THE USE OF PEAT, FERTILIZERS AND MINE OVERBURDEN TO STABILIZE STEEP TAILINGS SAND SLOPES

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ABSTRACT

The revegetation of tailings sand slopes that result from tar sands extraction pose many problems. The tailings material has a low moisture holding capacity, contains low amounts of plant nutrients and is potentially very erodable.

Large areas of tailings material have been successfully revegetated by Great Canadian Oil Sands Limited by employing a 15 cm thick amendment of peat on the surface. Even 5 years after seeding with grasses and legumes these areas must receive regular fertilization to maintain a good surface cover.

In new experiments the tailings sand surface was amended with peat or peat/overburden mixtures. A good surface cover was rapidly established by the addition of N, P, K and S containing fertilizers. Most efficient use of the fertilizers occurred when 80 kg-N, 35 kg-P, 75 kg-K and 20 kg-S were added per hectare rather than when larger amounts were added. Rapid plant growth enabled erosion to be kept at a minimum. Losses of plant nutrients through leaching and surface water runoff were not serious in relation to the amounts added as fertilizer. Additional application of fertilizer later in August did not increase dry weight yield but did enhance nutrient uptake into the plant tops. Dry weight production of tops and roots was about the same in the first year of growth. Root growth was largely restricted to the surface 15 cm of peat and overburden.

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1. INTRODUCTION

Research studies into the revegetation of steep tailings sand slopes resulting from tar sand extraction in the Fort McMurray area of Alberta are currently into their third year. Detailed reports of the first two years of study are available as monographs[1,2]. This paper is concerned with some of the field scale investigations carried out at the Great Canadian Oil Sands Limited (GCOS) plant in Fort McMurray where active reclamation has been in progress for several years.

2. STUDY OF PREVIOUSLY REVEGETATED TAILINGS SAND SLOPES

During the summer of 1975 field scale studies centred upon investigation of ways of improving steeply sloping areas of tailings sand that had already been seeded with grasses and legumes. One such area had received a surface application of about 15 cm of peat during the winter of 1970/71. In the spring of 1971 the area was seeded with the seed mix shown in Table 1. Between May 1971 and July 1974, the area received 8 small additions of fertilizer that amounted to a total of 222 kg-N; 110 kg-P and 150 kg-K per hectare. Revegetation had been successful in that a protective plant cover had been established. However, nutrient deficiencies made it difficult to sustain a healthy growth of plants throughout the growing season. During periods of heavy rainfall there

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TABLE 1. Seed mix used to revegetate a tailings sand slope at the GCOS plant at Fort McMurray, Alberta

Species	Percentage by volume
Brome Grass (Bromus inermis)	33
Crested Wheat Grass (Agropyron cristatum)	24
Creeping Red Fescue (Festuca rubra)	15
Sweet Clover (Melilotus sp.)	14
Alsike Clover (Trifulium hybridum)	14
Added at a rate of 30 lb/ac (about 27 kg/ha)	

was a danger of the peat mantle becoming undercut resulting in serious erosion of the slope.

In the early summer of 1975 most of the plant cover was made up of Creeping Red Fescue and to a lesser extent, Brome Grass. Crested Wheat Grass and the legumes were almost absent. Addition of fertilizers to an experimental area resulted in both qualitative and quantitative improvements in the sward. The different fertilization programs involved once or twice yearly additions of N, P, K and S containing fertilizers at rates varying from no addition up to 290 kg-N; 36 kg-P; 145 kg-K and 29 kg-S per hectare. Tables 2, 3, and 4 show plant yields and nutrient uptake during 1975 and 1976. The results indicated that although large increases in plant productivity could be induced through addition of nutrients, the area could not be considered self sustaining if fertilization was discontinued. For instance, treatments that received large additions of fertilizer in 1975 but none in 1976 did not continue to yield well in 1976. Carry-over of fertilizer nutrients from one year to the next seemed to be short lived and plants showed nutrient deficiency symptoms (especially

TABLE 2. Improvement of a 5-year revegetated tailings sand dike slope amended with 15 cm of peat

	Fertilizers added (kg/ha) 1975				1976				Plant dry weight yield (kg/ha)	
	N	P	K	S	N	P	K	S	1975	1976
To	0	0	0	0	0	0	0	0	980	2390
T1	71	18	71	7	71	18	71	0		3760
T1A	143	36	71	14	71	18	71	0	3670	3710
T3	143	36	143	14	0	0	0	0		2600
T3A	286	36	286	29	0	0	0	0	4040	2910
T5	35	9	18	32	34	9	18	7	2670	3760

Between May 1971 and July 1974 the area received 222 kg-N, 110 kg-P and 150 kg-K per hectare.

TABLE 3. Nitrogen uptake into plant tops on a 5 year revegetated tailings sand dike slope amended with 15 cm of peat.

	Nitrogen uptake (kg/ha) 1975	1976
To	9	22
T1	49	55
T3	90	42
T5	14	68

nitrogen) later in the summer of 1976. Frequent small additions of fertilizer were more beneficial than larger yearly or biennial applications. A limited study of root growth indicated that, over the 5 year revegetation period, root tissues had accumulated to the extent that root:shoot ratios varied between about 4:1 to 7:1. Turnover of nutrients bound up in roots could be expected to be much slower than for the above ground tissues.

The growth of roots was largely limited to the surface layer of peat. This inability to get roots to penetrate significantly into the tailings sand layers below was considered a serious deficiency.

3. ASSESSMENT OF RECLAMATION MATERIALS

The possible readily available surface material amendments were characterized with respect to their chemical, physical and biological properties. The most promising materials were surface peats and mine overburdens. The results of analysis of some materials are shown in Table 5, 6 and 7.

Freshly deposited tailings sand has an alkaline reaction and a high content of soluble sodium resulting from the caustic bitumen extraction process. The soluble salts leach out readily and within 1 or 2 years the tailings sand has a nearly neutral to slightly alkaline pH. Properties of low moisture retention, low available plant nutrients and a high erosion potential make the tailings sand a very poor surface to revegetate directly without any amendment.

The characteristics of mine overburdens vary somewhat depending upon location. Although they are also sandy in nature, the presence of some clay makes them less erodable than the tailings sand. The natural levels of soluble salts are quite high due to the presence of moderate

TABLE 5. Properties of tailings sands, peats and overburden - (I).

	pH	Cond. mmhos/cm	Soluble Cations (meq/100 g) Na	Ca	K	Mg	Organic C (%)	Total N (%)	Extr. Bitumen (%)
Tailings sand (fresh)	9.7	1.17							
Tailings sand (weathered)	6.2	0.46	0.026	0.040	0.003	0.026	0.33	0.03	0.18
Overburden #2	7.8	2.66	0.71	0.51	0.051	0.28	1.00	0.08	0.15
Peat (pH 4.1)	4.1	0.16							
Peat (pH 5.4)	5.4	0.29							

TABLE 6. Properties of tailings sands, peats and overburden - (II).

	Available Nutrients (ppm) NH_4-N	NO_3-N	P	K	SO_4-S	C.E.C. meq/100 g	Exch. + Sol. Cations meq/100 g Na	Ca	K	Mg
Tailings sand (weathered)	1.5	1.3	2.3	9	7.0					
Overburden #1	0.2	0.0	3.5	33	278	3.9	0.43	12.0	0.64	1.70
Overburden #2	14.0	2.2	1.8	205	107	ND	2.76	8.4	0.53	2.14
Peat (pH 4.1)	0.0	0.0	4.0	130	460	127	0.65	33.3	3.80	9.00
Peat (pH 5.4)	41.6	53.8	2.8	233	10.4	ND	0.73	52.8	0.60	0.61

ND - not determined

TABLE 7. Properties of tailings sands, peats and overburden - (III).

	Particle size distribution Sand (%)	Silt (%)	Clay (%)	Moisture 1/3 Bar (%)	Bacteria $\times 10^6$/g	Fungi $\times 10^6$/g	Algae $\times 10^6$/g
Tailings sand	96	1	3	1.4	0.15	0.10	0.0
Overburden #1					1.30	0.20	6.2
Overburden #2	79	12	9	9.9	14.00	0.20	0.0
Peat (pH 4.1)				250	2.20	130	9.8
Peat (pH 5.4)				72.0			

amounts of sodium carbonate and sulfate. However, the electrical conductivity is rarely high enough to indicate a serious concern in the overburden's ability to support plant growth. In comparison to the tailings material, overburdens are very well buffered around their neutral to mildly alkaline pH. The overburdens are also a good source of available potassium and sulfur.

TABLE 8. Water holding characteristics of tailings sand, peat, overburden and mixes of these materials

	Moisture (%)	
	1/3 bar	15 bar
Tailings sand	1.8	0.9
Overburden	9.9	4.1
Peat (pH 5.4)	72.0	43.6
Tailings sand/peat (1:1 v/v)	15.8	12.5
Tailings sand/peat/overburden (1:1:1 v/v/v)	10.7	4.9

Both acidic and neutral peats are found in the mining area. They are generally low in available plant nutrients, especially nitrogen and phosphorus, although levels do vary with the source of the peat. The main advantages of peats in reclamation are high water holding characteristics and a good cation exchange capacity. Table 8 shows the beneficial effect on water holding capacity by the inclusion of peat in some different soil mixes. In comparison to tailings sand and many overburdens, the peats contain high numbers of microorganisms which are necessary in mediating transformations that result in the mineralization of organic materials and the release of available plant nutrients. The inoculation of the revegetation surface with micro-organisms from the peat probably represents one of the more important long term effects of soil surface amendments to the tailings sand slope.

4. FIELD RECLAMATION EXPERIMENTS IN 1976.

Work with different soil mixes in growth chamber experiments was carried out in 1975. Results showed that, as long as optimum moisture and nutrient conditions could be maintained, tailings sand, peat, overburden, lean tar sands and various mixes could all support plant growth. Particularly encouraging results were obtained with tailings sand/peat and tailings sand/peat/overburden mixes.

Using the data from growth chamber studies and material characterization, new revegetation field trials were started in 1976. The basic objectives of the experiments were to study the success of revegetation on tailings sand slopes using different peat and overburden amendments and different fertilizer programs. Investigations also concerned ways of improving root penetration and assessment of the performance of several grass and legume species. Once again the location of the experiments was the tailings pond dike at the G.C.O.S. plant at Fort McMurray.

The design of the main experiment is shown in Figure 1. The various main and sub-treatments are shown below.

Main treatments applied to the tailings sand surface

	fertilizer additions in kg/ha				
	N	P	K	S	
Treatment A	80	35	75	20	Applied in June
B	150	40	150	20	Applied in June
C	150	40	150	20	Applied in June
	150	40	150	20	Applied in August

Fertilizer was added as 21-0-0, 11-55-0, 34-0-0 and 0-0-62. Treatments B and C received one application of finely ground limestone at 5 tonnes/ha in June 1976.

Subtreatments applied to the tailings sand surface

1. 15 cm of peat applied to the tailings sand surface
2. As 1. with contour trenches
3. As 1. with "Aquatain" soil stabilizer
4. As 1. with "Bitumuls" soil conditioner
5. 5 cm overburden applied over 15 cm of peat (untilled)
6. 10 cm overburden tilled into 15 cm of peat
7. 5 cm overburden tilled into 15 cm of peat
8. As 1. but not seeded until October, 1976.

Subsequent discussions will be limited to treatments 1, 5, 6 and 7 only.

The seed mix used is shown in Table 9. Seeding was completed on July 16, 1976.

A device to intercept runoff water and eroded soil was set up on some of the experimental treatments. The top of the plot was boarded off to prevent runoff water from the areas upslope from being collected. Two wooden boards were joined together to form a 'V' shape so that the opening produced was exactly one meter across. The boards were sunk about 8 cm into the ground at the bottom of the plot. The apex of the 'V' was located so that it collected from a 5 meter length of slope. A polythene funnel was buried at the apex so that the mouth was flush with the soil surface. A fine mesh screen was glued into the mouth to prevent

TABLE 9. Seed mix used in a revegetation experiment on a tailings sand slope at the GCOS plant, Fort McMurray

Species	Percentage Composition by weight
Altai Wild Rye	3.5
Streambank Wheat Grass	15.0
Smooth Fescue	16.0
Hard Fescue	3.0
Pubescent Wheat Grass	14.0
Slender Wheat Grass	12.0
Western Wheat Grass	3.5
Red Top	0.5
Kentucky Blue Grass	1.5
Lupine	8.0
Cicer Milk Vetch	6.0
Sanfoin	10.0
Alfalfa Rhizoma	6.0

Pendek Oats added at 40 kg/ha.

Seed, including oats, was added at a rate of 90 kg/ha soil from passing through. A closed 5 gallon plastic bucket was used as a reservoir to store the runoff water that was collected. It was connected to the funnel by polythene tubing and the pail was buried deep enough to allow water to freely run in under gravity. Water was collected from the reservoir at intervals throughout the summer and was analyzed for available N, P, K and S and for pH and conductivity. Eroded soil was also collected from the same collection area. Estimates were made of total soil erosion losses and of mineral nitrogen losses in eroded soil.

Leaching losses from the plots were estimated by using double pail lysimeters. These consisted of a 5 gallon plastic pail buried flush with the soil surface into which was lowered an identical pail filled with the required soil mix. Small holes had been drilled in the bottom of the inner pail which allowed water to drain out and collect in a thick polythene bag fastened around the inner pail. The lysimeters were individually seeded and fertilized at the same rates that were used on the plots. Leachate was analyzed for available nutrients, pH and conductivity.

Table 10 shows the results of soil analysis in June after peat and overburden had been applied but before fertilizer, lime and seed had been added.

The addition of peat resulted in a surface pH of 6.6 while inclusion of overburden increased the pH by up to 0.5 of a unit. Electrical conductivity was highest where overburden was added in addition to the peat. Even so, the values were not high enough to effect seed germination or subsequent plant growth. Moderate levels of mineral nitrogen occurred

TABLE 10. Soil analysis of the 0 - 15 cm depth in June, 1976.

Treatment	pH	Cond. (mmhos/cm)	NH_4-N	NO_3-N	P	K	SO_4-S
			(ppm)				
1. 15 cm peat	6.6	0.54	16	4	2	12	37
5. 5 cm overburden over peat	6.8	1.47	25	15	2	93	164
6. 10 cm overburden tilled into peat	7.1	1.54	21	10	2	65	164
7. 5 cm overburden tilled into peat	7.0	1.36	19	9	2	64	114

(Values above are means of plots to receive fertilizer treatment A. However, they are representative of the entire area.)

in the soils at this time. Ammonium nitrogen was more prevalent than the nitrate form. Phosphorus was very low in all four treatments. Potassium was very low where only peat had been added as an amendment. Higher values occurred in treatments 5, 6 and 7 due to the presence of the overburden. Levels of sulfate were adequate in terms of plant need in all the treatments. The highest amounts were found with the overburden treatments.

In September shoot and root samples were taken from each treatment to determine dry weight yields and nutrient uptake. The results for fertilizer treatments A and C are shown in Table 11. Yield differences between the two fertilizer programs and between subtreatments was not statistically different for the first season's growth. Production varied between 2460 and 3930 kg/ha for tops and between 1650 and 2810 kg/ha for root tissues. The oats, which was included as a nurse crop, made up the majority of the dry weight yield (see Table 12). In most instances the cover provided by the grass and legumes alone would have been adequate in terms of surface erosion control.

There were significant differences in the uptake of nutrients between the different fertilizer programs (see Table 13). Where extra fertilizer had been added in August (treatment C) the uptake of N, P and K into shoot tissues was increased although the amount taken up into root tissues was generally unaffected.

Soil analysis in September (see Table 14) showed that levels of N, P and K were low in treatments which received the lowest fertilization rate (80 kg-N, 35 kg-P, 75 kg-K and 20 kg-S per hectare in June). In treatment C (150 kg-N, 40 kg-P, 150 kg-K and 20 kg-S per hectare in June

TABLE 11. Plant dry weight yields - 1976.

Treatment	Tops	Roots
	(kg/ha)	
Fertilizer rate A		
1. 15 cm peat	2930	2810
5. 5 cm overburden over peat	3410	1690
6. 10 cm overburden tilled into peat	3930	2210
7. 5 cm overburden tilled into peat	3260	ND
Fertilizer rate C		
1. 15 cm peat	3040	1570
5. 5 cm overburden over peat	3430	1650
6. 10 cm overburden tilled into peat	3610	1900
7. 5 cm overburden tilled into peat	2460	ND

ND - not determined

TABLE 12. Distribution of plant types

Treatment	% of dry weight yield		
	Oats	Grasses	Legumes
Fertilizer rate C			
1. 15 cm peat	85	13	2
5. 5 cm overburden over peat	93	6	2
6. 10 cm overburden tilled into peat	91	7	2

TABLE 13. Nutrient uptake in plant tops and roots.

	Tops				Roots			
	N	P	K	S	N	P	K	S
	kg/ha				kg/ha			
Fertilizer rate A								
1. 15 cm peat	59	8	59	7	32	25	27	7
5. 5 cm overburden over peat	69	8	70	6	20	12	14	3
6. 10 cm overburden tilled into peat	81	9	79	6	20	14	13	4
7. 5 cm overburden tilled into peat	67	10	73	7				
Fertilizer rate C								
1. 15 cm peat	76	10	86	5	22	17	12	4
5. 5 cm overburden over peat	88	11	95	15	25	20	21	5
6. 10 cm overburden tilled into peat	86	10	110	6	23	17	25	4
7. 5 cm overburden tilled into peat	67	9	81	4				

TABLE 14. Soil properties in September - 1976.

	pH	Cond. mmohs/cm	NH_4-N	NO_3-N	P	K	SO_4-S
			ppm				
Fertilizer treatment A							
1. 15 cm peat	6.3	0.60	2	1	7	14	13
5. 5 cm overburden over peat	6.4	1.24	4	1	3	81	156
6. 10 cm overburden tilled into peat	7.0	1.23	2	1	6	54	135
7. 5 cm overburden tilled into peat	6.9	1.29	2	1	7	55	65
Fertilizer treatment C							
1. 15 cm peat	6.6	1.75	3	107	13	121	172
5. 5 cm overburden over peat	6.8	1.75	12	86	18	180	116
6. 10 cm overburden tilled into peat	7.0	2.60	3	85	26	161	103
7. 5 cm overburden tilled into peat	6.8	2.00	6	66	16	124	106

and August) available nutrients were more abundant. Mineral nitrogen occurred primarily as nitrate and some leaching losses could be expected during the fall and early spring. The pH of the different treatments showed the same relative trend observed in June with the overburden treatments showing a slightly higher pH than the peat-only treatments. The addition of lime resulted in a small increase in pH which had been reduced slightly by the addition of fertilizer in August. Similarly the extra fertilizer addition produced higher soil electrical conductivities. Values ranged from 1.75 mmhos/cm in the peat-only treatment to between 2.00 and 3.00 mmhos/cm in the overburden amended treatments. Although these values are moderately high they would not be expected to seriously affect the growth of the plant species used.

An approximate balance sheet of nutrient uptake and transfer can be drawn up using the data from plant and soil analysis and from lysimeter and runoff studies. Table 15 shows the estimates of soil erosion and mineral nitrogen losses in eroded soil. Although erosion was more severe in the overburden amended plots, in no case could the effect be considered serious where a plant cover had been produced. In contrast in treatment 8 which received a 15 cm application of peat but was not seeded until October, erosion was serious enough in places to warrant some repair work on the plots.

In relation to the amounts added as fertilizer, mineral nitrogen losses in eroded soil were minimal.

All the different surfaces involved (ie. tailings sand, peat, overburden and their mixes) have high water infiltration characteristics (21.6 to 30.5 cm/hr). As a consequence of this high absorptive capacity

TABLE 15. Estimates of soil erosion losses.

Treatment	Soil lost (cm)	Mineral nitrogen losses kg-N/ha
Fertilizer treatment C		
1. 15 cm peat	0.24	1.0
5. 5 cm overburden over peat	0.69	1.2
6. 10 cm overburden tilled into peat	0.81	1.4
7. 5 cm overburden tilled into peat	0.32	0.7

only between 0.79% and 2.5% of the intercepted rainfall was collected as runoff (see Table 16). The amounts of nutrients lost were also small in relation to the quantity added as fertilizer. Phosphorus losses were lowest. Nitrogen losses varied between 0.4 and 1.4 kg-N/ha with most of this composed of nitrate. Potassium and sulfate sulfur runoff losses were higher than for N and P. Losses were greatest in the overburden amended plots presumably due to the naturally higher levels of soluble sulfate and potassium in these materials.

Leaching losses were greater than runoff losses (see Table 17). Between 15.7% and 28.9% of the intercepted rainfall leached below the 30 cm depth. Nutrient losses were consistently higher in the overburden amended treatments.

Between 1.3 and 2.0 kg-N/ha was lost under fertilizer regime A while between 3.1 and 5.6 kg-N/ha was lost through leaching with treatment C (high June and August applications). Most was lost as nitrate. Phosphorus was practically immobile and losses accounted for less than

TABLE 16. Surface water runoff losses.

Treatment	Water Runoff (l/m^2)	Nutrient Losses (kg/ha) N	P	K	SO_4-S
Fertilizer rate C					
1. 15 cm peat	1.2	0.4	0.1	0.6	0.9
5. 5 cm overburden over peat	3.9	0.4	0.4	4.1	3.0
6. 10 cm overburden tilled into peat	4.5	1.4	0.1	3.5	3.4
7. 5 cm overburden tilled into peat	2.0	1.4	0.1	1.9	2.0

Addition in rainfall (kg/ha) during June-September 1977, 1.1 N, 0.0 P, 0.3 K and 4.5 S.

Intercepted rainfall during June-September 1977 = 178.5 l/m^2

TABLE 17. Estimates of water leaching losses.

	Water Leaching (l/m^2)	Nutrient Losses below 30 cm (kg/ha) N	P	K	SO_4-S
Fertilizer rate A					
1. 15 cm peat	29.4	1.7	0.1	1.1	9.8
5. 5 cm overburden over peat	34.2	2.0	0.1	2.3	31.1
6. 10 cm overburden tilled into peat	32.1	1.4	0.1	1.4	7.5
7. 5 cm overburden tilled into peat	33.8	1.3	0.1	1.1	7.7
Fertilizer rate C					
1. 15 cm peat	28.1	4.7	0.1	1.9	9.8
5. 5 cm overburden over peat	33.8	5.2	0.1	5.6	15.6
6. 10 cm overburden tilled into peat	30.5	5.6	0.1	5.0	11.9
7. 5 cm overburden tilled into peat	51.5	3.1	0.1	2.8	12.4

0.1 kg-P/ha during the summer. Potassium losses were approximately the same as for nitrogen. Amounts varied between 1.9 and 5.6 kg-K/ha at the highest rate of fertilizer addition and between 1.1 and 2.3 kg-K/ha at the lower rate. Sulfate sulfur losses were highest and most variable. Values recorded varied between 7.5 and 31.1 kg-SO_4-S/ha. Sulfate may originate from natural soil sulfates, fertilizer-S, and atmospheric sources. An estimated 4.5 kg SO_4-S/ha were deposited in rainfall between June and September. The majority of this could be expected to result from stack emissions.

Table 18 summarizes the uptake and transfer of nitrogen in revegetation treatments 1 and 5 during the summer of 1976. Most efficient use of fertilizer was achieved at the lower rate of addition. Differences between the two subtreatments 1 and 5 were not statistically significant within each different fertilizer treatment. At the low rate of addition of fertilizer from between 89 and 91 kg-N/ha was fixed in plant tissues. At the highest rate between 98 and 113 kg-N/ha was converted into plant shoots and roots. Leaching and runoff losses only accounted for between 6.3 and 9.0 kg-N/ha.

5. CONCLUSIONS

The results indicate that, provided moderate amounts of fertilizer are added, tailings sand slopes can be stabilized by the establishment of a plant cover. Soils that require revegetating in mined areas or other disturbed locations must be adequately characterized before costly programs are started. Poor chemical, physical and biological characteristics can often be improved by the use of local soils and overburdens.

TABLE 18. Summary of the fate of nitrogen.

	Fertilizer Added kg/ha	Plant kg/ha		Water Losses kg/ha		Eroded Soil kg/ha	Soil Mineral-N 0-30 cm kg/ha	
		Tops	Roots	Runoff	Leaching		June	Sept
Fertilizer rate A								
1. 15 cm peat	80	59	32	ND	1.7	ND	25	4
5. 5 cm overburden over peat	80	69	20	ND	2.0	ND	43	7
Fertilizer rate C								
1. 15 cm peat	300	76	22	0.4	4.9	1.0	74	61
5. 5 cm overburden over peat	300	88	25	2.6	5.2	1.2	43	60

The total nitrogen present in the surface 0-30 cm in June 1976 varied between 840 and 1860 kg-N/ha.

Further work should enable several important questions to be answered. Of immediate concern is the extent of continued fertilization needed before such areas can be considered self sustaining and essentially maintenance free. Of particular concern in potentially erodable areas mentioned here is the ability to increase root penetration below the surface amendment layers to increase physical stability of the area.

6. REFERENCES

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PROCEEDINGS

OF

THE SECOND ANNUAL GENERAL MEETING

OF THE

CANADIAN LAND RECLAMATION ASSOCIATION

August 17, 18, 19 & 20 — 1977 Edmonton, Alberta

(Sponsored by the Faculty of Extension, University of Alberta)

P R O G R A M

Canadian Land Reclamation Association

Second Annual General Meeting

August 17, 18, 19, 20, 1977

Edmonton, Alberta

Wednesday, August 17 (Optional Field Trips)

Field Trip No. 1 (Athabasca Tar Sands)

Leader: Philip Lulman (Syncrude Canada Ltd.)

Fee: $100.00 (covers bus and air transportation, lunch, and field trip information pamphlets)

Schedule: 7:30 am.- delegates board bus at Parking Lot T, located immediately south of the Lister Hall Student Residence complex. Air transportation from Edmonton Industrial Airport to Fort McMurray and return. Guided bus tour of surface mining and reclamation operations on Syncrude Canada Ltd. and Great Canadian Oil Sands Ltd. leases.
6:30 p.m.- delegates arrive back at Parking Lot T, University of Alberta campus.

Field Trip No. 2 (Aspen Parkland; Forestburg Coal Mine Reclamation)

Leader: George Robbins (Luscar Ltd.)

Fee: $25.00 (covers bus transportation, lunch, and field trip information pamphlets)

Schedule: 8:00 a.m. - delegates board bus at Parking Lot T, located immediately south of the Lister Hall student residence complex. Guided bus tour southeast of Edmonton, stopping at various points of interest (oil spill reclamation field plots; Black Nugget Park [abandoned minesite]; trench plots on Dodds-Roundhill Coal Field; solonetzic soil deep ploughing site) on the way to the Luscar Ltd. Coal Mine at Forestburg.
6:30 p.m. - delegates arrive back at Parking Lot T, University of Alberta campus.

Thursday, August 18

Events:	Opening of Formal Meeting; Presentation of Papers
Location:	Multi-Media Room, located on second floor of Education Building, University of Alberta.
8:00 a.m.	Authors of papers being presented on August 18 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching)
9:00 a.m.	Meeting Opened by Dr. Jack Winch (President of the C.L.R.A.; Head of the Department of Crop Science, University of Guelph). Comments by Dr. Winch.
9:15 a.m.	Welcome to delegates on behalf of the Government of Alberta by the Hon. Mr. Dallas Schmidt, (Associate Minister Responsible for Lands, Alberta Department of Energy and Natural Resources)
9:25 a.m.	Commencement of Paper Presentations. Morning session chaired by Mr. Henry Thiessen (Chairman of the Land Surface Conservation and Reclamation Council and Assistant Deputy Minister, Alberta Department of Environment).
9:30 a.m.	Paper 1. Combined Overburden Revegetation and Wastewater Disposal in the Southern Alberta Foothills by H.F. Thimm, G.J. Clark and G. Baker (presented by Harald Thimm of Chemex Reclamation and Sump Disposal Services Ltd., Calgary, Alberta).
10:00 a.m.	Paper 2. Brine Spillage in the Oil Industry; The Natural Recovery of an Area Affected by a Salt Water Spill near Swan Hills, Alberta by M.J. Rowell and J.M. Crepin (presented by Michael Rowell of Norwest Soils Research Ltd., Edmonton, Alberta)
10:30 a.m.	Coffee Recess
11:00 a.m.	Paper 3. The Interaction of Groundwater and Surface Materials in Mine Reclamation by Philip L. Hall of Groundwater Consultants Group Ltd., Edmonton, Alberta.
11:30 a.m.	Paper 4. Subsurface Water Chemistry in Mined Land Reclamation; Key to Development of a Productive Post-Mining Landscape by S.R. Moran and J.A. Cherry (presented by Stephen Moran of the Research Council of Alberta, Edmonton, Alberta).
12:00 noon	Lunch Recess

1:25 p.m. Continuation of Paper Presentations. Afternoon session chaired by Mr. Philip Lulman (member of C.L.R.A. executive; reclamation research ecologist with Syncrude Canada Ltd.).

1:30 p.m. Paper 5. Coal Mine Spoils and Their Revegetation Patterns in Central Alberta by A.E.A. Schumacher, R. Hermesh and A.L. Bedwany (presented by Alex Schumacher of Montreal Engineering Company Ltd., Calgary, Alberta).

2:00 p.m. Paper 6. Surface Reclamation Situations and Practices on Coal Exploration and Surface Mine Sites at Sparwood, B.C. by R.J. Berdusco and A.W. Milligan (presented by Roger Berdusco of Kaiser Resources Ltd., Sparwood, B.C.).

2:30 p.m. Paper 7. Agronomic Properties and Reclamation Possibilities for Surface Materials on Syncrude Lease #17 by H.M. Etter and G.L. Lesko (presented by Harold Etter of Thurber Consultants Ltd., Victoria, B.C.).

3:00 p.m. Paper 8. The Use of Peat, Fertilizers and Mine Overburden to Stabilize Steep Tailings Sand Slopes by Michael J. Rowell of Norwest Soils Research Ltd., Edmonton, Alberta.

3:30 p.m. Coffee Recess

4:00 p.m. Paper 9. Oil Sands Tailings; Integrated Planning to Provide Long-Term Stabilization by David W. Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta.

4:30 p.m. Paper 10. Bioengineering. The Use of Plant Biomass to Stabilize and Reclaim Highly Disturbed Sites by H. Schiechtel and K. (Nick) Horstmann (presented by Margit Kuttler).

5:00 p.m. End of August 18 Sessions.

Friday, August 19

Events: Presentation of Papers; C.L.R.A. Annual General Business Meeting; C.L.R.A. Annual Dinner.

Locations: Paper presentations and C.L.R.A. Annual General Business Meeting in Multi-Media Room, located on second floor of Education Building, University of Alberta.
- Annual Dinner held in Banquet Room located on second floor of Lister Hall.

8:00 a.m. Authors of Papers being presented on August 19 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching).

8:30 a.m. Showing of Film Rye on the Rocks. This film depicts reclamation situations at Copper Cliff, Ontario and is being shown for the purpose of introducing delegates to the site of the 1978 C.L.R.A. meeting (Sudbury, Ontario).

8:55 a.m. Continuation of Paper Presentations. Morning session chaired by Dr. J.V. Thirgood (Vice-President of C.L.R.A.; member of Forestry Faculty, University of British Columbia).

9:00 a.m. Paper 11. Reclamation of Coal Refuse Material on an Abandoned Mine Site at Staunton, Illinois by M.L. Wilkey and S.D. Zellmer (presented by Michael Wilkey of the Argonne National Laboratory, Argonne, Illinois).

9:30 a.m. Paper 12. A Case Study of Materials and Techniques Used in the Rehabilitation of a Pit and a Quarry in Southern Ontario by Sherry E. Yundt of the Ontario Ministry of Natural Resources, Toronto, Ontario).

10:00 a.m. Coffee Recess.

10:30 a.m. Paper 13. Amelioration and Revegetation of Smelter-Contaminated Soils in the Coeur D'Alene Mining District of Northern Idaho by D.B. Carter, H. Loewenstein and F.H. Pitkin (presented by Daniel Carter of Technicolor Graphic Services Inc., Sioux Falls, South Dakota).

11:00 a.m. Paper 14. The Influence of Uranium Mine Tailings on Tree Growth at Elliot Lake, Ontario by David R. Murray of the Elliot Lake Laboratory, Elliot Lake, Ontario.

11:30 a.m. Paper 15. Weathering Coal Mine Waste. Assessing Potential Side Effects at Luscar, Alberta by D.W. Devenny and D.E. Ryder (presented by David Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta).

12:00 noon Lunch Recess.

1:25 p.m. Continuation of Paper Presentations. Afternoon session chaired by Dr. John Railton, (Manager, Environmental Planning, Calgary Power Ltd., Calgary, Alberta).

1:30 p.m. Paper 16. The Distribution of Nutrients and Organic Matter in Native Mountain Grasslands and Reclaimed Coalmined Areas in Southeastern B.C. by Paul F. Ziemkiewicz of the Faculty of Forestry, University of B.C., Vancouver, British Columbia.

2:00 p.m. Paper 17. Systems Inventory of Surficial Disturbance, Peace River Coal Block, B.C. by D.M. (Murray) Galbraith of the British Columbia Ministry of Mines and Petroleum Resources, Victoria, British Columbia.

2:30 p.m. Paper 18. The Selection and Utilization of Native Grasses for Reclamation in the Rocky Mountains of Alberta by D. Walker, R.S. Sadasivaiah and J. Weijer (presented by David Walker of the Department of Genetics, University of Alberta, Edmonton, Alberta).

3:00 p.m. Coffee Recess; Distribution of Proceedings.

3:30 p.m. Commencement of 1977 General Business Meeting of the Canadian Land Reclamation Association. Meeting chaired by Dr. J.V. Winch, C.L.R.A. President.

7:30 p.m. Commencement of C.L.R.A. Annual Dinner in Banquet Room, second floor of Lister Hall.

Guest Speaker: William T. Plass, Principal Plant Ecologist, U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Princeton, West Virginia.

Topic of Speech: Challenges in Co-operative Reclamation Research.

Note: Following the Annual Dinner and Mr. Plass's speech, delegates may retire to the adjacent Gold Room. A bartender will be on service until midnight.