance fertilization and the residual effects of nutrient additions, the soil nutrient status has been raised to such a level as to be non-limiting to growth. This does not seem to be a reasonable explanation, however, since fertilization of even highly fertile agricultural soils will produce increased crop production and it is unlikely that the soils of the study site would have higher fertility. A more plausible explanation would be that although the nutrient levels in the soil are low, it may be the lack of moisture on the site which is the limiting factor. This is the most likely explanation of the observed results even though the summer of 1978 was not particularly dry. In any case, it is apparent that fertilization of dry, low elevation sites does not produce the desired resalts of increasing vegetative production and is therefore not a viable investment of reclamation dollars.

The results of the analysis of data from the Harmer site are given in Table 3. In this analysis two of the sources of variation proved significant.

TABLE 2

ANALYSIS OF VARIANCE OF ERICKSON FERTILIZER DATA

SOURCE	DF	F	P	% VAR
N	3	0.26	0.85	---
P	3	1.82	0.24	---
REP	2	0.64	0.53	---
N*P	9	1.92	0.11	---
N*REP	6	1.77	0.13	---
P*REP	6	0.64	0.70	---
N*P*REP	18	0.72	0.77	---

TABLE 3

ANALYSIS OF VARIANCE OF HARMER FERTILIZER DATA

SOURCE	DF	F	P	% VAR
N	3	2.30	0.177	---
P	3	2.87	0.162	---
REP	2	8.40	0.001	5.770
N*P	9	1.29	0.306	---
N*REP	6	1.72	0.134	---
P*REP	6	2.19	0.060	---
N*P*REP	18	5.69	0.000	35.182

The differences between replicate blocks (REP) accounted for almost six per cent of the variation while the three way interaction between nitrogen and phosphorus levels and replicate block accounted for approximately thirty-five per cent of the variation. These data suggest that the soil condition varied greatly among replicate blocks. To eliminate this variation and to gain a better understanding of the three way interaction the data from each replicate block were analysed separately as shown in Table 4. From these results it can be seen that both nitrogen and phosphorus had a significant influence on growth but that the effect varied from one replicate to the next. In Replicate 1, the levels of both nutrients and their interaction were significant while in Replicate 2, phosphorus was non-significant and in Replicate 3 nitrogen was non-significant.

CONCLUSIONS

In relation to the original objectives of the study, therefore, it can be concluded that, in most areas, phosphorus is a required fertilizer component. Unfortunately, further analysis could not determine the optimum application rate of either nutrient. Because of their inconclusive nature, these analyses have not been included in this paper.

Perhaps the most important conclusion to be drawn from the analysis of the Harmer data is in regard to the high variability in the soils of the study site. Bearing in mind that the blocks were placed less than three metres apart, this gross variation has significant ramifications toward present research and management practices. At the outset of the study it was hoped that an overall fertilization strategy could be devised for application to all elevation sites. In reality, however, a different strategy would be required to satisfy the requirement of each replicate block. When extended to include the numerous hectares of reclaimed areas it becomes obvious, than an accurate, overall fertilization strategy is an impossibility. Instead, it appears that the best approach may well be the present "seat of the pants" method in which a complete fertilizer is

TABLE 4

ANALYSIS OF VARIANCE OF HARMER FERTILIZER DATA BY REPLICATE

	SOURCE	DF	F	P	% VAR
REP 1	N	3	6.29	0.005	20.055
	P	3	5.52	0.009	17.600
	N*P	9	4.74	0.003	45.327
REP 2	N	3	4.35	0.020	19.961
	P	3	1.22	0.336	---
	N*P	9	3.63	0.012	49.998
REP 3	N	3	0.19	0.905	---
	P	3	4.41	0.019	12.109
	N*P	9	8.83	0.000	72.740

applied at some arbitrary rate with repeated application when necessary.

ACKNOWLEDGMENTS

Kaiser Resources Ltd. wishes to gratefully acknowledge the Cominco Ltd. for supplying the fertilizer and experimental design for this study.

FOLLOW-UP SLOPE EXPERIMENTS AT FORDING COAL LIMITED

Paper prepared jointly
by:

R.J. BERDUSCO
and
J.L. POPOWICH

FORDING COAL LIMITED

FOLLOW-UP OF SLOPE EXPERIMENTS AT FORDING COAL LIMITED

INTRODUCTION

Fording Coal Limited operates the Fording River Coal Mine in southeastern British Columbia.

Fording Coal ownership is 60 percent Canadian Pacific Investments and 40 percent Cominco Limited. The operation produces 3 million long tons of metallurgical coal annually primarily for export to Japan.

Coal extraction involves the use of both truck-shovel and dragline mining during which some 25 million bank cubic yards of waste are handled annually.

This paper discusses a study initiated in 1977 which was designed to investigate optimal resloping techniques used in waste dump reclamation. Waste dumps at an elevation of 1700 metres were resloped from 37 degrees to a range of slope angles from 24 to 34 degrees with various aspects. Dump material consisted of carbonaceous mudstones, siltstones and sandstone.

A 15 to 30 centimetre layer of calcareous glacial till was placed over portions of the 26, 28 & 30 degree areas to compare relative stability and revegetation potential with waste rock. Hydroseeding with a grass legume mixture followed.

This paper summarizes the conclusions of the 1977 observations which discussed equipment limitations, stability and costs and discusses 1978 follow-up work mainly with respect to revegetation.

REVIEW OF STUDY OBJECTIVES

Specific Study Objectives Were:

1. To establish resloped areas with varying slope angles, exposure and base materials to allow field reclamation research to determine vegetation growth on slope angles with varying conditions.

2. To evaluate equipment performance, safety, planning and operating guidelines when resloping waste dumps at various angles.

3. To establish field reclamation research in locations representative of principal mining methods.

4. To initiate full scale reclamation work in areas of final spoiling.

The underlying theme of this research is the optimizing of available spoiling areas and reclamation efforts. This is particularly important at the Fording River Operation as available spoiling areas are limited, because of the narrow valley and proximity to streams and support facilities.

SUMMARY OF 1977 CONCLUSIONS

Observations of Work Carried out in 1977 Can be Summarized as Follows:

1. Equipment used (D-8, D-9 and D-6 Crawler Dozers) worked most effectively on slopes up to 28 to 30 degrees. This equipment had a natural tendency to cut slopes to 28 degrees. Slopes from 30 to 34 degrees resulted in cross pushing with low productivity and deep track markings.

2. At angles above 28 degrees, the dozers would climb effectively in a forward position only. Reverse climb was possible but resulted in low productivity.

3. Total resloping costs encountered ranged from 1890 to 4350 dollars per plan acre worked with an average of 3270 dollars per acre. Total resloping costs expressed per loose cubic yard moved ranged from 28 to 41 cents with an average of 37 cents per loose cubic yard. Slopes ranged from 27 to 49 metres in length.

4. Stability and drainage appeared adequate on all slopes from 24 to 34 degrees. Small circular failures were encountered on 32 to 34 degree slopes but appeared to be related to isolated areas of fine wet material.

5. Generally it appears that from an operational point of view, waste dump slopes can be worked to 28 to 30 degrees. Operator safety, drainage, and surface stability appear to be adequate.

DISCUSSION OF 1978 FOLLOW-UP WORK

From an Assessment of the Study Area Conducted in 1978, the Following Observations can be made:

1. Seedling populations were similar for all slope angles, aspects and positions. Seedling density on all slopes was adequate to provide dense vegetations during subsequent growing seasons.

2. Grass seedling density was significantly greater on waste rock than on glacial till covering waste rock. However, seedlings grown on waste rock were very small and severely chlorotic relative to seedlings grown on glacial till.

3. Glacial till placed on 26, 28, and 30 degree slopes eroded readily and large amounts of fines collected at the toe of slopes. Waste rock slopes did not erode.

4. Data collected during the first growing season indicated that grasses will establish satisfactorily on waste rock slopes with angles ranging up to 34 degrees provided there are sufficient fines on a stable surface. Additional time is required to evaluate long-term effects of slope angle and aspect on plant growth and surface stability.

REFERENCES

1. Popowich, J., Spoil dump resloping at Fording River Operations.

2. Stathers, J.E. & Gardiner, R.T., Annual Reclamation Research Report. 1978/1979.

WORKSHOP SUMMARIES

RECLAMATION OF METAL MINE WASTES - PART 2

RECLAMATION RESEARCH,

AND SUGGESTIONS FOR FUTURE SYMPOSIA

Friday, March 9, 1979

Following completion of the Third and Fourth Technical Sessions of the Symposium, participants entered into a second set of workshop groups to debate a series of workshop questions. This Section of the proceedings summarizes their findings.

WORKSHOP - FRIDAY MORNING

Discussion topics should consider reclamation of metal mine wastes and research. Please feel free to discuss any topic arising out of the previous day's talks. The following four questions should initiate discussion:

DO YOU HAVE ANY RECOMMENDATIONS ON THE FORMAT AND CONTENT FOR FUTURE SYMPOSIA?

WHAT ARE THE MAJOR PROBLEMS IN RECLAMATION OF METAL MINE WASTES?

WHAT ARE THE CRITERIA THAT SHOULD BE USED TO DECIDE WHEN AN AREA CAN BE CONSIDERED RECLAIMED?

WHAT DO YOU SEE AS THE CURRENT RESEARCH PRIORITIES IN BRITISH COLUMBIA? WHO SHOULD UNDERTAKE THIS RESEARCH?

WORKSHOP 2

QUESTION 1 - DO YOU HAVE ANY RECOMMENDATIONS ON THE FORMAT AND CONTENT FOR FUTURE SYMPOSIA.

Findings Related to Question 1

Locations and Time:

- The Interior is the best location for the Symposium, with Vernon as a good place. March is the best time.

Introductions:

- The Symposium should begin with a general speaker to discuss reclamation in general, covering briefly the jargon used and techniques to be discussed. This applies to the Awards Banquet as well. The history of the Award and its terms of reference should be explained. This might be achieved by a printed program to be given out at the Awards Banquet.

Workshops:

- Only one workshop should be held, and the topic of discussion should be more definitive.

- A more structured workshop session should be attempted, involving more technical aspects, utilizing experts from various fields. This might be best achieved through a seminar format.

Papers:

- Topics become repetitive so only new topics should be presented and a strict quality control should be maintained. More variety is needed.

- Fewer but longer, more in-depth talks should be presented.

- Vary the order of papers so that all the similar reports don't occur together.

- Mine tailings ponds should be treated as a separate topic next year, since associated problems are quite different from those encountered in dealing with reclamation of rock dumps.

- Speakers from areas outside B.C. should be invited to present their approaches to similar problems.

- People from other industries should be invited to attend, e.g. B.C. Hydro, Forestry.

- Input from the government as to what is required for satisfactory reclamation on a few specific representative sites.

- More breaks between papers.

- Abstractsshould be distributed prior to each session.

- Speakers should clearly state their objectives.

Suggestions for Next Year's Topics:

- Uranium waste.

- Ministry of Highways to give a summary of their problems and successes with highway cuts.

- Effect of the All Terrain Vehicle Act.

- Exploration disturbance reclamation.

- Use of native species in reclamation.

- Potential of nitrate pollution.

- Clarification of policy on artesian flows in British Columbia

QUESTION 2 - WHAT ARE THE MAJOR PROBLEMS IN RECLAMATION OF METAL MINE WASTES

Findings Related to Question 2

- Revegetation of acid tailings ponds is probably not a long-term solution in terms of environmental pollution. Contamination of ground water with heavy metals is the real threat.

- Tailings ponds must be designed to minimize problems of leaching of toxic elements into the ground water.

- The effect of leaching of nitrates due to fertilization should also be considered.

QUESTION 3 - WHAT ARE THE CRITERIA THAT SHOULD BE USED TO DECIDE WHEN AN AREA CAN BE CONSIDERED RECLAIMED.

Findings Related to Question 3

- A site may be considered reclaimed when (a) a cover is established that doesn't need maintenance or (b) when it is of use to other resource management programs.

- The objectives must be evaluated before it can be determined whether a site has been adequately reclaimed.

- The area must be left chemically, mechanically and biologically stable, consistent with a predetermined use which may vary from an industrial site to wildlife range.

- As little as possible to get it past Jake McDonald.

- Deleterious effects to the environment must be stopped. This is site-specific.

QUESTION 4 - WHAT DO YOU SEE AS THE CURRENT RESEARCH PRIORITIES IN BRITISH COLUMBIA. WHO SHOULD UNDERTAKE THIS RESEARCH.

Findings Related to Question 4

- Native species use.

- Research in this area should be carried out in co-operation with Industry. University research must be more practical and be tied to the objectives of Industry.

- Universities should do the detailed research with financial aid from Industry.

- Current research should include work on slope, angles and tailings ponds that appear homogeneous but are not.

APPENDICES

APPENDIX A

POSTER SHOW PARTICIPANTS

Acres Consulting Services Ltd.
9th Floor
850 West Hastings Street
Vancouver, B.C.
V6C 1E1

Active Machinery
Kelowna, B.C.

Axel Johnson Ltd.
1475 Boundary Road
Vancouver, B.C.
V5K 4V2

B.C. Research
3650 Westbrook Crescent
Vancouver, B.C.
V65 2L2

Buckerfields Ltd.
Pearson Road
R.R. #5
Vernon, B.C.

Canadian Forestry Equipment Ltd.
(Greenpark)
11004 - 166A Street
Edmonton, Alberta
T5P 4H6

Erocon
P.O. Box 11062
Tacoma, Washington 98411
U.S.A.

Mr. K. Holmsen
Industrial Forestry Consultant
540 Shannon Way
Delta, B.C.
V4M 2W5

I.E.C.
202 - 5600 Cedarbridge Way
Richmond, B.C.
V6X 2A7

Interior Reforestation
P.O. Box 487
Cranbrook, B.C.
V1C 4J1

Kingsley and Keith (Canada) Ltd.
789 West Pender Street
Vancouver, B.C.
V6C 1H2

Klohn Leonoff Consultants
10180 Shellbridge Way
Richmond, B.C.
V6X 2W7

McElhanney Surveying and Engineering
200 - 1200 West Pender Street
Vancouver, B.C.
V6E 2T3

Ministry of the Environment
Map and Air Photo Sales
Parliament Buildings
Victoria, B.C.

Montreal Engineering Ltd.
Resources Department
900 One Palliser Square
125 Nineth Avenue S.E.
Calgary, Alberta
T2G 0P6

Multi Turf Specialists Ltd.
6455 - 64 Street
Delta, B.C.
V4K 3N3

Norwest Soils Research Ltd.
6788 - 99 Street
Edmonton, Alberta
T6E 5B8

Pedology Consultants
P.O. Box 5626
Edmonton, Alberta
T6E 5A6

Richardson Seed Co.
7342 Winston Street
Burnaby, B.C.
V5A 4J1

Reid, Collins and Associates Ltd.
1178 West Pender Street
Vancouver, B.C.
V6E 3X4

R.M. Hardy and Associates
205 Fifth Avenue S.W.
910 Valley Square 2
Calgary, Alberta
T2P 2W5

Techman Ltd.
6th floor
320 - 7th Avenue S.W.
Calgary, Alberta
T2P 2M7

Terrasol Revegetation Erosion
Box 2092
Vancouver, B.C.
V6B 3T2

Wesago
1850 Southwest Marine Drive
Vancouver, B.C.
V6P 6P2

THIRD ANNUAL

BRITISH COLUMBIA

MINE RECLAMATION

SYMPOSIUM

SPONSORED BY

Technical and Research Committee
on Reclamation
of the
B.C. Ministry of Energy,
Mines and Petroleum Resources

and

The Mining Association of
British Columbia

March 7 - 9, 1979
VERNON LODGE
VERNON, B.C.

APPENDIX B

AGENDA

WEDNESDAY, MARCH 7, 1979

12:00 AM - 2:00 PM Registration

AFTERNOON SESSION - ENVIRONMENTAL PROTECTION AND RECLAMATION OF EXPLORATION DISTURBANCES

2:00	Opening Remarks by Chairman - D. M. Galbraith
2:10	Opening of Session by Session Chairman - N. Carter
2:15	Reclamation of exploration disturbances at Sage Creek - M.J. Tapics, Sage Creek Coal Ltd.
2:30	Trenching techniques at the BP Sukunka Project - B. Redgate, BP Exploration Canada
2:45	Effective utilization of helicopters in reconnaisance drilling - L.A. Smith, Pacific Petroleums Ltd.
3:00	Coffee
3:30	Reclamation of exploration disturbances at Fording Coal - R. Berdusco, A. Magnusson, Fording Coal Limited
3:45	Helicopter suported drilling program at the Kutcho Creek property - C. Aird, Esso Minerals Canada Ltd.
4:00	Effectiveness of the Climbing backhoe in coal exploration - K. Pomeroy, Denison Mines Ltd.
4:15	End of Session
6:00	Refreshments
7:00	Dinner and Guest Speaker - Mr. G. Page, Coal Association of Canada

THURSDAY, MARCH 8, 1979

MORNING SESSION - RECLAMATION OF METAL MINE WASTES.

8:30	Opening of session by Chairman - A. Bellamy
8:35	Operational reclamation experiences at Cominco's Bluebell and Pinchi Lake Mines - R.T. Gardiner, J.E. Stathers, Cominco Ltd.
9:00	Reclamation of Dump Slopes - J.D. Graham, Lornex Mining Corp.
9:20	Irrigation with Sewage Effluent on the old Granby Tailings at Princeton, B.C. - J.D. McDonald, D.P. Lane, Ministry of Energy, Mines and Petroleum Resources.
9:40	Experiments in Tailings Reclamation at Granisle Copper - J.R. Chalmers, B. Tripp, Granisle Copper Ltd.
10:00	Coffee at Workshop
11:30	Workshop Summaries
11:45	Chairman's Summary
12:00	Lunch (ad hoc)

AFTERNOON SESSION - RECLAMATION OF METAL MINE WASTES

1:15	Opening of Session by Chairman - B. Burge
1:20	Government funded reclamation program on pre-legislation tailings ponds - A.L. O'Bryan, Ministry of Energy, Mines and Petroleum Resources.
1:40	Reclamation at Newmont Mines, Princeton, B.C. - J. McCue, Newmont Mines Ltd.
2:00	Revegetation for Wildlife use - B. van Drimmelen, Ministry of the Environment
2:20	Current Revegetation Techniques at Craigmont Mine - L. Gavelin, Craigmont Mines Limited.
2:40	Reclamation practices at Island Copper Mine - C. Pelletier, R. Hillis, Utah Mines Ltd.
3:00	Coffee and introduction to the Poster Session
5:00	End of Poster Session
6:00	Refreshments
7:00	Banquet and Presentation of the Annual Reclamation Award by the Hon. J.J. Hewitt, Minister, Ministry of Energy, Mines and Petroleum Resources

FRIDAY, MARCH 9, 1979

MORNING SESSION - RECLAMATION RESEARCH

8:30	Opening of Session by Chairman - Dr. L.M. Lavkulich
8:35	Phosphorus requisite for legume dominated vegetation on mine wastes - R.T. Gardiner, J.E. Stathers, Cominco Ltd.
8:50	Hat Creek Reclamation Studies - Results of first year program - F.G. Hathorn, B.C. Hydro and Power Authority and R.L. Docksteader, D.K. McQueen, Acres Consulting Services Ltd.
9:05	Natural revegetation of disturbances in the Peace River Coal Field - D.V. Meidinger, Dept. of Biology, U. of Victoria
9:20	Migration of Acid Substances in Sullivan Tailings - S. Ames, Dept. of Soil Science, U.B.C.
9:35	Maintenance Fertilizer Research at Kaiser Resources Ltd. - J.W. Fyles, Dept. of Biology, University of Victoria
9:50	Follow-up of slope experiments at Fording Coal - J. Popowich, R. Berdusco, Fording Coal Ltd.
10:05	Coffee at Workshops
11:30	Workshop Summaries
11:45	Chairman's Summary

NOTICE TO LADIES

Welcome to the Vernon Symposium. Please feel free to attend any of the speaker sessions you wish. You are also welcome to attend both banquets and tickets ($10.00) will be available at the door.

We have organized two daytime events which we hope will be of interest.

Distillery Tour

A tour of the Hiram Walker Distillery at Winfield has been arranged for Thursday morning.

Coach to leave at 8:45 a.m. from the Vernon Lodge.

Lunch to be served at Woods Lake.

Return to Vernon Lodge by 1:15 p.m.

PLEASE NOTIFY BETH STONER AT THE SYMPOSIUM REGISTRATION COUNTER BY WEDNESDAY EVENING IF YOU PLAN TO ATTENT THIS FUNCTION.

Coffee Session

An informal coffee session will be held at "pool side" at 10:00 a.m. Friday. A short demonstration of flower arranging will be given.

APPENDIX C

List of Symposium Registrants

Name	Address
Adamson, T.J.	Cyprus Anvil Mining Corp., 330 - 355 Burrard St., Vancouver B.C. V6G 2G8
Aird, C.	Esso Minerals Canada, 314 - 1281 West Georgia Vancouver, B.C. V6C 3J7
Allen, I.V.F.	B.C. Research, 3650 Westbrook Mall, Vancouver, B.C. V6S 2L2
Ames, Susan E.	Soil Science, University of B.C. Vancouver, B.C.
Baase, B.	Craigmont Mines Ltd., Box 3000, Merritt, B.C. VOK 2BO
Barnes, B.	Sukunka Coal Mines Ltd., Box 30 Chetwynd, B.C.
Bell, M.	Biology Dept., University of Victoria, Victoria, B.C. V8W 2Y2
Bellamy, A.	Bethlehem Copper Corp. Box 520, Ashcroft, B.C. VOK IAO
Berdusco, R.J.	Fording Coal Ltd., Box 100 Elkford, B.C. VOB 1HO
Bergey, W.R.	Teck Corporation Ltd., 1199 West Hastings Vancouver, B.C.
Bik, M.J.	Elco Mining Ltd., P.O. Box 1993, Stn. "M" Calgary, Alberta T2P 2M2
Biggs, W.	Entech Environmental Consultants Ltd. 5284 Parker Avenue, Victoria, B.C.
Bodie, D.	Kaiser Resources Ltd., Box 2000 Sparwood, B.C. VOB 2GO
Bodnarchuk, A.J.	Ministry of Highways, Parliament Buildings Victoria, B.C.
Brett, S. A.	Buckerfields Ltd., P.O. Box 7000 Vancouver, B.C. V6B 4E1
Bull, G.	Willis Cunliffe Tait & Co. Ltd. 301 - 1575 Fifth Avenue, Prince George, B.C. V2L 3L9

Burge, B.	Sage Creek Coal Ltd., #510 - 580 Granville Vancouver, B.C. V6C 1W8
Carter, N.	B.C. Ministry of Mines and Petroleum Resources, Parliament Buildings, Victoria, B.C.
Chalmers, J.	Zapata Granby, Granisle, B.C. V0J 1W0
Cherene, L.J.	Kaiser Resources Ltd., 1500 West Georgia Vancouver, B.C. V6G 2Z8
Christie, W.D.	Reid, Collings & Associates, 1178 West Pender, Vancouver, B.C. V6E 3X4
Clark, K.	Arcon Associated Resource Consultants, 130 Lonsdale Avenue, North Vancouver, B.C.
Cobban, G.	The Western Miner/The Northern Miner #305 - 1200 West Render, Vancouver, B.C. V6E 2T4
Crane, K.G.	Luscar Ltd., 800 Royal Trust Tower, Edmonton Centre Edmonton, Alberta T5J 2Z2
Crepin, J.M.	Norwest Soil Research Ltd., 6788 - 99th Street, Edmonton, Alberta T6E 5B8
Crisafio, R.	Crows Nest Industries Ltd., P.O. Box 250, Fernie, B.C. V0B 1M0
Crook, R.	ELUC Secretariat, Parliament Buildings, Victoria, B.C., V8V 1X4
Dai, T.S.	Syncrude Canada Ltd., 10030 - 107th Street, Edmonton, Alberta T5J 3E5
Davy, T.	Coal Association of Canada, 355 - 4th Avenue S.W., Calgary, Alberta T2P 0J1
Day, A.A.	Ker, Priestman & Assoc. Ltd., 2659 Douglas Street, Victoria, B.C. V8T 4M3
Dean, P.M.	Cyprus Anvil Mining Corp., 330 - 355 Burrard St. Vancouver, B.C.
Densmore, B.	1618 Ross Street, Victoria, B.C.
Dick, J.	ELUC Secretariat, Ministry of the Environment, Parliament Buildings, Victoria, B.C.
Diggon, H.M.	Ideal Basic Industries Rock Products, Box 160, Vananda, B.C.
Doan, G.C.	Kingley & Keith (Canada) Ltd., #1000 - 789 West Pender, Vancouver, B.C. V6C 1H2
Docksteader, R.	Acres Consulting Services Ltd., 9th Floor, 850 West Hastings, Vancouver, B.C. V6C 1E1

Domich, G.	Multi Turf Specialists, 6455 - 64th Street, Delta, B.C. V4K 3N3
Donaldson, R.E.	Buckerfields Ltd., Pearson Road, R.R.#5, Vernon, B.C. V1T 6L8
Dudas, B.	Inspector of Mines & Resident Engineer, 2747 East Hastings, Vancouver, B.C. V5K 1Z8
Duncan, N.J.	Energy Resources Conservation Board, 603 - 6th Avenue, Calgary, Alberta T2P OT4
Errington, J.	B.C. Ministry of Energy, Mines and Petroleum Resources, 525 Superior Street, Victoria, B.C.
Espenant, L.	B.C.F.C. Prince George, 1600 - 3rd Avenue, Prince George, B.C.
Farenholtz, W.	Kootenay Tractor & Supplies, 323 Vernon Street, Nelson, B.C. VIL 4E3
Finkle, D.	Active Machines, 356 Cawston Avenue, Kelowna, B.C. VIY 6Y9
Fyles, J.T.	Senior Associate Deputy Minister, Ministry of Energy, Mines and Petroleum Resources, Parliament Buildings, Victoria, B.C. V8W 2Y2
Fyles, J.W.	Biology Dept., University of Victoria, Victoria, B.C. V8W 2Y2
Galbraith, M.	B.C. Ministry of Energy, Mines and Petroleum Resources, Parliament Buildings, Victoria, B.C.
Gardiner, R.T.	Cominco Ltd., Trail, B.C. VIR 4L8
Gavelin, L.	Craigmont Mines Ltd., P.O. BOX 3000 Merritt, B.C. VOK 2BO
Gibson, G.	Cominco Ltd., #22 - 200 Granville Square, Vancouver, B.C. V6C 2R2
Gilbertson, J.	Erocon, P.O. Box 11062, Tacoma, Washington 89411, U.S.A.
Gilliland, J.C.	Climax Molybdenum, 13949 West Colfax, Building #1, Golden, CO 80401 U.S.A.
Glover, F.	Climax Molybdenum, 13949 West Colfax, Building #1, Golden, CO 80401 U.S.A.
Goetting, B.	Teck Corporation Ltd., Beaverdell, B.C. VOH 1AO
Graham, J.D.	Lornex Mining Corp., Box 1500, Logan Lake, B.C. VOK 1WO

Groenevelt, J.C.	McElhanney Survey & Engineering, 200 - 1200 West Pender Street, Vancouver, B.C. V6E 2T3
Guarnaschelli, C.	Hardy Associates Ltd., 4052 Graveley St., Burnaby, B.C. V5C 3T6
Guild, N.I.	Ker, Priestman & Assoc. Ltd., 2659 Douglas Street, Victoria, B.C. V8T 4M3
Hall, T.	Ministry of Energy, Mines and Petroleum Resources, Box 7438, Fort St. John, B.C. VIJ 4M9
Hathorn, F.G.	B.C. Hydro & Power Authority, 2863 West 38 Avenue, Vancouver, B.C.
Hermesh, R.	Montreal Engineering, 9001 Palliser Square East, Calgary, Alberta
Hewitt, J.J.	Minister, Ministry of Energy, Mines and Petroleum Resources, Parliament Buildings, Victoria, B.C.
Hill, R.	Afton Mines, Box 937, Kamloops, B.C. V2C 5N4
Hillis, R.	Utah Mines Ltd., Island Copper, P.O. Box 370, Port Hardy, B.C. VON 2PO
Holmsen, K.	Industrial Forestry Consultant, 540 Shannon Way, Delta, B.C. V4M 2W5
Howie, H.	Pollution Control Board, Ministry of the Environment, Parliament Buildings, Victoria, B.C.
Hutter, J.F.	Inspector of Mines & Resident Engineer, Box 877, Smithers, B.C. VOJ 2NO
Jones C.	17403 - 101 Avenue, Surrey, B.C.
Jones, D.J.,	I.E.C., #202 - 5600 Cedarbridge Way, Richmond, B.C. V6X 2A7
Jones, G.	B.C. Land Management Branch, Parliament Buildings, Victoria, B.C.
Jones, J.	Bethlehem Copper Corp. Box 520, Ashcroft, B.C. VOK 1AO
Karlsen, E.	ELUC Secretariat, Parliament Buildings, Victoria, B.C. V8V 1X4
Kerr, K.R.	Kerr, Wood Leidal Assoc., 144B West 16 Street, North Vancouver, B.C.
Kind, R.	T.M. Thomson & Assoc., 1006 Government Street, Victoria, B.C. V8W 1X7

Kustan, E.H.	Canadian Superior Oil Ltd., Three Calgary Place, 355 Fourth Avenue S.W., Calgary, Alta. T2P 0J3
King, W.	Canadian Forestry Equipment Ltd., 11004 - 166A St. Edmonton, Alberta, T5P 4H6
Lamb, A.	Interior Reforestation Ltd., Box 487, Cranbrook, B.C. V1C 4J1
Lane, D.	B.C. Ministry of Energy, Mines and Petroleum Resources, 525 Superior Street, Victoria, B.C.
Langevin, A.	Syncrude Canada Ltd., P.O. Box 4009, Fort McMurray, Alberta T9H 3L1
Lant, J.	Coleman Collieries Ltd., Box 640, Coleman, Alberta T0K 0M0
Lavkulich, L.M.	Dept. of Soil Sciences, U.B.C. Vancouver, B.C. V6T 1W5
Leskiw, L.A.	Pedology Consultants, P.O. Box 5626, Edmonton, Alberta T6E 5A6
Love, R.	B.C. Ministry of Energy, Mines and Petroleum Resources, 525 Superior Street, Victoria, B.C.
Lulman, P.D.	LGL Limited, 10110 - 124 Street, Edmonton, Alberta T5N 1P6
Lunn, S.	Pan Canadian Petroleum, Box 2850, Calgary, Alberta T2P 2S5
McCue, J.	Newmont Mines Limited, Box 520, Princeton, B.C. V0X 1W0
MacCulloch, J.P.	Inspector of Mines & Resident Engineer, 101 - 2985 Airport Drive, Kamloops, B.C. V2B 7W8
McDonald, J.	B.C. Ministry of Energy, Mines and Petroleum Resources, 525 Superior Street, Victoria, B.C.
MacLean, D.	DRG Packaging, 85 Laird Drive, Toronto, Ontario M4G 3T8
MacCullum, S.Y.D.	Sibbald Group
Magnusson, A.	Fording Coal Ltd, Box 100, Elkford, B.C. V0B 1H0
Mahony, P.	Montreal Engineering Co. Ltd., 535 Thurlow Street, Vancouver, B.C. V6E 3L2
Marty, W.	Byron Creek Collieries, Box 270, Blairmore, Alberta

Meidinger, D.V.	Dept. of Biology, University of Victoria, Victoria, B.C. V8W 2Y2
Meier, J.J.	Byron Creek Collieries, Box 270, Blairmore, Alberta TOK OEO
Mihajlovich, M.	Alberta Forest Service, 11th Floor, Petroleum Plaza, South Tower, 9915 - 108 Street, Edmonton, Alberta T5K 2C9
Milligan, T.	Kaiser Resources Ltd., Box 2000, Sparwood, B.C. VOB 2GO
Mitchell, L.C.	Noranda Mines Ltd., Hendrix Lake, B.C. VOK IRO
Mitchell, M.A.	Ranger Oil (Canada) Ltd., 50 - 200 Granville, Vancouver, B.C. V6C 1S4
Morris, D.	Westcoast Transmission, 1333 West Georgia, Vancouver, B.C.
Murdoch, D.	Fallis Equipment Ltd., 5811 No. 3 Road, Richmond, B.C.
Newson, A.C.	Norcen, 715 - 5th Avenue S.W., Calgary, Alberta T2P 2X7
Nicholson, T.R.	The Mining Association of B.C., #104 - 1075 Melville Street, Vancouver, B.C. V6E 2W4
Noble, B.	Esso Resources (Canada) Ltd., 500 - 6th Avenue S.W. Calgary, Alberta T2P OSI
Nyland, W.	BP Exploration, 335 - 8th Avenue S.W., Calgary, Alberta T2P 1C9
O'Bryan, A.L.	Ministry of Energy, Mines and Petroleum Resources, 310 Ward Street, Nelson, B.C. VIL 5S4
O'Neill, R.H.	Axel Johnson Industries Ltd., 1475 Boundary Road, Vancouver, B.C. V5K 4V2
O'Toole, M.	Cardinal River Coal, Box 2570, Hinton, Alberta TOE ICO
Page, G.	Coal Association of Canada, 355 - 4th Avenue S.W. Calgary, Alberta T2P OJI
Parmar, S.	B.C. Research, 3650 Wesbrook Mall, Vancouver, B.C. V6S 2L2
Pearson, D.F.	Ministry of the Environment, Rm. 143, 553 Superior Street, Parliament Buildings, Victoria, B.C.

Pells, F.	Brenda Mines Ltd., P.O. Box 420, Peachland, B.C. VOH IXO
Polster, D.	Techman Ltd., 6th Floor, 320 - 7th Avenue S.W. Calgary, Alberta T2P 2M7
Pomeroy, K.	Dennison Mines Ltd., Coal Div., P.O. Box 11575, Vancouver, B.C. V6N 4N7
Popowich, J.	Fording Coal Ltd., P.O. Box 100, Elkford, B.C. VOB IHO
Portfors, E.	Klohn Leonoff Consultants Ltd., 10180 Shellbridge Way, Richmond, B.C. VOX 2W7
Railton, J.	Calgary Power Ltd., 110 - 12th Avenue S.W., Box 1900, Calgary, Alberta
Redgate, B.	BP Exploration, 335 - 8th Avenue S.W., Calgary, Alberta T2P IC8
Richardson, A.	Richardson Seed Company Ltd., Rear of 7342 Winston Street, Burnaby, B.C. V5A 2H1
Robbins, G.	Luscar Sterco Ltd., 800 Royal Trust Tower, Edmonton Centre, Edmonton, Alberta
Robertson, J.	Acres Consulting Services, 9th Floor, 850 West Hastings, Vancouver, B.C. V6C 1E1
Robertson, J.D.	Afton Mines Ltd., P.O. Box 937, Kamloops, B.C. V2G 5N4
Robinson, J.W.	Inspector of Mines & Resident Engineer, 2226 Brotherstone Road, Nanaimo, B.C. V9S 3M8
Robinson, B.	Chief Inspector of Mines, B.C. Ministry of Energy, Mines and Petroleum Resources, Parliament Buildings, Victoria, B.C.
Ryder, D.	Cardinal River Coal, Box 2570, Hinton, Alberta TOE ICO
Sadar, E.	Inspector of Mines & Resident Engineer, 101 - 2985 Airport Drive, Kamloops, B.C. V2B 7W8
Sahlstrom, P.	Terrasol Revegetation Erosion, Box 2092, Vancouver, B.C. V6B 3T2
Schori, A.,	Techman Ltd., P.O. Box 2840, Calgary, Alberta T2P 2M7
Schaneman, R.	Manalta Coal Ltd., P.O. Box 2880, Calgary, Alberta T2P 2M7

Sharpe, M.	Lornex Mining Corp. Ltd., 10 Beryl Drive, P.O. Box 35, Logan Lake, B.C. VOK 1WO
Sims, H.P.	Alberta Environment, Oxbridge Place, 12th Floor, 9820 - 106th Street, Edmonton, Alberta T5K 2J6
Singleton, G.	R.M. Hardy Consultants, 205 - 5th Avenue S.W. Calgary, Alberta T2P 2W5
Singleton, J.	4 - 2161 Columbia Avenue, Trail, B.C. VIR IK8
Smith, E.	B.C. Forest Service, Parliament Buildings, Victoria, B.C.
Smith, L.A.	Pacific Petroleums Ltd., Box 6666, Calgary, Alberta T3A 1R7
Speer, R.	Montreal Engineering Ltd., 125 - 9th Avenue S.W. 900 One Palliser Square, Calgary, Alberta T2G OP6
Stathers, E.	Cominco Ltd., Trail, B.C. VIR 4L8
Stoner, B.	B.C. Ministry of Energy, Mines and Petroleum Resources, 525 Superior Street, Victoria, B.C.
Tapics, M.	Sage Creek Coal Ltd., #2600 - 120 Adelaide Street, Toronto, Ontario M5H 1W5
Taylor, M.S.	Cassiar Asbestos Corp., Cassiar, B.C. VOC 1EO
Tidsbury, A.D.	Inspector of Mines & Resident Engineer, 1652 Quinn Street, Prince George, B.C. V2N 1X3
Trasolini, G.	Environment Canada, EPS, Kapilano 100, Park Royal, West Vancouver, B.C.
Tripp, B.	Zapata Granby, Granisle, B.C. VOJ IWO
Vaartnou, M.	Vaartnou & Sons Enterprise Ltd., 7125 - 77 Avenue, Edmonton, Alberta T6B OB5
van Drimmelen, B.	Fish & Wildlife Branch, Ministry of the Environment Parliament Buildings, Victoria, B.C.
Vaughan-Thomas, T.	Inspector of Mines - Coal, 1652 Quinn Street, Prince George, B.C. V2N 1X3
Walmsley, J.R.	Bethlehem Copper Corp., P.O. Box 520, Ashcroft, B.C. VOK 1AO
Warner, B.	Ministry of Energy, Mines and Petroleum Resources, 1652 Quinn Street, Prince George, B.C. V2N 1X3

Weston, S.	Wesago, 1850 S.W. Marine Drive, Vancouver, B.C. V6P 6B2
Willox, R.J.	Westroc Industries Ltd., P.O. Box 217, Invermere, B.C.
Wright, M.	Gulf Canada Resources, Inc., 8th Floor, 715 - 5th Avenue S.W., Calgary, Alberta
Younkin, W.	R.M. Hardy Consultants, 910 Bow Valley Square II, 205 Fifth Avenue S.W., Calgary, Alberta T2P 2W5
Ziemkiewicz, P	Energy & Natural Resources, Petroleum Plaza - South Tower, 9915 - 108 Street, Edmonton, Alberta T5K 2C9
Zamluck, J.	Arcon Assoc. Resource Consultants, 130 Lonsdale Avenue, North Vancouver, B.C.

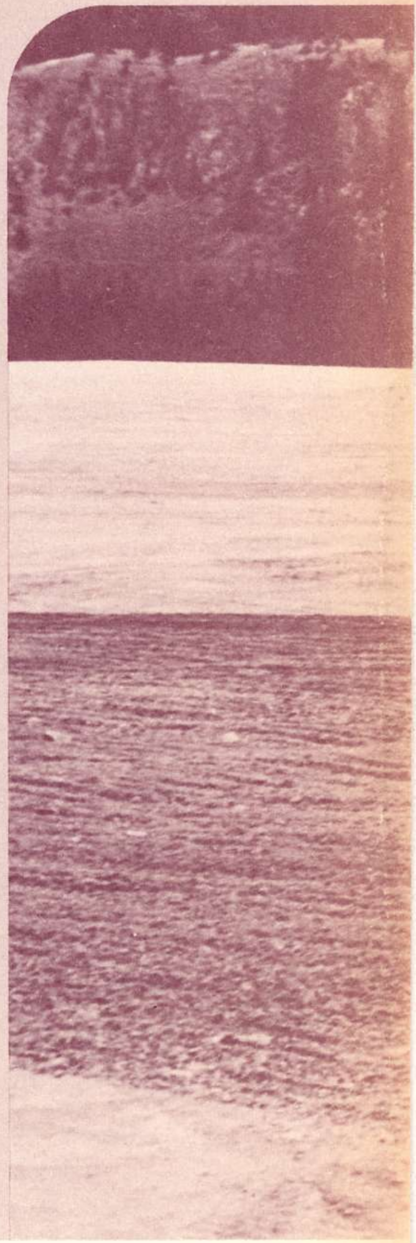
List of Student Participants

University of Victoria

Billingley, Walter
Bredesen, Dede
Dow, Duncan
Gray, Barbara
Lawrence, Joanne
Lehner, Myrna
Macdonald, Ross
MacKenzie, Sheelagh
Mayhew, Garth
Perks, Steve
Simmerling, Harald
Woodland, Heather

University of British Columbia

Giudici, Mary
Macadam, Anne
Milne, Helen
Murphy, Kevin
Natsukoshi, Karen
Quesnel, Harry
Rollerson, Terry
Rouse, Clayton
Suttie, Kathleen



Queen's Printer for British Columbia ©
Victoria, 1979

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