Michael J. Rowell, Ph.D.
Norwest Soil Research Ltd.

ENVIRONMENTAL RESEARCH MONOGRAPH 1977-4
A Public Service of
Syncrude Canada Ltd.

CONTINUED STUDIES OF SOIL IMPROVEMENT AND REVEGETATION OF TAILINGS SAND SLOPES

FOREWORD

Syncrude Canada Ltd. is conducting revegetation research on disturbed land surfaces in the Athabasca Tar Sands. The following report describes experiments which took place during 1976 on the face of the Great Canadian Oil Sands Ltd. tailings pond dyke. The report is the third to be published by Syncrude under the broad heading of revegetation, and the second to deal specifically with tailings sand slopes. The previous two reports are numbered 1974-3 and 1977-1, respectively, in Syncrude's Environmental Research Monograph series.

It is Syncrude's policy to publish its environmental consultants' final reports as they are received, withholding only proprietary technical information or that of a financial nature. Because we do not necessarily base our decisions on just one consultant's opinion, recommendations found in the text should not be construed as commitments to action by Syncrude.

Syncrude Canada Ltd. welcomes public and scientific interest in its environmental activities. Please address any questions or comments to Syncrude Environmental Affairs, 10030 - 107 Street, EDMONTON, Alberta, T5J 3E5.

ACKNOWLEDGEMENTS

The research project reported here is the second year of study into different aspects of soil reclamation and revegetation in the Athabasca tar sand area. The work was carried out for Syncrude Canada Ltd. under contract 98-0051-R.

We wish to acknowledge the co-operation and assistance of Mr. Don Klym and his staff of Great Canadian Oil Sands Limited. Without their help in providing the experimental sites and the amendment materials this study would not have been possible.

ABSTRACT

Studies were continued in 1976 into the improvement of a five year old revegetated area on a tailings sand dike by the implementation of different fertilizer programs.

In June, 1976 levels of available N, P, K and S were adequate for plant growth. However, even where fertilizers were added levels of mineral N had dropped to low levels by September, 1976.

Plant top production early in the 1976 season was increased by application of nitrogen fertilizer during the previous August. Continued good growth throughout the summer only occurred when extra N, P, K, and S fertilizers were added in June, 1976. The most efficient use of fertilizer occurred when nitrogen was added at a rate of about 80 Kg/ha or less. At the higher fertilizer application rates there was a tendency for Brome Grass to replace Creeping Red Fescue as the dominant grass in the sward.

The accumulation of root tissues has occurred over the past five years to the extent that current root:shoot ratios vary from about 4:1 to 7:1 .

Erosion of the area was negligible in 1976.

In two new revegetation experiments on steep tailings sand slopes, erosion could be minimized by the rapid establishment of a plant cover. This was most effective where the surface was amended with peat, mine overburden and with N, P, K and S fertilizers. The amounts of fertilizer added in the first year varied between 80 Kg-N, 35 Kg-P, 75 Kg-K and 20 Kg-S per hectare and 300 Kg-N, 80 Kg-P, 300 Kg-K and 40 Kg-S per hectare.

Nutrient losses in surface water runoff amounted to a maximum of only 2.6 Kg-N, 0.4 Kg-P, 4.1 Kg-K and 3.4 Kg-S per hectare in the treatments studied.

Water infiltration into the dike was rapid and varied between 24.0 and 30.5 cm/hr. Estimates suggested that between 13% and 34% of the intercepted rainfall leached below the 30 cm depth while plants were being established during the first year of growth.

Estimates of nutrient losses below the root zone (30 cm) ranged between 1.3 and 31.2 Kg-N/ha; less than 0.1 Kg-P/ha; 1.1 and 10.1 Kg-K/ha and 4.8 to 38.1 Kg-S/ha in the different treatments studied.

By the end of the growing season the levels of availble N, P and to a certain extent K were low except where a second application of fertilizer had been made in August.

The seed mix used contained oats as a nurse crop and 9 grass and 4 legume species. Plant growth was adequate to protect the soil surface from serious erosion. The dry weight production by the oats was considerably greater than for either the grasses or legumes. The cover produced by grasses and legumes alone would have been adequate in terms of erosion control except in those treatments involving heavy applications of mine overburdens.

The dry weight production of root and shoot tissues was about the same. Root growth was largely restricted to the surface 15 cm. Deeper tillage of peat and overburden resulted in a greater proportion of the roots in the 15-30 cm depth.

Total numbers of bacteria, fungi and actinomycetes as well as total soil respiration was considerably greater in soils from the revegetation experiments in comparison to samples of fresh or weathered tailings sand.

Plate 1. Root core taken from treatment To in Experiment I in September, 1976. The photograph shows that a dense root mat made up largely of Creeping Red Fescue has been produced after about five years of growth. Most of the roots are restricted to the surface 15 cm. peat layer. Some have penetrated into the tailings sand below.

Plate 2. View of part of experiment II just before the area was seeded in July, 1976.

Plate 3. Early growth on experiment II on treatment 1-C, August 4, 1976 about three weeks after seeding.

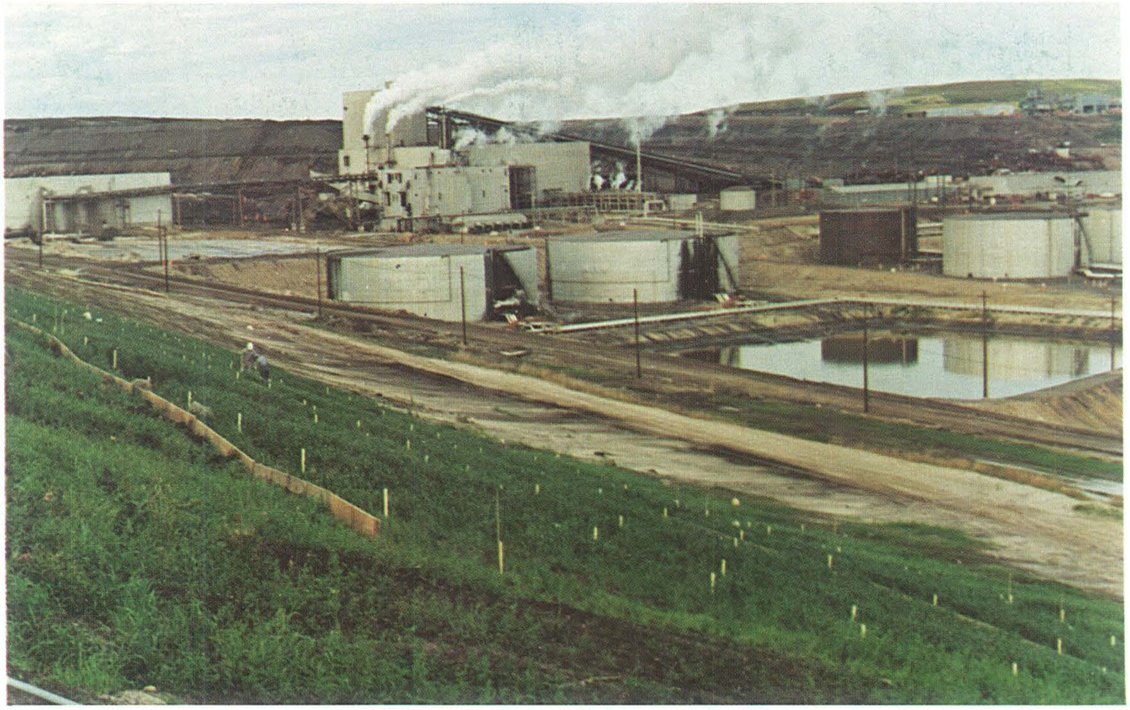


Plate 4. General view of experiment II and experiment III (lower right) on August 27, 1976.

Plate 5. Total plant cover on treatment 1-A, experiment II, 1976. The nurse crop of oats dominates the overall appearance of the plot.

Plate 6. Plant cover on treatment 1-A when the oats plants have been harvested. The protection afforded by the oats has helped to establish a good cover of grasses and legumes.

Plate 7. Plant growth can not be successfully established on unfertilized tailings sand slopes. Root penetration is shallow and the plants are severely deficient of nutrients.

Plate 8. Where peat has been added to the tailings sand surface and fertilizers applied plants can be established rapidly. Rooting is largely limited to the surface peat layer.

CONTENTS

FIGURES

TABLES

1. ANALYTICAL METHODS

1.1 Laboratory Preparation

Soil samples from the field were broken up by hand in the laboratory and subsamples were taken to determine moisture contents. The rest of the sample was air dried in an aluminum dish. Dry soils were ground to 2 mm size and stored for analysis. With total nitrogen and organic carbon analysis the soil was ground to pass a 60 mesh screen.

Harvested plant samples were dried and weighed to determine dry weight yields. The entire sample was then chopped into smaller pieces, mixed by hand and a representative subsample ground to 20 mesh in a Wiley mill.

Root cores were stored in the deep freeze until they could be treated. Root material was separated from the soil by washing with a fine spray of water over a set of sieves. Root tissues were dried and finely ground before being analyzed.

Water samples were taken in plastic containers and were stored in a refrigerator until they were analyzed.

1.2 Physical and Chemical Methods

Physical and chemical methods of analysis were carried out by standard methods as detailed in either Agronomy Monograph No. 9, Parts I and II(1) or in the Manual on Soil Sampling and Methods of Analysis(2).

Particle size analysis was determined by the hydrometer method. Measurements were only made on tailings sand and overburden prior to amendment (see Appendix). No pretreatment to oxidize organic matter was needed since all the samples involved all had very low organic matter contents (e.g. less than 2% organic matter). Moisture retention by soils was measured at 1/3 and 15 atmospheres using a standard pressure plate apparatus. Soil pH was measured in a 1:2.5 soil/water paste with a glass electrode. Electrical conductivity was determined on the extract from a saturated paste. Bitumen was measured by methylene chloride Soxhlet extraction. Water soluble sodium was determined by atomic absorption spectroscopy in the saturated extract. Ammonium and nitrate were determined by steam distillation after extraction with 1$\underline{M}$ potassium chloride. Extractable cations (Ca, Na, Mg and K) were determined by atomic absorption spectroscopy after extraction with neutral 1$\underline{M}$ ammonium acetate. Available phosphorus was measured colorimetrically using an ammonium molybdate/ammonium vanadate-nitric acid reagent after extraction with 0.03$\underline{N}$ ammonium fluoride/0.03$\underline{N}$ sulfuric acid. Sulfate was determined colorimetrically with a bismuth reagent following the reduction of sulfate with a hydriodic acid/formic acid/hypophosphorous acid reagent. The extractant was 0.1$\underline{M}$ calcium chloride. Total nitrogen was determined by Kjeldahl digestion followed by steam distillation. Organic carbon was estimated by the Walkley-Black wet digestion method. Total exchange capacity was determined by ammonium acetate saturation and displacement.

Total nitrogen analysis of plant materials was determined as described for soil samples. Measurement of total phosphorus, sulfur, potassium and calcium involved digestion of the plant material with a 5:1 mixture of nitric acid and perchloric acid. When the digestion was complete the solution was diluted and the P, S, K and Ca contents determined as previously described.

Water infiltration rates were determined in the field using a double ring system. A constant head of water was maintained in both cylinders that had been driven into the ground. The volume required to maintain a constant head in the central cylinder was recorded over a period of time until equilibrium was reached. The constant rate achieved was recorded in units of cm/hr.

1.3 Biological methods

Numbers of bacteria, actinomycetes and fungi present in the soil were determined by plate counting methods. Bacteria were counted on Standard Methods Agar. Plates were incubated for seven days at 25°C before bacterial colonies were counted. Numbers of actinomycete colonies were counted after 21 days.

Fungi were counted on a Streptomycin/Penicillin nutrient medium with the following composition per litre.

Glucose	10g
Peptone	5g
Yeast extract	2.5g
Streptomycin	40 ug/ml
Penicillin	20 units/ml
Agar	15g
pH	6.0

Plates were incubated for ten days at 25°C before fungal colonies were counted.

The dilution ranges employed ranged from 10^{-3} to 10^{-5} for fungi and 10^{-5} to 10^{-7} with bacteria. With the tailings sand samples the dilutions were two orders of magnitude lower.

Soil respiration rates were measured in the field and in the laboratory. In the field, plastic containers 12 cm in diameter were inverted and pressed into the soil surface. Each contained a small vial of 0.1M sodium hydroxide. Carbon dioxide released from the soil surface under the container was absorbed by the sodium hydroxide. Carbon dioxide absorption could be quantitatively determined by titration of the unused sodium hydroxide in the vial against standard acid using phenolphthalein as indicator. Soil respiration was measured over a six hour period. Temperature measurements at a depth of 4 cm were taken every two hours. From the dimensions of the container, soil respiration could be expressed on a area basis in the field.

In the laboratory, soil was incubated for about two weeks at field capacity moisture content. A 30-50 g sample was placed in a glass jar in which was suspended a small test tube containing sodium hydroxide. As in the field, the production of carbon dioxide could be estimated by back titration of sodium hydroxide. The temperature was maintained at 22°C. Respiration over a 24 hour period was measured.

1.4 Statistical Methods

Replicated data was treated statistically to determine standard deviation about the mean and to indicate probable treatment differences.

The more important data shows individual replicate values and standard deviations in the tables within the text. A complete set of data, which gives full replication with standard deviations and other statistical treatments may be obtained on request.

Where it was applicable, significant differences between treatments were examined using a one way analysis of variance. Where analyses of variance were performed, significances may be noted in the text by following notation:

***	Significant at the 1% level
**	Significant at the 2.5% level
*	Significant at the 5.0% level
(*)	Marginally significant
N.S	Not significant

If significance was noted, LSD values (Least Significant Difference at the 5% level) are given in the tables.

Where significance was indicated by an analysis of variance, further statistical treatments using two sample or paired t-tests were often carried out.

Correlations between different parameters were investigated by linear regression analysis.

2. CONTINUED STUDIES ON A VEGETATED TAILINGS SAND DIKE AT FORT MCMURRAY, ALBERTA. - EXPERIMENT (I).

2.1 Introduction

The study area is located on the eastern face of the tailings pond dike at the Great Canadian Oil Sands Limited plant at Fort McMurray.

During the winter of 1970/71, a layer of peat about six inches (15 cm) in thickness was added to the slope. In the following spring, the area was seeded with the seed mix described below at a rate of 30 lbs./acre (26.8 Kg/ha)

Brome Grass	(Bromus inermis)	33% by volume
Crested Wheat Grass	(Agropyron cristatum)	24% by volume
Creeping Red Fescue	(Festuca rubra)	15% by volume
Sweet Clover	(Melilotus sp.)	14% by volume
Alsike Clover	(Trifolium hybridum)	14% by volume

Soil samples taken in September of 1969 indicated that the tailings sand had a surface pH of 8.5, relatively low conductivity (salt content) and was very low in available nutrients. In May, 1971, the first addition of fertilizer was made. Between that time and July, 1974, Great Canadian Oil Sands Limited (G.C.O.S.) made six further applications of fertilizer. The amounts added were very low (see Table 1).

Table 1. Fertilizers added to a Vegetated Tailings Sand Dike at the G.C.O.S. Plant, Fort McMurray between May, 1971 and July, 1974.

DATE	FERTILIZER TYPE	FERTILIZER RATE/ACRE	NUTRIENT EQUIVALENTS lbs./acre N	P	K
May, 1971	10:30:10	400	40	52.3	33.7
Sept., 1971	6:24:24	200	12	20.9	39.9
	33.5:30:0	200	67		39.9
June, 1972	6:24:24	100	6	10.5	20.0
	33.5:0:0	100	33.5		
May, 1973	15:15:15	200	30	13.1	24.9
August, 1973	15:15:15	200	30	13.1	24.9
July, 1974	15:15:15	200	30	13.1	24.9
		TOTAL lb/ac	248.5	123	167.9
		(Kg/ha	222	110	150)

The slope of the dike in this region varies from 23^{o} to 28^{o} and the soil can become very unstable if the peat mantle becomes eroded away. Some discussion was made of general erosion and water seepage problems at the site in the 1975/1976 report[3].

2.2 Objectives

The general objectives of the experiment were:

(i) To determine the fate of fertilizer nutrients added to the dike,

(ii) To study the effectiveness of different fertilizer programs in relation to the maintenance of an adequate plant cover on the dike.

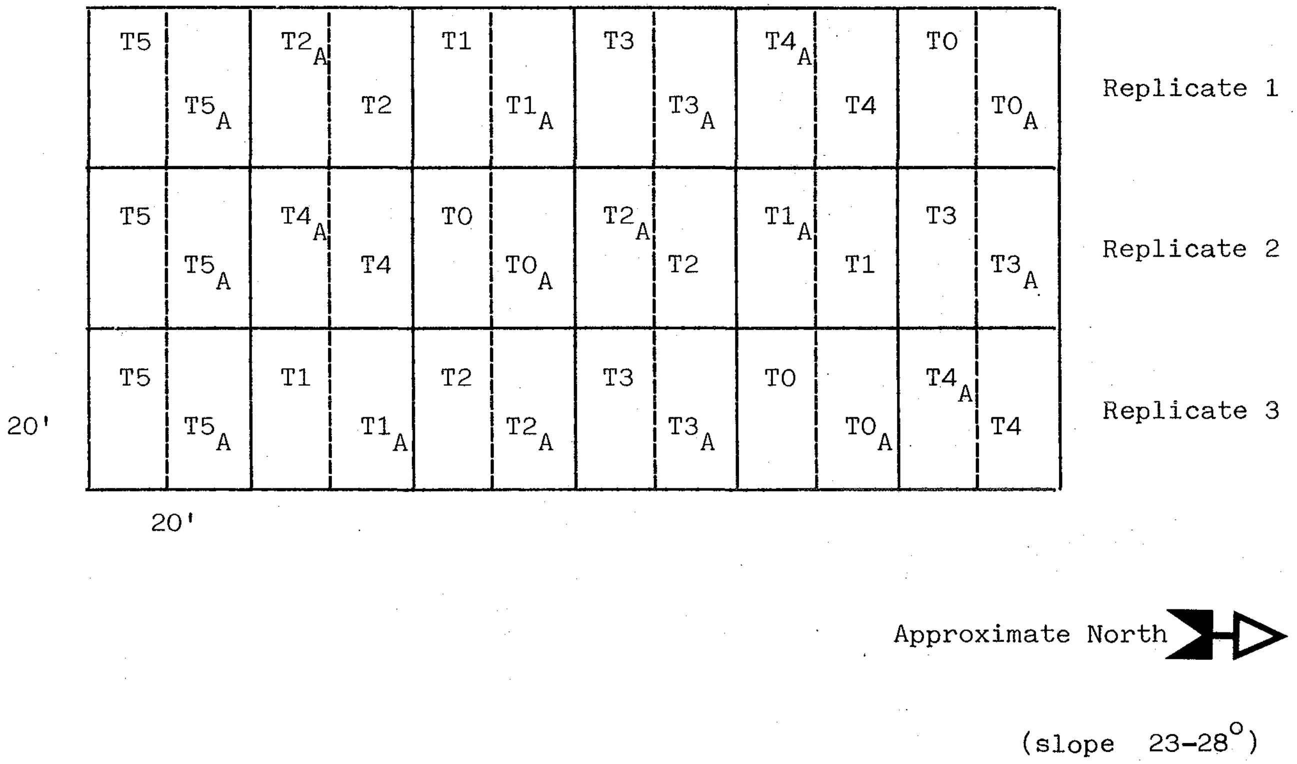
2.3 Experimental Design

Initially a partially randomized design was set up which incorporated six treatments replicated three times. Later, each treatment was subdivided to give 36 plots as shown in Figure 1.

In terms of the treatments applied, a comparison was made between no fertilizer addition, low yearly additions (G.C.O.S. practice) and high yearly or high biannual additions. Table 2 shows the amounts and times when fertilizers were added in 1975. Water collection traps were set up on treatments To, T2, T4 and T5 as well as on areas outside the plots to determine the extent of fertilizer losses in runoff water. The original experiment was set up using avoirdupois units. To maintain continuity with the other experiments, metric conversions are given wherever possible.

In 1976, the basic experiment design remained the same, although the work plan and the fertilization program were modified. The initiation of new experiments in 1975 made possible a comparison of newly vegetated areas with

Figure 1. Field plan of experiment on a vegetated tailings sand dike at the GCOS plant site at Fort McMurray, Alberta (Experiment [I]).



T5	$T5_A$	$T2_A$	T2	T1	$T1_A$	T3	$T3_A$	$T4_A$	T4	T0	$T0_A$	Replicate 1
T5	$T5_A$	$T4_A$	T4	T0	$T0_A$	$T2_A$	T2	$T1_A$	T1	T3	$T3_A$	Replicate 2
T5	$T5_A$	T1	$T1_A$	T2	$T2_A$	T3	$T3_A$	T0	$T0_A$	$T4_A$	T4	Replicate 3

Table 2. Fertilizers added to a Vegetated Tailings Sand Dike at the G.C.O.S. Plant, Fort McMurray during 1975.

Treatment	Spring (June 19th)				Summer (Aug.17th)				Total			
				(lbs per acre)								
	N	P	K	S	N	P	K	S	N	P	K	S
To	0	0	0	0	0	0	0	0	0	0	0	0
To_A	0	0	0	0	80	0	0	8	80	0	0	8
T1	80	20	80	8	0	0	0	0	80	20	80	8
T1_A	80	20	80	8	80	0	0	8	160	20	80	16
T2*	80	20	80	8	0	0	0	0	80	20	80	8
T2_A*	80	20	80	8	80	0	0	8	160	20	80	16
T3	160	40	160	16	0	0	0	0	160	40	160	16
T3_A	160	40	160	16	160	0	0	16	320	40	160	32
T4*	160	40	160	16	0	0	0	0	160	40	160	16
T4_A*	160	40	160	16	160	0	0	16	320	40	160	32
T5	13.5	5.2	10	12	24	5.2	10	24	37.5	10.4	20	36
T5_A	13.5	5.2	10	12	67.5	5.2	10	24	80	10.4	20	36

* Lime added, June 19th at 5 tons/acre (appox. 4.5 Tonnes/ha)

Fertilizers added to all but T5 and T5_A as:

ammonium nitrate, ammonium sulfate, ammonium phosphate, potash, potassium sulfate.

Fertilizers added to T5 and T5_A as ammonium sulfate and ammonium phosphate/potassium sulfate.

To convert lb/ac to Kg/ha multiply by 0.894.

one such as this which had been vegetated for several years.

Table 3 shows the fertilization program used in 1976 and that proposed for the next few years.

2.4 Work Plan

As in 1975, two cuts of plant material were made to estimate productivity. More detailed studies related to fertilizer uptake and loss, and a general assessment of site stability were made in 1976. These more detailed studies were restricted to treatments To, T2, and T5. Two sets of soil samples were taken. The first in June, after the first set of plant samples were taken and the other in September when the final plant cut was made. In view of the results of runoff and erosion studies conducted during 1975, the water traps were not reinstalled in 1976.

2.5 Results

2.5.1 Summary of Conclusions from 1975

(i) The application of over 80 lbs-N/acre, 40 lbs-P/acre and 80 lbs-K per acre per year seemed to have resulted in the production of a good vegetative cover (Equivalent to 71.5 Kg-N, 35.8 Kg-P and 71.5 Kg-K/ha).

(ii) Although dry matter production was good enough to consider cropping the area for hay, this practice was not considered desirable. The nutrients removed could not be recycled in the soil in subsequent years so that more fertilizer additions would be needed to maintain growth.

(iii)Brome Grass and Creeping Red Fescue were the dominant species that had survived on the slope. At the higher rates of fertilizer addition Brome Grass predominated while at minimal rates of nutrient amendment Creeping Red Fescue competed more favorably.

Table 3. Fertilizer additions during 1976 and proposed additions to 1979 on a vegetated tailings sand dike at the G.C.O.S. plant site at Fort McMurray, Alberta.

	Rate of fertilizer addition (lb/acre)																					
	1976				1977						1978						1979					
	June				June			Aug.			June			Aug.			June			Aug.		
	N	P	K	S	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
To																						
To_A					80	20	80										80	20	80			
T1	80	20	80		80	20	80				80	20	80				80	20	80			
$T1_A$	80	20	80		80	20	80	80	20	80	80	20	80				80	20	80	80	20	80
T2	80	20	80		80	20	80	80	20	80	80	20	80				80	20	80*	80	20	80
$T2_A$	80	20	80		80	20	80	80	20	80	80	20	80				80	20	80*	80	20	80
T3					160	40	160										160	40	160			
$T3_A$					160	40	160	160	40	160							160	40	160	160	40	160
T4					160	40	160										160	40	160*			
$T4_A$					160	40	160	160	40	160							160	40	160*	160	40	160
T5	38	10	20	8	38	10	20				38	10	20				38	10	20			
$T5_A$	38	10	20	8	38	10	20	62			38	10	20	62			38	10	20	62		

* Possible addition of lime depending on soil pH.
To convert lb/ac to Kg/ha multiply by 0.894.

(iv) Vegetative cover on this part of the dike was sufficient to stop erosion as long as large scale channeling of the runoff water could be prevented.

(v) Little fertilizer nitrogen was lost in rainfall runoff. Most of the added nitrogen seemed to be taken up efficiently by the plants.

(vi) Root penetration was confined almost exclusively to the surface peat layer.

2.5.2 Soil Analysis

(a) June, 1976

A series of soil samples were taken on June 22, 197~~5~~6 some four days after the first plant samples had been removed. Every plot was sampled at the 0-15 cm and 15-30 cm depth (0-6" and 6-12"). In addition, treatments T0, T2, T4 and T5 were sampled at 30-60 cm, 60-90cm and 90-120 cm depths. To provide a representative sample at least six cores were taken at each plot.

The results are presented in Table 4. In comparison to the analysis of samples taken during 1975, the soil properties were generally similar (see Table 1 and 11, 1975/1976 report, reference number 3).

Surface pH values ranged from 6.35 to 6.62 where no lime had been added and between 6.75 and 7.12 where lime had been applied at a rate of 5 tons/acre in 1975 (4.5 Tonnes/ha). With increase in depth, the soil became mildly alkaline. However, the values never exceeded a pH of 8 to the depth sampled. Analysis of the tailings sand in 1969 before the peat was added indicated pH values of about 8.5.

Conductivity of the surface 30 cm was generally between 0.5 and 0.7 mmhos/cm. Slightly higher values were recorded for some of the treatments that had received extra fertilizer in August, 1975 ($T2_A$, $T3_A$, $T4_A$, and $T5_A$).

Table 4. Analysis of soil samples from a vegetated tailings sand dike at the GCOS plant site at Fort McMurray, Alberta - June, 1976 (Experiment [1]).

		pH	Cond.	Org.C	T.E.C.	H_2O	Mineral nitrogen		P	K	SO_4-S	Sol-Na	Ext-Na	Tot. N
			mmhos/cm	%	meq/100g	%	NH_4-N	NO_3-N						%
							ppm		ppm					
T0	0-15 cm	6.60	0.62	4.2	16.3	13.1	20.1	0.6	22.0	122	42.9	7.3	9.4	0.13
	15-30	6.80	0.50	1.5	4.2	6.3	10.0	0.7	3.3	23	26.8	4.4	6.2	0.03
	30-60	7.00	0.48	0.9	2.0	4.1	13.9	0.3	1.2	17	20.4	7.5	6.2	
	60-90	7.38	0.47			5.5	20.2	2.1	0.5	39	24.3	5.5	7.1	
	90-120	7.28	0.51			7.9	15.0	0.2	1.3	26	21.3	5.5	6.5	
$T0_A$	0-15 cm	6.42	0.54			8.8	18.2	0.4						
	15-30	6.80	0.34			4.1	9.8	0.6						
T1	0-15 cm	6.47	0.67			17.9	25.3	1.2						
	15-30	6.73	0.64			6.9	6.5	0.9						
$T1_A$	0-15 cm	6.42	0.60			10.4	12.0	1.4						
	15-30	6.85	0.43			2.8	7.8	0.8						
T2	0-15 cm	6.93	0.75	5.7	20.0	16.9	12.3	1.1	16.7	164	71.9	13.0	13.5	0.24
	15-30	7.15	0.58	1.8	4.9	5.7	9.7	0.6	3.0	28	35.6	5.8	7.3	0.04
	30-60	7.15	0.59	0.7	1.8	4.5	15.7	2.1	3.3	23	23.9	5.6	7.3	
	60-90	7.30	0.53			4.8	13.0	0.2	1.8	19	21.5	5.3	6.9	
	90-120	7.33	0.65			5.5	10.8	0.8	2.2	23	27.3	7.7	10.1	
$T2_A$	0-15 cm	6.75	0.90			11.6	20.5	0.6						
	15-30	7.13	0.68			2.9	8.4	0.2						
T3	0-15 cm	6.47	0.63			11.6	32.8	1.2						
	15-30	6.68	0.68			4.0	15.0	0.8						
$T3_A$.	0-15 cm	6.35	0.82			14.4	36.9	5.0						
	15-30	6.67	0.70			4.4	18.0	1.4						
T4	0-15 cm	7.12	0.76	4.5	17.2	10.9	35.0	1.6	33.2	259	58.5	14.2	13.7	0.13
	15-30	7.07	0.65	2.5	8.5	7.7	10.1	0.9	4.5	31	46.0	7.3	9.0	0.04
	30-60	7.22	0.62	1.1	2.8	4.1	15.3	0.4	3.8	27	26.3	8.3	8.3	
	60-90	7.63	0.55			5.0	8.7	1.1	1.8	23	24.4	5.5	6.7	
	90-120	7.48	0.63			5.6	14.8	0.3	2.8	36	28.4	8.2	9.1	
$T4_A$	0-15 cm	6.90	0.90			11.4	26.0	3.0						
	15-30	7.40	0.73			3.6	14.1	2.7						
T5	0-15 cm	6.60	0.72	6.5	20.6	14.6	21.5	0.7	24.3	130	69.6	9.2	11.7	0.15
	15-30	6.92	0.61	1.7	4.7	6.0	16.9	1.4	4.5	23	34.8	5.1	6.9	0.02
	30-60	7.30	1.24	1.0	2.8	5.4	18.2	1.3	3.8	29	43.2	20.1	23.9	
	60-90	7.58	0.99			5.0	11.8	0.0	1.5	29	21.9	12.4	9.6	
	90-120	7.67	1.62			5.6	18.8	1.5	2.3	41	27.2	24.2	17.9	
$T5_A$	0-15 cm	6.62	0.77			12.7	28.1	0.4						
	15-30	7.15	0.61			6.6	10.8	1.1						

All values are means of three replicates.
Statistical analyses are presented in the Appendix.

Samples taken to a depth of 120 cm (4 feet) did not appear to have any buildup of salts. An exception was treatment T5 which had values consistently above 1 mmhos/cm between a depth of 30 cm and 120 cm. This might be due to the presence of salt containing overburden material at this depth on that area of the dike. It should be noted that treatment T5 was not randomized and is located as a block on the southern edge of the experimental area.

Analysis of the available major plant nutrients, N, P, K, and S, showed that early in the growing season supplies were quite good.

Mineral nitrogen was almost exclusively present in the ammonium form. Amounts in the surface 15 cm varied from 12.0 ppm to 35.0 ppm. In all the treatments that were sampled to 120 cm ammonium-N was always present. Nitrate nitrogen concentrations were all below 5 ppm. The treatments that had received high rates of fertilizer last year did not have significantly higher contents of mineral total nitrogen in relation to low fertilizer treatments. However, amounts of NO_3-N in the surface 15 cm where significantly higher at the 5% level in treatments T3, $T3_A$, T4 and $T4_A$ (t-test).

Most of the available phosphorus was present in the surface 15 cm. Values ranged from 16.7 ppm to 33.2 ppm. Below the 15 cm depth, values were all below 4.5 ppm. No significant trends related to previous fertilizer additions were evident.

The majority of the potentially available potassium was also restricted to the surface peat layer. Concentrations varied between 122 ppm for treatment To to 259 ppm in treatment T4. There did appear to be some benefit from the previous season's addition of fertilizer potassium. Surface values in treatments T2 and T4 were significantly higher than treatments To and T5 (5% significance shown with a t-test).

Sulfate-S concentrations were quite high in all the samples that were analyzed. Values were significantly higher at the surface. Below the 15 cm depth, a concentration of 20-30 ppm SO_4-S was normally recorded. There seemed to be a relationship between surface concentrations of sulfate and the rates of fertilizer-S added previously.

Organic carbon contents in the surface 15 cm of treatments T0, T2, T4 and T5 varied between 4.2 percent and 6.5 percent. Differences between treatments were not significant. Much of the surface 15 cm is made up of root biomass (see later). Therefore, it seems that since 1970/71, when the peat was added, considerable decomposition has taken place to reduce the content of peat carbon. Organic carbon was quite low in the lower depths studied.

The total nitrogen content of the surface 15 cm varied from 0.13 percent to 0.24 percent. Surface C:N ratios ranged from 23.8 to 43.3 percent. Unfortunately, we do not have any similar data related to the original peat used as the amendment to this area.

Most of the cation exchange capacity of the soil seems to be derived from the organic component. Total exchange capacity was closely related to organic carbon contents (r^2= 0.95 for all depth). Average T.E.C. values of between 16.3 and 20.6 meq/100g were found. The exchange capacity below the surface 15 cm was quite low indicating a rather limited ability to hold cations once they leach below the surface mat of peat and roots.

There was no evidence for the accumulation of sodium within the soil profile to a depth of 120 cm. Values recorded were all low and generally were below 15 ppm. Almost all the sodium present seemed to be water soluble. With treatment T5, sodium contents were consistently higher than other treatments below the 30 cm depth. As with the conductivity readings, there seemed to be some evidence that a small pocket of more saline material existed at depth in this region of the plot.

Soil moisture levels at this time were moderately low. No rainfall had been recorded for the whole week prior to sampling while temperatures had been quite high. In the sand below the peat, the 30-60 cm layer generally held the least water. Below a depth of about 60 cm moisture content seemed to begin to rise again slightly.

(b) September, 1976

Treatments T1, T1$_A$, T2, T2$_A$, T5 and T5$_A$ were fertilized after the June soil samples were taken (See Table 3).

A second set of plant and soil samples were taken on September 15. Samples were taken in the same way as before. The results of analysis are shown in Table 5. In comparison to the June samples, the soils were slightly more acidic and available nitrogen and potassium were lower.

The surface pH of the unlimed treatments ranged from 5.83 to 6.08 while values between 6.28 and 6.55 were determined with limed areas. These values were from about 0.3 to 0.6 units lower than was recorded in June.

Conductivity values had generally increased slightly. This was particularly the case where high rates of fertilizer had been added in 1975 and where additional nutrients were added during 1976. Treatment T2$_A$ had the highest conductivity (1.20 mmhos/cm). This value is still well below levels that would be considered harmful to plant growth. Conductivity to 120 cm was low.

Soil moisture contents at the surface were higher than had been recorded in June. The period between the sampling had included three days of moderately heavy rainfall (August 13, 31.2 mm; August 26, 36.8 mm; and September 6, 39.9mm).

Mineral nitrogen contents were lower than earlier in the year, even

Table 5. Analysis of soil samples from a vegetated tailings sand dike at the GCOS plant site at Fort McMurray, Alberta - September, 1976 (Experiment [I]).

		pH	Cond. mmhos/cm	H_2O %	Mineral nitrogen		P	K	SO_4-S
					NH_4-N	NO_3-N			
					ppm			ppm	
T0	0–15 cm	6.03	0.65	49.1	3.1	1.5	28.2	100	36.8
	15–30	6.33	0.57	7.9	2.3	1.2	2.3	14	21.6
	30–60	6.57	0.42	5.9	1.3	0.7			
	60–90	6.83	0.38	7.3	1.0	0.8			
	90–120	7.18	0.50	8.3	1.2	0.6			
$T0_A$	0–15 cm	5.83	0.58	25.3	4.4	1.6			
	15–30	6.07	0.57	15.4	1.4	1.1			
T1	0–15 cm	5.93	0.68	22.0	6.9	2.9			
	15–30	6.17	0.65	9.1	1.7	0.9			
$T1_A$	0–15 cm	5.88	1.01	26.1	6.5	2.9			
	15–30	6.15	0.80	3.5	1.3	1.0			
T2	0–15 cm	6.55	1.05	56.1	5.6	9.6	26.5	203	67.0
	15–30	6.52	0.73	15.1	2.6	1.5	4.8	19	22.3
	30–60	6.61	0.40	5.9	1.6	1.4			
	60–90	7.00	0.48	6.0	1.1	0.6			
	90–120	6.78	0.41	5.6	1.4	1.0			
$T2_A$	0–15 cm	6.43	1.20	35.6	8.7	15.1			
	15–30	6.43	0.76	5.7	2.6	0.8			
T3	0–15 cm	5.98	0.64	44.3	4.6	1.8			
	15–30	6.30	1.00	15.3	4.3	1.4			
$T3_A$	0–15 cm	5.98	0.68	39.5	4.8	2.7			
	15–30	6.23	0.80	11.1	1.7	0.8			
T4	0–15 cm	6.28	0.91	37.3	3.4	0.9	20.5	143	65.8
	15–30	6.38	0.83	23.1	2.3	1.0	2.7	24	42.6
	30–60	6.43	0.44	6.8	1.2	0.7			
	60–90	6.70	0.41	5.7	0.9	0.8			
	90–120	7.12	0.47	7.3	1.4	0.9			
$T4_A$	0–15 cm	6.35	0.66	33.3	6.4	1.3			
	15–30	6.18	0.74	12.2	2.4	1.0			
T5	0–15 cm	6.08	0.90	50.1	6.7	1.9	18.2	89	97.0
	15–30	5.90	0.63	13.0	2.8	0.8	2.7	22	29.4
	30–60	6.22	0.71	6.6	1.5	0.8			
	60–90	6.53	0.92	5.8	1.1	0.6			
	90–120	7.57	0.68	6.4	1.1	0.5			
$T5_A$	0–15 cm	5.98	0.73	50.0	8.8	1.6			
	15–30	6.32	0.69	14.9	2.2	0.6			

All values are means of three replicates.

with the plots that had received extra fertilizers this year. In the top 15 cm ammonium-N varied between 3.4 and 8.8 ppm. Nitrate-N was between 0.9 and 15.1 ppm. Mineral nitrogen was generally very low below a depth of 15 cm. No relationship could be found between total mineral nitrogen contents and the amounts of nutrients added. Those treatments that had been fertilized in 1976 (T1, $T1_A$, T2, $T2_A$, T5, and $T5_A$) did contain significantly more NH_4-N and NO_3-N in the surface 0-15 cm than those which had not been fertilized in 1976.

Available phosphorus contents were fairly similar to those recorded in June. Again, most of the phosphorus occurred in the surface 15 cm. No significant differences could be found between the treatments studied (T0, T2, T4, T5).

Available potassium was between 89 ppm and 203 ppm in the surface 15 cm of treatments T0, T2, T4 and T5. Amounts were very low below 15 cm.

Sulfate sulfur contents were generally similar in the June levels. Amounts in the surface 15 cm ranged between 36.8 ppm and 97.0 ppm.

2.5.3 Vegetative Growth

(a) Field Observations and Measurements

Where higher amounts of fertilizer had been added in relation to area surrounding the experimental site,the growth of Brome Grass generally increased at the expense of Creeping Red Fescue.

During August, semi-quantitative measurements of the percentage area covered by each species were made (see Table 6). Again, the relationship of species distribution to fertilization is evident especially where both sides of the split plot are examined (e.g., T1, $T1_A$, T4, $T4_A$, etc). For

Table 6. Distribution of Plant Species on Experimental Plots On a Vegetated Tailings Sand Dike at the G.C.O.S. Plant, Fort McMurray.

Treatment	Percentage Cover				
	Creeping Red Fescue	Brome Grass	Alsike Clover	Sweet Clover	Crested Wheatgrass
TO	88	9	2	1	0
TO_A	79	18	0	1	2
T1	66	33	0	1	0
$T1_A$	42	58	0	0	0
T2	50	50	0	0	0
$T2_A$	45	55	0	0	0
T3	80	20	0	0	0
$T3_A$	30	70	0	0	0
T4	69	25	1	0	5
$T4_A$	52	45	0	0	3
T5	80	19	1	0	0
$T5_A$	71	28	1	0	0

All values are means of three repicates

example, treatment T3 has 80 percent cover by Creeping Red Fescue and 20% by Brome while $T3_A$ has only 30% cover by Creeping Red Fescue and 70% by Brome. Both treatments were fertilized in June, 1975 while $T3_A$ received extra nitrogen in August, 1975. Neither were fertilized in 1976. However, the desirability of manipulating the predominance of one species over the other in this case is not clear at this time.

Despite the fact the soil analysis showed that available nutrient levels were all above minimum, plant deficiencies were evident as early as June. Deficiencies became progressively more severe as the season progressed. Nitrogen, potassium and phosphorus deficiency symptoms could be noted on many plots. However, no clear trends related to experimental treatments were evident. Areas around the experimental site were not fertilized in 1976 and showed very poor growth throughout the year. A portion of the plant material in this area had turned brown by mid-summer. Experimental areas that were fertilized late in 1975 or early in 1976 generally had a good vegetative cover and looked green and healthy for most of the summer.

(b) Plant Productivity

Areas of one meter square were clipped from each of the 36 plots in June and September. In this way, estimates of early growth and total growth could be estimated. Samples were transported to the laboratory and were dried and weighed. Each samples was chopped up coarsely, mixed and a subsample taken and ground for subsequent chemical analysis.

Table 7 shows the yields of the June, 1976 plant material. It was most evident that early growth was promoted by the late fertilization in the previous August. All the "A" treatments gave significantly higher yields in June in comparison to the respective treatment that did not receive

Table 7. Dry weight yield of plant tops in June and September, Experiment (I), 1976.

Treatment	Plant Top Yield (Kg/m^2)									
	June, 1976					September, 1976				
	R1	R2	R3	Average	S.D.	R1	R2	R3	Average	S.D.
T0	0.030	0.036	0.097	0.054	0.037	0.192	0.229	0.297	0.239	0.053
$T0_A$	0.115	0.060	0.080	0.085	0.028	0.355	0.324	0.293	0.324	0.031
T1	0.038	0.105	0.088	0.077	0.035	0.352	0.423	0.353	0.376	0.041
$T1_A$	0.073	0.153	0.137	0.121	0.042	0.367	0.371	0.375	0.371	0.040
T2	0.046	0.116	0.089	0.084	0.035	0.392	0.389	0.377	0.386	0.007
$T2_A$	0.121	0.087	0.130	0.113	0.023	0.397	0.330	0.366	0.364	0.034
T3	0.094	0.081	0.124	0.100	0.022	0.252	0.233	0.295	0.260	0.032
$T3_A$	0.204	0.117	0.189	0.170	0.047	0.291	0.255	0.328	0.291	0.037
T4	0.109	0.104	0.073	0.095	0.020	0.366	0.293	0.307	0.322	0.039
$T4_A$	0.209	0.186	0.094	0.166	0.065	0.321	0.328	0.262	0.304	0.036
T5	0.066	0.093	0.085	0.081	0.014	0.357	0.363	0.409	0.376	0.028
$T5_A$	0.096	0.129	0.174	0.133	0.039	0.297	0.467	0.451	0.403	0.098
Significance				**					***	
L.S.D.				0.061					0.073	

fertilizer during August, 1975 (means were statistically different at the 1% level of significance). The yield was lowest (0.170 Kg/m^2) in the unfertilized treatment To while the highest yield (0.170 Kg/m^2) was recorded with treatment T3$_A$. Rapid early growth is most important in providing a good protective cover against erosion of the soil surface. Fort McMurray seems particularly prone to at least one or two violent rain storms during spring and early summer.

Differences between treatments were less dramatic when the entire seasons growth was examined. Yields are recorded in Table 7. The treatments that had received single or double increments of 160 lbs-N acre in 1975 but no fertilizer in 1976 (i.e., T3, T3$_A$, T4, T4$_A$) yielded lower than treatments T1, T1$_A$, T2, T2$_A$ which had received fertilizer at 80 lbs-N/acre equivalent during 1975 and 1976 (statistically different at the 1% level). Even the addition of 35 lbs-N/acre equivalent in June, 1976 (T5 and T5$_A$) resulted in an excellent plant biomass production. Treatments which did not receive fertilizers in 1976 produced a disproportionately high amount of growth by June. Between June and September, growth was apparently quite slow in these treatments.

The unfertilized treatment, To, gave the lowest total yield (0.239 Kg/m^2), while the highest yield (0.403 Kg/m^2) was recorded for treatment T5$_A$.

As part of the last year's study, some preliminary measurements of root distribution were made. Results indicated that about 80% of the root biomass was restricted to the surface peat layer (0-6 inches).

Root biomass and distribution studies were expanded in 1976 to determine if rooting characteristics were related to experimental treatments. Plate 1 shows a root core taken from treatment To in September, 1976. Visually most of the roots seemed to be located in the peat zone. A few roots did penetrate quite deeply into the sand. Table 8 shows the yield of roots for different treatments to a depth of 60 cm. Root sections 15 cm x 15 cm in size were taken in duplicate from treatments To, T2, T4 and T5 at 0-15 cm and 15-30 depth. The final sample for the 30-60 cm depth was composed of eight samples taken with a 6 cm diameter corer. The root samples were stored in a deep freeze until they could be treated. In this way, biological decomposition of the roots was kept to a minimum. The roots were separated from the rest of the soil by a wet sieving method. The procedure was tedious but seemed to be relatively efficient. Undoubtedly some of the fine roots were lost in the process. However, we estimate that recovery was between 90 and 95 percent efficient for sandy samples and about 75 percent efficient for the peat layers. This method does not distinquish between living and dead roots.

As was found in the limited study last year, most of the roots were in the surface 15 cm. The percentage recovered varied between 85.1 and 94.6 percent. There was no significant difference between total root biomass. Root production varied between 1.372 Kg/m^2 and 1.726 Kg/m^2. The yield of roots relative to the above ground production to September, 1976 ranged from 7:1 for treatment To to 4:1 for treatments T2 and T5.

The differences were due to variation in above ground biomass.

(c) Plant Analysis

The nutrient content of plant tops sampled in June and September showed some relationship to the levels of available nutrients in the soil at the same time. In particular, the nitrogen contents for the June cut

Table 8. Total dry weight yield of plant roots, Experiment (II), September, 1976.

	Yield of roots (Kg/m^2)																Root/Shoot
	0–15 cm.					15–30 cm.					30–60 cm.						
	R1	R2	R3	Ave.	S.D.	R1	R2	R3	Ave.	S.D.	R1	R2	R3	Ave.	S.D.	TOTAL	
T0	0.802	1.231	2.702	1.578	0.996	0.064	0.173	0.122	0.120	0.055	0.040	0.031	0.013	0.028	0.014	1.726	7.2
T2	1.650	1.441	1.408	1.500	0.131	0.086	0.049	0.099	0.078	0.026	0.013	0.017	0.002	0.007	0.006	1.585	4.1
T4	1.599	1.081	0.826	1.168	0.394	0.188	0.087	0.219	0.165	0.069	0.007	0.021	0.087	0.038	0.043	1.372	4.3
T5	1.594	1.496	1.009	1.366	0.313	0.156	0.169	0.123	0.149	0.024	0.012	0.068	0.022	0.034	0.030	1.550	4.1
																N.S.	

were quite similar regardless of the treatment involved (See Table 9). June values were generally higher than for material harvested in September (Table 10). It will be noted that in September the available nitrogen in the soil was quite low. Nitrogen contents of June samples varied between 1.36 and 2.72 percent while in September the range was 0.89 percent to 2.76 percent. The decline in nitrogen content over the season was most evident for treatments that were not fertilized in 1976. Table 11 shows this in a better perspective by comparing the total amount of nitrogen taken up by the plants.

Phosphorus showed a similar though less dramatic trend to that demonstrated by nitrogen. The June samples had phosphorus contents that varied from 0.27 percent to 0.45 percent while the phosphorus content of the material harvested in September was between 0.21 percent and 0.30 percent. The observed reduction in phosphorus content was most marked with treatment To (unfertilized) which dropped from 0.45 percent to 0.24 percent phosphorus. The total potassium contents of the September plant samples were significantly higher than those in June (paired t-test using treatment means indicated significant differences at the 2.5% level).

Sulfur contents revealed no significant differences between experimental treatments. Concentrations were slightly lower in the September set of samples. June values varied between 0.12 percent S and 0.20 percent S, while the range was 0.09 percent to 0.17 percent S in September.

The calcium content of top material was similar in both sets of plant samples. Limed treatments were not significantly higher in calcium than plants grown without lime addition in 1975.

Table 9. Analysis of plant tops, June 1976, Experiment (I).

Treatment	N	P	K	S	Ca	Nitrate
	(%)					
To	2.05	0.45	1.76	0.17	0.51	0.77
To_A	2.04	0.33	1.58	0.12	0.48	0.86
T1	1.86	0.36	2.13	0.17	0.56	0.96
$T1_A$	2.02	0.35	1.83	0.16	0.56	1.26
T2	2.38	0.38	1.18	0.15	0.49	0.96
$T2_A$	2.08	0.31	1.73	0.13	0.48	0.31
T3	2.29	0.31	1.72	0.20	0.54	0.14
$T3_A$	2.36	0.35	1.55	0.20	0.57	0.89
T4	2.72	0.38	1.18	0.17	0.44	0.99
$T4_A$	2.63	0.29	1.30	0.16	0.53	0.68
T5	2.49	0.29	1.22	0.14	0.41	0.58
$T5_A$	2.39	0.27	1.48	0.15	0.52	0.87
Significance	***	N.S.	***	N.S.	N.S	***
L.S.D	0.41		0.42			0.20

Table 10. Analysis of plant tops and roots, September 1976, Experiment (I).

Treatment	Tops	(%)					Roots	(%)			
	N	P	K	S	Ca	NO_3	N	P	K	S	Ca
To	0.93	0.24	1.51	0.09	0.58	0.46	0.69	0.66	0.91	0.11	0.74
To_A	0.89	0.25	1.74	0.09	0.46	0.19					
T1	1.47	0.30	2.25	0.11	0.40	0.47					
$\mathrm{T1}_A$	1.40	0.29	1.98	0.10	0.45	0.37					
T2	2.61	0.28	2.20	0.12	0.52	0.40	0.82	0.68	0.69	0.11	0.83
$\mathrm{T2}_A$	2.76	0.31	2.55	0.17	0.52	0.53					
T3	1.63	0.22	1.44	0.09	0.45	0.16					
$\mathrm{T3}_A$	1.56	0.23	1.44	0.11	0.44	0.13					
T4	1.38	0.21	1.43	0.14	0.53	0.12	0.84	0.73	0.61	0.09	0.81
$\mathrm{T4}_A$	1.94	0.24	1.69	0.10	0.43	0.24					
T5	1.80	0.29	2.04	0.09	0.47	0.22	0.85	0.65	0.57	0.11	0.70
$\mathrm{T5}_A$	1.99	0.30	2.10	0.15	0.49	0.43					
Significance	***	*	**	N.S.	N.S.	N.S.	(*)	N.S.	N.S.	N.S.	N.S.
L.S.D.	0.76	0.06	0.69				0.18				

Table 11. Total uptake of nutrients by plant tops and roots, Experiment (I), 1976.

Treatment	Tops (Kg/ha)										Roots (Kg/ha)				
	June 1976					Sept. 1976									
	N	P	K	S	Ca	N	P	K	S	Ca	N	P	K	S	Ca
To	11	2	10	0.9	3	22	6	36	2.2	14	119	114	157	19	128
To$_A$	17	3	13	1.0	4	28	8	56	2.9	15					
T1	14	3	16	1.3	4	55	11	85	4.1	15					
T1$_A$	24	4	22	1.9	7	52	11	73	3.7	17					
T2	20	3	10	1.3	4	101	11	85	4.6	20	130	108	109	17	132
T2$_A$	24	4	20	1.5	5	101	11	93	6.2	19					
T3	23	3	17	2.0	5	42	6	37	2.3	12					
T3$_A$	40	6	26	3.4	10	45	7	42	3.2	10					
T4	26	4	11	1.6	4	44	7	46	4.5	17	115	100	84	12	111
T4$_A$	44	5	22	2.7	9	59	7	51	3.0	13					
T5	20	2	10	1.1	3	68	11	77	3.4	18	132	101	88	17	109
T5$_A$	32	4	20	2.0	7	80	12	85	6.0	20					

Results are means of three replicates

Root material from the three depths of each treatment studied was combined and analyzed as a composite sample. The results are presented in Table 10.

The nitrogen content of roots from treatment To (0.69%N), which was unfertilized was significantly lower (significant at the 2.5% level in an unpaired t-test) than treatments T2, T4 and T5 (0.82 to 0.85 percent N). Treatment T2 had been fertilized in 1975 and 1976 (see Tables 2 and 3). Treatments T4 and T5 had only received fertilizer in 1975. The nitrogen contents of the root tissues were substantially lower than in the tops (average 0.80%N in the roots to 1.70%N in the tops).

The phosphorus content of the root material was higher than that recorded for the top material (0.65 percent to 0.73 percent, roots; 0.21 percent to 0.45 percent, tops). No significant differences could be found between the different treatments.

The average root potassium content for treatment To was greater (0.91%K) than with treatments T2, T4 and T5 (0.57 to 0.69 %K). However, the variation between replicates was so great that the difference was not statistically significant. The potassium content of root tissues was about one half that found in the above-ground material.

The total sulfur content of roots was similar for all the treatments analyzed (0.09 to 0.11 percent S) and was generally lower than had been found for the shoot tissues.

Calcium contents were rather variable and the average values showed no significant differences between treatments. Root concentrations varied between 0.70 percent and 0.83 percent Ca. They were a little higher than was found for the tops.

It is difficult to discuss the value of different fertilizer treatments in a quantitative way. The experimental area has only been studied in detail since 1975. Before this date the vegetated area had received several small additions of fertilizer. The residual effect of these fertilizers applied during the 1971-1974 period is not known. Furthermore a complete balance sheet of fertilizer use could only be drawn up if isotopically labelled fertilizers had been used. However, some general comments may be made.

Heavier fertilization increases the growth of Brome Grass at the expense of Creeping Red Fescue. The latter grass produces a dense mass of litter which has indirectly resulted in problems such as tree and shrub damage due to infestation by mice. Brome Grass does not produce such a dense surface mat and provides a less favorable habitat for rodents.

The information given below gives a very rough approximation of the partitioning of nitrogen in different treatments that were studied in more detail in 1976. Again the approximate nature of any interpretations made with such data in respect to fertilizer use should be stressed.

Treatment	Nitrogen added		Nitrogen in soil*		Nitrogen in plants**	
	1971/74	1975/6	Available	Total	Tops	Roots
	(Kg/ha)		(Kg/ha)		(Kg/ha)	
To	222	0	25	1035	22	119
T2	222	143	22	1680	101	130
T4	222	143	33	1185	44	115
T5	222	67	51	1075	68	132

* Total nitrogen includes ammonium nitrogen and root nitrogen. Available nitrogen was calculated from the mineral nitrogen present to a depth of 30 cm in September 1976.

** All values are for September, 1976. Tops refer to live material only.

This indicates that a considerable amount of potentially available nitrogen occurs in the total nitrogen component. This includes a relatively small amount of labile material such as the so called 'active fraction' of soil humus, dead microbial cells, dead root tissues, metabolic by-products of microbial metabolism, root exudates etc. as well as a larger component comprising the more resistant soil humic compounds. Even if only 1-2% is mineralized each season, some 200-300 Kg-N/ha would be released, of which, maybe 25-40% could be potentially available to plants.

If we consider the 'unfertilized' treatment T0 as the baseline, we can make some approximate calculations from the 1976 data. If we assume an approximately 1:1 root to shoot production during 1976 then, using the data in Table 10, we find that 16 Kg-N/ha were taken up into roots and 22 Kg-N/ha into tops with treatment T0. If by a similar analogy we look at the other treatments using this as a baseline, we may estimate the fertilizer uptake in other treatments T2, T4 and T5. Treatment T2, which received 71.5 Kg-N/ha in both 1975 and 1976 had 81 Kg-N/ha in top material (i.e. 101-22 Kg-N/ha) and about 25 Kg-N/ha in the roots. This indicates an uptake of approximately 106 Kg-N/ha from an addition of 143 Kg-N/ha over two years. It would appear that some mineralization of fertilizer added 1975 and taken up into the plant tissues has already occurred.

With treatment T4, 143 Kg-N/ha were added as fertilizer in 1975 but none was added in 1976. Much poorer use of the residual fertilizer seems to have occurred. Only 22 Kg-N/ha occurs in the tops and about 13 Kg-N/ha in the roots from the addition of fertilizer.

In treatment T5, 33.5 Kg-N/acre was added in both 1975 and 1976. In 1976 a total fertilizer uptake of 67 Kg-N/ha seems to have occurred. This is made up of 46 Kg-N/ha in the tops (68-22 Kg-N/ha) and about 21 Kg-N/ha in the new root tissues. This again seems to emphasize the efficient use of smaller yearly additions of fertilizer.

All these values are of course very approximate and involved several assumptions, many of which may not be totally valid.

2.6 Summary Conclusions

(1) The peat soil surface seemed to be able to prevent the rapid acidification of the soil by sulfur dioxide. Soil pH values were still well within the range tolerated by most plants. The liming carried out in 1975 and caused an increase in pH of about one half pH unit at the surface.

Samples that were taken in September had lower surface pH values in comparison to the June samples. The first set of soil samples taken in 1977 should indicate whether this is a general acidifying trend or just a result of leaching reactions during the summer.

(2) Soluble sodium contents were low. There was no evidence for the buildup of salts at the surface in this area on the dike. Conductivity values were always well below those expected to affect the growth of plants.

(3) Available N, P, K and S were present in moderate amounts in the soil in June. Levels of mineral nitrogen were low in September. Nutrient

deficiency symptoms of N and sometimes P and K were evident during the summer.

Nutritional problems seem to stem from the fact that most available nutrients are restricted to the surface peat layer. Root penetration below the peat into this nutritionally poor zone is quite poor.

(4) Percentage moisture contents were always greater in the peat layer. However, the values recorded in the tailings sand below indicate that some available water is present. Moisture is probably not the main factor limiting root growth here.

(5) The relationship between the growth of Creeping Red Fescue and Brome Grass and fertilizer addition was again noted this year. The side of the split plot that had received additional fertilizer had a higher percent cover by Brome Grass than the opposite side of the plot. Generally the best spread and growth of Brome Grass relative to Creeping Red Fescue occurred at the higher fertilizer rates.

(6) Good production of above ground plant biomass early in the year was promoted by a late application of fertilizer the previous summer. Continued growth during the rest of the year was favored by fertilization in June 1976. The response in 1976 to large applications of fertilizer the previous year was not as marked as may have been anticipated. It is important to determine whether this is due to the rapid leaching characteristic of the soils, to slow mineralization or to other causes.

(7) The accumulation of root tissues was very noticeable on this part of the dike. Dry weight ratios of root:shoot varied from about 4 to 7. It was assumed that root turnover was slower than the decomposition of the above ground parts of the plants.

(8) In general the nutrient quality of early plant growth was greater than towards the end of the year. This was most noticeable with treatments that did not receive fertilization in 1976.

(9) Plot erosion was very slight in 1976.

A more general discussion of the whole revegetation project is given in section 6.

3. REVEGETATION STUDY ON A TAILINGS SAND DIKE AT FORT MCMURRAY, ALBERTA INVOLVING DIFFERENT SOIL AND FERTILIZER AMENDMENTS. - EXPERIMENT (II)

3.1 Introduction

The field experiment that was started last year provided useful information in relation to the improvement of plant cover on previously vegetated areas of a tailings sand dike. However, since the area studied had been revegetated for several years, the results may not be directly applicable to revegetation of bare slopes.

The laboratory and growth chamber studies in 1975 provided some basic information concerning the chemical and biological characteristics of various soil mixes that might be helpful in designing field experiments in 1976. The basic objectives of the experiments were to be:

(i) to study the effectiveness of different surface amendments in establishing plant growth

(ii) to determine the effectiveness of different fertilizer programs in relation to rates and relative amounts of different nutrient elements added

(iii)to study the establishment of legumes on the slope

(iv) to investigate ways of encouraging deeper rooting through incorporation of surface soil amendments or by placement of fertilizers

(v) to study ways of reducing erosion of surface applied materials and fertilizer amendments

The most desirable way to meet these objectives would have been through the establishment of several small experiments with each one studying one objective in detail. However, the constraints of time and finance made some compromises necessary. Two experiments were designed (Experiment II and Experiment III) to look at different problem areas. The objectives were also modified somewhat. For instance, it was not possible to study each nutrient element separately in the fertilizer mixes used. Instead only high, medium and low rates were studied separately. Also, legumes were studied in a seed mix which contained both legumes and grasses. In general terms, Experiment (II) was concerned with surface and fertilizer amendments while Experiment (III) involved deep rooting studies. The latter experiment is described separately in Section 4. The location of each experiment at the G.C.O.S. site is shown in Figure 2.

3.2 Objectives

The modified objectives of Experiment (II) are as follows:

(i) to examine the effectiveness of different fertilizer applications rates from the standpoint of primary productivity.

(ii) to examine ways of reducing erosion by surface amendments,

(iii)to evaluate ways of examining soil/plant systems to predict the probable state of permanence of the system. Only baseline parameters were measured this year.

(iv) to study the performance of different plant species with special reference to legumes.

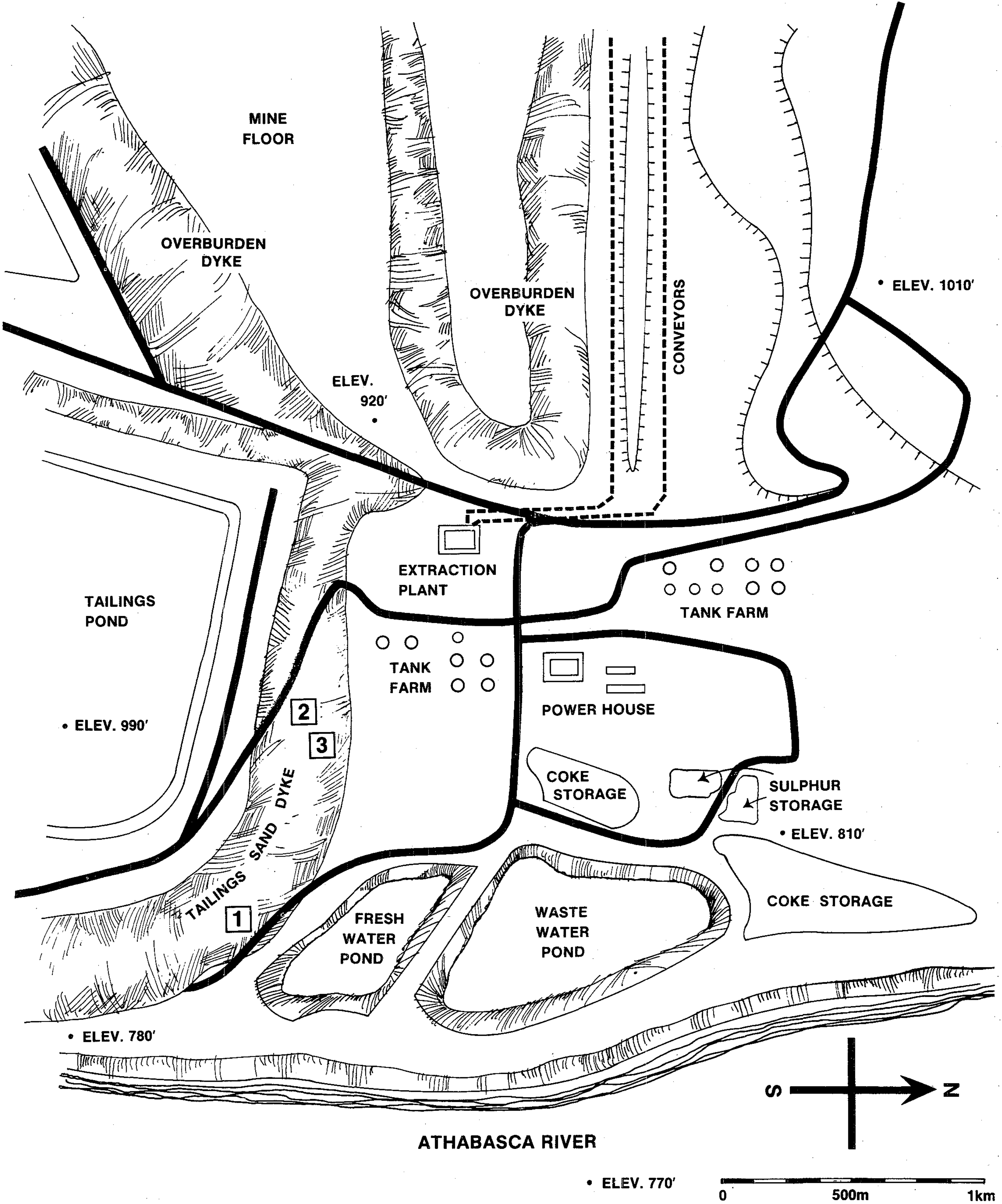


FIGURE 2. Location of experimental areas at the G.C.O.S. plant site

3.3 Experimental Design

The experiment was set up as a randomized block design with each individual treatment replicated three times. Three main treatments were related to different fertilizer rates. The eight sub-treatments were related to surface variables such as soil material amendments, soil conditioners and physical manipulations. A description of each treatment is given below.

Main Treatments (3)

A. 80 Kg-N/ha (23.3 Kg NO_3-N/ha; 56.7 Kg NH_4-N/ha)
35 Kg-P/ha
75 Kg-K/ha
20 Kg-S/ha
Applied in June as 21-0-0, 34-0-0, 11-55-0 and 0-0-62.

B. 150 Kg-N/ha (58.3 Kg NO_3-N/ha; 91.7 Kg NH_4-N/ha)
40 Kg-P/ha
150 Kg-K/ha
20 Kg-S/ha
Applied in June as above.
Lime 5 Tonnes/ha

C. Fertilizer mix as described for B; applied in June and August with no lime added in August.

Sub-Treatments (8)

1. Peat tilled to a depth of 15 cm.
2. Peat tilled to a depth of 15 cm. with contour trenches

constructed across the plot.

3. Peat tilled to a depth of 15 cm with "Aquatain" soil stabilizer added to the soil surface.

4. Peat tilled to a depth of 15 cm with "Bitumuls" soil stabilizer added to the soil surface.

5. Overburden added at a rate of 750 tonnes/ha (about 5 cm) onto the surface of applied peat.

6. Overburden added at a rate of 1500 tonnes/ha (about 10 cm) tilled into the surface 15 cm of peat and tailings sand.

7. Overburden added at a rate of 750 tonnes/ha tilled into the surface 15 cm of peat and tailings sand.

8. Peat tilled into a depth of 15 cm (i.e., as treatment 1) but not seeded until October 1976.

Plot Size: 5 m x 4 m

Replication: 3

Total number of plots: 72

A plan of the experimental area is shown in Figure 3. In addition to these basic treatments, runoff collectors were set up on main treatment C and double pail lysimeters were installed on all plots except sub-treatments 2 and 8. These are described more fully in the following section.

3.4 Plot Establishment

3.4.1 Soil Material Amendments

The surface peat amendment had already been spread onto the experimental area by G.C.O.S. before the site was surveyed and staked out. There was considerable variability in the depth of peat over the region. The depth

Figure 3. Field plan of experiment on an unvegetated area on a tailings sand dike at the GCOS plant site at Fort McMurray, Alberta (Experiment [II]).

Top of slope

B	2	1	6	3	7	8	5	4
A	7	1	5	4	2	6	8	3
C	8	3	5	1	6	7	2	4

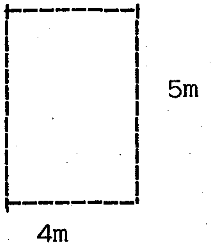
Replicate 3

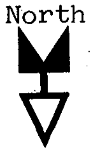
A	5	2	8	3	4	7	1	6
C	7	6	1	3	2	4	5	8
B	1	6	4	5	8	2	3	7

Replicate 2

C	7	2	3	6	1	4	5	8
B	4	5	6	2	3	8	7	1
A	8	6	7	3	4	2	1	5

Replicate 1





(slope 23-30°)

varied from as much as 25 cm on parts of replicate 3 to less than 7 cm on parts of replicate 1. Where there was not enough peat, extra was added from a stockpile on the berm at the top of the plot. This peat was not identical to that already added to the plot. No attempt was made to remove peat from plots that had over the intended 15 cm depth of peat.

Mine overburden was delivered to the top of the plot area by G.C.O.S. personnel. It was carried to the designated plots by wheelbarrow and spread evenly by raking. The overburden was not graded and the lumps varied in size up to 30 cm in diameter. However, after rainfall the overburden swelled up slightly and the larger particles broke down quite readily when they dried out again. When the overburden and extra peat had been added the soil amendments were tilled into the surface to a depth of about 15 cm. This phase was started on the 23rd of June and was completed by the 28th of June.

3.4.2. Lime and Fertilizer Addition

Lime and fertilizer were weighed out separately, for each plot. Lime was added by manual spreading and was then incorporated into the surface 5 to 8 cm by raking

Plate 2 shows the experimental area after lime has been spread onto the surface of treatments B and C. Treatment A was not limed.

Fertilizer was broadcast onto each plot and as with the lime, the material was mixed into the surface 5 to 8 cm by raking.

3.4.3 Installation of Runoff Collectors

The runoff collectors were fairly similar in design to those used in Experiment (I) in 1975. The top of the plot was boarded off to prevent runoff water from the areas above from being collected. Two boards were joined together to form a "V" shape to that the mouth formed was exactly one meter across. The boards were sunk about 8 cm into the ground.

The apex of the "V" was located such that it collected from a five meter length of slope. At the apex, a polyethylene funnel was buried so that the mouth was flush with the soil surface. A fine mesh screen was glued into the mouth of the funnel to prevent soil from passing into the reservoir. A closed five gallon plastic bucket was used as the reservoir to store the runoff water collected. It was connected to the funnel by polythene tubing and was buried deep enough to allow water to run in freely under gravity. In all 21 traps were set up. They were located on treatments 1C, 2C, 3C, 4C, 5C, 6C, and 7C. On one of the plot roadways, another five gallon container was set up to collect rainwater. Plate 2 shows the experimental area when all the runoff collectors had been set up.

3.4.4 Double Pail Lysimeters

A set of so called "double pail" lysimeters were set up on the plot to study the fate of nutrients added to the soil. In this study, the degree of control over the experimental treatments applied could be much more precise in comparison to those on the main plot area. On the main plot, control over the addition of peat was particularly poor. Also investigation of nutrient leaching could be studied in greater detail using lysimeters.

In all, 54 lysimeters were installed. Treatments 1, 3, 4, 5, 6 of all the fertilizer treatments were studied. These treatments are generally similar to those bearing the same number on the main plot. They do, however, reflect the original intention of the experimental design which was that peat would not be added as a layer over the entire plot. A description of each treatment is given below.

Main Treatments (3)

A,B and C as described before.

Sub-Treatments (6)

1. Filled to within 15 cm of the top with tailings sand. Top 15 cm is a mixture of peat and tailings and in a 1:1 v/v ratio.
2. As treatment 1, with "Aquatain" soil stabilizer.
3. As treatment 1, with "Bitumuls" soil stabilizer.
4. Filled with tailings sand to within 7.5 cm of the top and a layer of overburden 7.5 cm in depth placed on the surface.
5. Tailings sand to within 20 cm of the surface. A mixture of overburden and tailings sand in a 3:1 v/v ratio placed on to a depth of 20 cm.
6. Tailings sand to a depth of 15 cm from the surface.

Replication: 3

Total Number of Lysimeters: 54

Figure 4 shows how the lysimeters were installed. The lower pail was buried flush with the soil surface in the bottom western corner of the plot. Here it would not interfere with runoff collection or plant and soil sampling. About 20 small holes were drilled in the bottom of the top pail to allow drainage water to percolate freely out of the bucket. The pails were filled to their respective depths with tailings sand taken from the bottom of the plot area from a depth of 15 cm to 45 cm. The various surface mixes were prepared in large batches and added to the pail and were carefully packed. After the pail had been filled with the correct soil mix

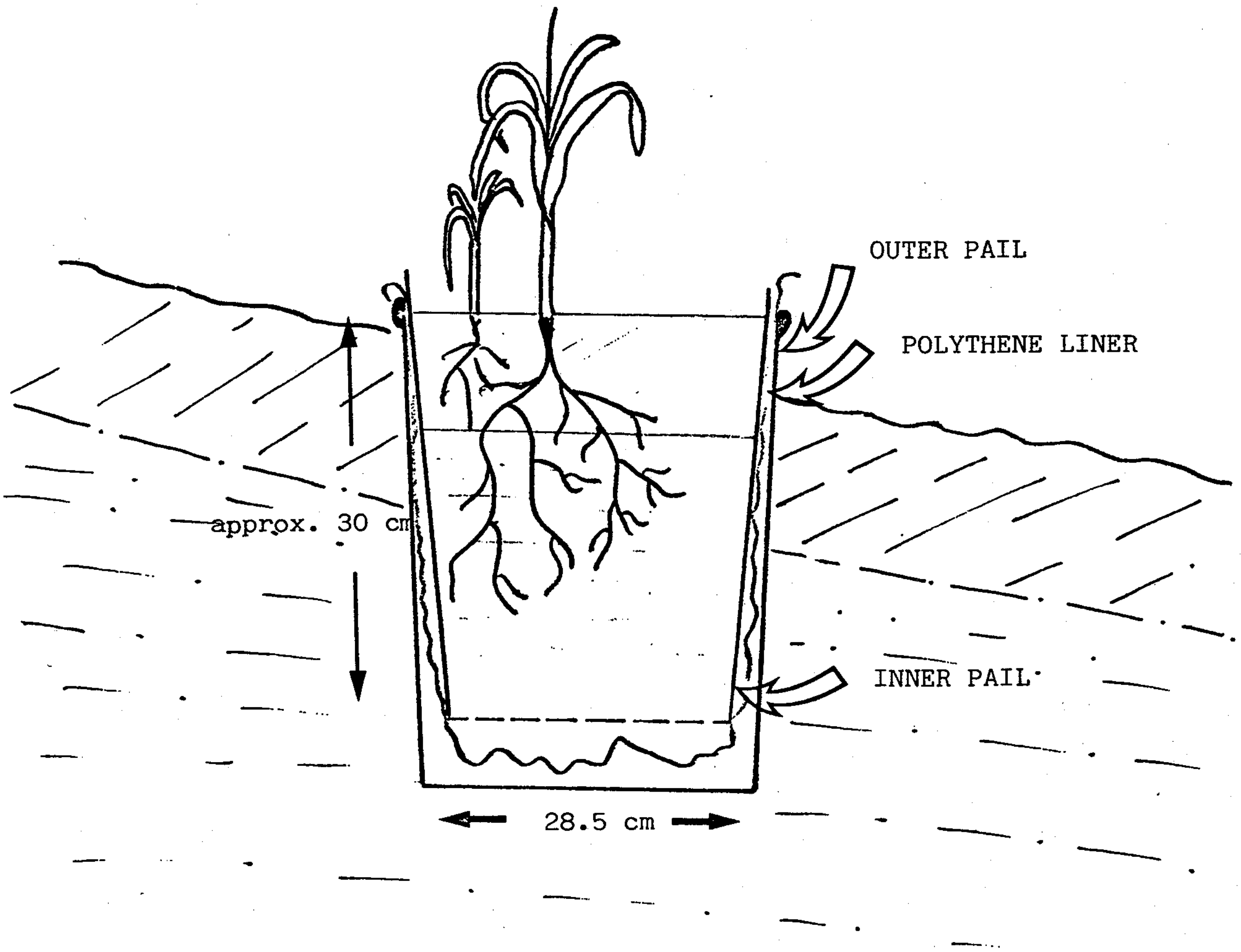


Figure 4. Diagram of lysimeter located on plot

a thick polythene bag was placed over the bottom and the bucket carefully lowered into the first pail. The fit was such that no surface runoff or soil could seep into the polythene liner. To collect the runoff water, the top pail was removed and the polythene liner replaced with a new one.

Lysimeters were seeded at the same time as the rest of the experimental area. Fertilizers were broadcast onto the surface, just after the lysimeter was installed in the ground. Seed and fertilizer were prepared separately for each lysimeter. An exact number of seeds were added corresponding to the same rate which was used with the main plot. The seed mix used is given below.

	SEEDS/PAIL
Altai Wild Rye	2
Streambank Wheat Grass	14
Smooth Brome	13
Hard Fescue	13
Pubescent Wheat Grass	11
Red Top	10
Canada Blue Grass	16
Kentucky Blue Grass	16
Lupine	1
Cicer Milk Vetch	5
Sanfoin	1
Alfalfa Rhizoma	7
Pendek Oats	7
Western Wheat Grass	10

The seeds were broadcast onto the surface and packed down by hand.

3.4.5 Trenching and Addition of Stabilizers

The contour trenches for treatment 2 were dug just after the lime and fertilizers had been added. Two trenches were dug across the plot about 30 cm deep and 45 cm wide. The spoil material dug from the trenches was scattered evenly over the surface of the plot. After seed was added, the area was rolled carefully. However, due to the danger of caving in the trenches, this process could not be carried out as well as on the other plots.

Aquatain soil stabilizer was added to treatment 3 while Bitumuls stabilizer was added to treatment 4. Both conditioners were added using a watering can.

Aquatain is a liquid adhesive mulch produced by United Stabilization Chemicals Ltd., and distributed through United International Industries Ltd., of Calgary. It is claimed to be useful in holding seeds on steep sloped areas and to afford protection against wind and water erosion. Aquatain forms a gelatinous film over the ground which eventually shrinks to leave a network of open pores which allow the penetration of air and water while at the same time reducing evaporation. Aquatain was added at the recommended rate of 1 lb per 1,700 square feet per 50 gallons of water (28.7 Kg/ha/227 litres).

Bitumuls was added undiluted at the recommended rate of 1.2 gallons per square yard (6.5 litres/m^2). Bitumuls is produced by Chevron Asphalt Limited. It is an asphalt emulsion that is non-toxic to grasses and other plants. It is designed to produce an adhesive bond with surface mulches and assist in conserving soil moisture by reducing evaporation.

3.4.6 Main Plot Seeding

When all the surface amendments, lime and fertilizer had been added, the seed mix was broadcast onto each plot surface. The composition of the seed mix, which was supplied by Buckerfields Ltd. of Vancouver, is given below:

	Percent by Weight
Altai Wild Rye	3.5
Streambank Wheat Grass	15.0
Smooth Brome	16.0
Hard Fescue	3.0
Pubescent Wheat Grass	14.0
Slender Wheat Grass	12.0
Red Top	0.5
Canada Blue Grass	1.0
Kentucky Blue Grass	1.5
Lupine	8.0
Cicer Milk Vetch	6.0
Sanfoin	10.0
Alfalfa Rhizoma	6.0
Western Wheat Grass	3.5

The grass/legume mix was added at a rate of 50 Kg/ha together with 40 Kg/ha of Pendek Oats as a nurse crop. All the grasses and legumes supplied had a viability of over 90 percent and germinated within two weeks under laboratory conditions.

After the seed was broadcast, it was gently raked into the soil surface and packed down with a 50 Kg roller. Seeding was concluded on July 16.

3.5 Work Plan

Soil samples were taken immediately after the soil amendments (peat and overburden) had been added and incorporated.

All soil samples were taken with Oakfield hand samplers. For the surface samples about 12 cores were taken from each plot. Due to the non-uniform addition of peat, each plot was sampled to a depth of 30 cm to show the extent of surface variability. The sub-surface was assumed to be more uniform. Each main treatment was sampled from 30 cm to 120 cm by bulking two individual cores from each plot. In this way, any gross differences in the tailings sand below the peat and overburden layers would become evident.

Collections of water from the lysimeters and runoff reservoirs were made throughout the summer. Four collections in all were taken between July and September.

During the early growth period, quantitative measurements of germination rate and plant height were made.

Extra fertilizer was added to treatment C on the main plot experiment during August 25 and 26. At this time, plant growth in the lysimeters was not as well advanced as on the main plot area and it was decided that no extra fertilizer would be added.

The main plot was not sampled again until September when plant and soil samples were taken.

A complete set of soil samples to 120 cm in depth was taken from all plots except treatment 8 (fall seeded). Meter square areas were clipped by hand to assess plant productivity. On selected plots (1A, 1C, 4C, 5C and 6C) oats, grasses and legumes were harvested separately.

During October, the lysimeters were sampled. No plant samples were taken. Two soil cores were taken from each pail and bulked to give one sample for the 0-15 cm depth and another from 15 cm to the bottom (about 30 cm in depth).

Treatment 8 was fertilized and seeded in October.

3.6 Results

3.6.1 Soil Samples

(a) July 8-9, 1976

Table 12 shows the results of analysis of the soil samples that were taken after the peat and overburden had been incorporated.

Surface moisture contents were variable and were largely dependent upon the amount of peat that had been incorporated into the surface of the tailings sand. At this stage, the moisture contents of the different treatments which included overburden were not significantly different from non-overburden treatments.

In view of the fact that the surface 15 cm was primarily peaty in nature the available moisture contents were moderately low at this time. However moisture was not low enough to retard germination. At greater depth (30-120 cm) within the pure tailings sand layers, the moisture content varied between 4.5 and 6.3 percent.

Table 12. Analysis of soil samples from an unvegetated tailings sand dike at the G.C.O.S. plant site at Fort McMurray, Alberta, July 8, 1976 (Experiment [II]).

		pH	Cond.	H_2O	Mineral nitrogen		P	K	SO_4-S	NH_4OAc Extract.			T.E.C	Org. C	Tot. N
			mmhos/cm	%	NH_4-N	NO_3-N	ppm			Na	Ca	Mg	meq/100g	%	%
					ppm					ppm					
1-A	0-15 cm	6.62	0.54	16.2	15.8	3.7	1.9	12	37.2	17.2	1854	186	9.4	1.96	0.12
	15-30 cm	7.35	0.35	4.9	10.4	0.3	2.7	7	13.9	12.7	263	47	1.1	0.96	0.02
2-A	0-15 cm	6.32	0.88	45.0	35.9	20.6	0.4	25	45.6	27.5	4302	456	27.3	7.20	0.33
	15-30 cm	7.10	0.55	8.4	27.4	1.5	3.2	9	24.8	24.0	819	87	3.5	1.12	0.05
3-A	0-15 cm	6.57	0.97	46.2	13.1	13.7	1.6	21	93.9	26.1	3386	319	13.3	6.13	0.28
	15-30 cm	7.28	0.59	12.7	11.9	2.7	2.9	10	19.6	7.7	1267	128	5.2	1.39	0.10
4-A	0-15 cm	6.57	0.78	47.1	19.2	14.7	0.9	18	137	51.2	3104	371	24.9	9.49	0.20
	15-30 cm	7.42	0.50	15.3	10.0	2.7	2.7	12	27.2	10.2	2237	145	6.5	1.48	0.05
5-A	0-15 cm	6.82	1.47	36.5	24.9	15.3	1.6	93	164	51.7	2277	421	19.8	6.17	0.18
	15-30 cm	7.22	0.90	11.9	14.3	2.0	2.4	12	57.9	27.8	1348	144	6.4	2.35	0.07
6-A	0-15 cm	7.12	1.54	26.0	20.6	10.2	2.4	65	164	53.3	2917	377	15.0	4.70	0.15
	15-30 cm	7.25	0.62	9.7	21.3	0.6	4.4	13	21.1	20.5	910	106	3.9	1.16	0.07
7-A	0-15 cm	6.97	1.36	25.6	19.4	9.0	2.4	64	114	44.6	3333	377	16.6	5.65	0.22
	15-30 cm	6.90	0.45	13.6	16.6	0.8	3.5	16	16.1	28.2	1209	156	7.6	1.79	0.06
8-A	0-15 cm	6.58	0.71	31.1	23.6	10.7	1.3	42	75.1	20.6	3021	277	16.0	5.69	0.20
	15-30 cm	7.30	0.46	10.2	14.5	0.8	3.8	12	17.2	10.2	944	93	3.5	1.29	0.04
Comp	30-60 cm	7.88	0.42	5.2	14.7	0.1	0.6	6	18.7						
	60-90 cm	7.92	0.47	4.5	12.7	0.0	1.3	6	11.6						
	90-120 cm	7.47	0.46	5.4	7.9	0.0	1.1	6	14.3						
Significance		N.S.	***	N.S.	N.S.	N.S.	N.S.	**	N.S.	N.S.					
L.S.D			0.47					46							

Statistics are for the 0-15 cm. depth only.

Table 12. .... Continued)

		pH	Cond.	H_2O	Mineral nitrogen		P	K	SO_4-S	NH_4OAc Extract.			T.E.C.	Org. C	Tot. N
			mmhos/cm	%	NH_4-N	NO_3-N				Na	Ca	Mg	meq/100g	%	%
					ppm		ppm			ppm					
1-B	0-15 cm	6.44	0.83	32.5	28.2	17.6	0.5	30	117	36.9	4260	421	23.1	11.38	0.26
	15-30 cm	7.12	0.41	7.0	12.0	0.4	3.2	9	9.3	16.8	686	68	2.3	0.89	0.04
2-B	0-15 cm	6.77	0.62	32.0	10.7	2.2	3.3	24	55.9	31.1	2573	302	15.2	7.28	0.18
	15-30 cm	7.22	0.40	7.0	8.1	0.1	2.8	8	8.8	16.6	323	52	1.2	0.68	0.02
3-B	0-15 cm	6.88	0.88	28.4	16.7	8.5	2.1	21	147	42.1	2344	277	12.7	4.67	0.05
	15-30 cm	7.40	0.45	7.9	10.1	0.3	1.6	12	10.4	26.0	415	58	1.8	0.89	0.02
4-B	0-15 cm	6.47	0.69	39.9	21.5	16.4	0.4	19	79.2	32.5	3344	338	21.9	7.85	0.22
	15-30 cm	7.25	0.39	9.8	13.1	1.3	1.6	10	11.9	26.9	1025	99	4.1	1.40	0.07
5-B	0-15 cm	6.98	2.01	35.1	35.6	16.7	0.7	128	221	67.7	3917	492	19.0	5.68	0.17
	15-30 cm	7.02	0.56	17.7	19.3	2.8	1.3	17	28.3	29.4	1765	175	8.0	3.14	0.07
6-B	0-15 cm	6.80	1.69	32.4	30.4	19.2	0.8	182	233	74.2	4584	567	21.2	8.19	0.15
	15-30 cm	6.87	0.54	9.2	12.8	1.3	2.1	15	21.6	14.1	1031	111	4.3	1.61	0.03
7-B	0-15 cm	7.30	1.02	17.7	50.5	7.8	1.9	41	74.5	29.4	2354	288	12.2	4.80	0.14
	15-30 cm	7.62	0.51	7.8	17.8	0.2	2.2	10	12.3	7.6	694	89	2.6	1.14	0.03
8-B	0-15 cm	6.38	0.72	32.2	27.8	13.3	0.8	19	87.1	28.6	2802	279	18.9	10.53	0.22
	15-30 cm	7.47	0.44	14.2	11.7	0.8	1.4	15	14.0	15.8	1344	134	5.5	1.61	0.06
Comp	30-60 cm	7.70	0.42	4.8	11.0	0.0	0.5	5	9.7						
	60-90 cm	7.95	0.46	6.3	11.7	0.0	0.9	6	19.6						
	90-120 cm	7.85	0.43	4.7	10.1	0.1	0.7	6	12.8						
Significance		N.S.	***	N.S.	N.S.	N.S.	**	***	N.S.	N.S.					
L.S.D.			0.44				1.6	79							

Table 12. .... Continued)

		pH	Cond.	H_2O	Mineral nitrogen		P	K	SO_4-S	NH_4OAc Extract			T.E.C.	Org.C	Tot.N
			mmhos/cm	%	NH_4-N	NO_3-N				Na	Ca	Mg	meq/100g	%	%
					ppm		ppm			ppm					
1-C	0-15 cm	6.57	0.82	41.5	58.4	8.1	1.6	31	61.2	25.9	2573	244	13.7	5.89	0.18
	15-30 cm	7.30	0.59	12.5	28.7	1.8	2.1	12	22.7	17.9	925	86	3.8	1.28	0.04
2-C	0-15 cm	6.30	0.76	41.0	25.3	17.2	1.8	25	106	31.7	3917	360	25.2	10.10	0.28
	15-30 cm	7.03	0.55	9.6	8.1	1.7	2.3	12	22.1	30.4	1054	101	4.6	1.67	0.08
3-C	0-15 cm	6.62	0.74	46.8	92.5	11.7	1.4	21	59.6	21.7	3292	307	19.0	7.26	0.23
	15-30 cm	7.18	0.56	7.9	23.9	1.3	2.5	12	14.9	18.5	779	85	3.6	1.38	0.07
4-C	0-15 cm	6.50	0.71	29.9	13.0	8.2	0.8	20	85.3	29.8	3209	309	17.9	4.40	0.15
	15-30 cm	7.15	0.65	9.1	13.0	1.9	2.2	20	34.5	25.6	806	95	3.2	1.25	0.07
5-C	0-15 cm	7.25	1.52	18.4	26.0	9.1	2.6	73	106	58.4	2167	267	10.6	2.13	0.13
	15-30 cm	7.30	0.57	8.8	15.7	2.5	2.2	13	16.9	30.0	790	88	3.8	1.94	0.07
6-C	0-15 cm	6.87	1.56	27.5	18.5	13.6	1.4	89	163	52.5	3219	358	18.4	6.77	0.19
	15-30 cm	7.15	0.72	16.6	14.3	3.4	1.7	35	32.7	20.2	1844	180	9.1	3.14	0.09
7-C	0-15 cm	6.72	1.12	37.6	11.8	8.6	1.2	106	112	38.8	3427	386	19.5	6.91	0.27
	15-30 cm	7.38	0.71	11.2	8.7	1.5	2.0	16	26.3	17.1	1144	118	4.8	1.72	0.07
8-C	0-15 cm	6.68	0.66	34.5	12.3	5.6	1.8	18	45.2	17.9	2333	235	12.4	3.68	0.15
	15-30 cm	7.53	0.45	7.7	8.9	0.3	2.0	11	11.2	15.4	400	66	1.9	0.92	0.03
Comp	30-60 cm	8.00	0.41	5.3	7.7	0.4	2.6	8	16.1						
	60-90 cm	7.73	0.45	4.8	6.9	0.3	2.3	7	14.9						
	90-120 cm	7.58	0.46	5.6	7.6	0.0	2.5	8	13.6						
Significance		N.S.	***	N.S.	N.S.	N.S.	N.S.	**	N.S.	***					
L.S.D.			0.34					54		18.9					

Statistics are for the 0-15 cm. depth only - for complete analysis see Appendix

Surface pH values ranged from neutral to slightly acidic. Treatments which involved incorporation of overburden materials (treatments 5,6 and 7) were generally slightly less acidic than other treatments. No obvious discontinuity in surface pH was evident over the experimental area. With increasing depth, the soil became gradually more alkaline. The pH of the 15-30 cm depth was generally between pH 7.0 and 7.5, while from 30 cm to 120 cm values between 7.47 and 8.00 were recorded.

The presence of mine overburden increased the conductivity (salt content) of the soil. A maximum value of 2.01 mmhos/cm was recorded with treatment 5B. This value would not be considered high enough to limit the growth of most plant types. Salt contents below the 30 cm depth were much lower than in the surface and varied from 0.41 to 0.47 mmhos/cm.

As might have been anticipated, some buildup of mineral nitrogen had occurred early in the year. The amounts were moderately variable over the experimental area. Ammonium was generally more abundant than nitrate. The highest concentrations of mineral nitrogen were in the surface 15 cm. Average values varied from 10.7 ppm to 92.5 ppm with NH_4-N and from 2.2 ppm to 20.6 ppm for NO_3-N. Mineral nitrogen levels were much less below the 30 cm depth. Here ammonium-N ranged between 7.7 ppm and 14.7 ppm while nitrate-N values were below 0.4 ppm. Mineral nitrogen was sufficiently high that even without fertilizer the plants could probably initially obtain adequate nitrogen for growth. However, supplies would likely become depleted rapidly.

Available phosphorus was very low in all treatments.

Overburden amended plots (treatments 5, 6 and 7) generally had moderate to good amounts of potentially available potassium in the surface 15 cm. The lowest amounts were normally found with treatment 7 where a low amount of overburden was tilled in with the peat. The other treatments, that contained only peat as the surface amendment, had much lower concentrations of available potassium in the 0-15 cm depth (12.1-31.3 ppm). In all plots, the potassium level declined markedly with depth. Below 30 cm concentrations varied between 5.2 and 8.2 ppm.

Soil sulfate contents over the entire plot were adequate to supply the sulfur requirements of an actively growing vegetative cover. Overburden materials were naturally rich in sulfate. The highest concentrations of sulfate-S occurred in the 0-15 cm depth of treatment 5 (surface applied overburden) and treatment 6 (high rate of overburden tilled in). Sulfate contents in treatment 7 were generally similar to the treatments that had only received amendments of peat. Concentrations over the experimental area varied from 37.2 ppm to 233 ppm SO_4-S in the surface 15 cm. Concentrations in the lower depths were much less but in no case did they drop below a concentration of 8 ppm.

Calcium was the dominant extractable cation. The concentration in the surface 15 cm varied between 1,854 ppm and 4,584 ppm. Concentrations in the 15-30 cm depth were lower.

Magnesium concentrations varied between 186 ppm and 567 ppm in the surface 0-15 cm. Levels in the 15-30 depth were considerably lower.

As had been found in Experiment (I), the concentration of sodium was relatively low. Values were generally higher in the surface 15 cm in comparison to the 15-30 cm depth. Treatments 5, 6 and 7 generally contained higher concentrations of sodium. It seems to be due to the moderately high levels of extractable sodium in the mine overburden material.

The variability in the depth of peat applied to the study area resulted in large differences in exchange capacity, organic carbon and total nitrogen between replicates.

Some generalizations can be made from the results. Most of the total cation exchange capacity of the soil was restricted to the surface 15 cm where most of the added peat and overburden was located. Average values ranged from 9.4 to 27.3 meq/100 g for the 0-15 cm depth. Organic carbon contents were correlated with total exchange capacity (r^2=0.87). This would indicate that most of the soils ability to hold cations is related to the organic constituents. The average organic carbon content for the surface 15 cm varied from 1.96 to 11.38 percent. There was considerable variability between replicates. In general, experimental plots on replicate 1 had a lower organic C content than did either replicate 2 or 3. Similar variability was found with total nitrogen contents. Values in the 0-15 cm depth ranged between 0.05 percent and 0.33 percent.

(b) <u>September 26-28, 1976</u>.

Table 13 shows the analysis of the soil samples taken during September.

Moisture contents in the surface 15 cm in September were not significantly different from those of July for treatment 1, 2, 3, and 4. However for the overburden amended treatments 5, 6 and 7 moisture contents were lower than July. Moisture content of the 15-30 cm depth also seemed to be a little lower than was found in July. It would appear the accumulations of peat at the soil surface reduced evaporation and promoted soil moisture

Table 13. Analysis of soil samples taken September 26-28, 1976 from Experiment II on a tailings sand dike at the G.C.O.S. plant, Fort McMurray, Alberta.

	pH	Cond.	H_2O	Mineral nitrogen		P	K	SO_4-S
		mmhos/cm	%	NH_4-N	NO_3-N			
				ppm		ppm		
1-A 0-15 cm	6.28	0.60	14.2	2.0	0.7	6.7	17	12.5
15-30	6.83	0.46	3.3	1.0	0.5	2.7	6	3.3
30-60	6.93	0.34	4.3	0.7	0.4			
60-90	6.97	0.34	5.0	0.7	0.5			
90-120	7.05	0.35	5.6	0.5	0.2			
2-A 0-15 cm	6.22	0.57	16.4	2.1	4.5	5.4	19	55.8
15-30	6.75	0.51	8.5	1.3	0.9	2.0	8	6.3
30-60	7.30	0.40	5.5	0.3	0.6			
60-90	7.00	0.39	5.4	1.1	0.5			
90-120	6.92	0.40	4.8	0.9	0.0			
3-A 0-15 cm	6.10	0.65	55.7	1.7	4.7	6.2	15	82.0
15-30	6.60	0.64	23.7	1.6	1.5	1.5	8	9.8
30-60	7.18	0.46	9.3	0.9	0.5			
60-90	7.10	0.54	5.4	0.5	0.3			
90-120	6.72	0.43	5.4	1.6	0.5			
4-A 0-15 cm	6.33	0.94	41.7	2.8	4.5	2.9	28	120
15-30	6.73	0.64	14.3	1.9	1.2	1.6	9	72.7
30-60	6.95	0.43	4.5	2.7	0.5			
60-90	6.90	0.47	5.2	1.0	0.4			
90-120	6.77	0.51	6.0	2.0	0.3			
5-A 0-15 cm	6.37	1.24	20.2	4.1	1.3	2.6	81	156
15-30	6.35	0.77	6.1	2.3	0.5	1.5	12	54.3
30-60	7.18	0.49	4.0	1.5	0.3			
60-90	7.08	0.42	4.9	1.2	0.8			
90-120	7.45	0.44	5.3	1.4	0.5			
6-A 0-15 cm	6.95	1.23	11.4	2.2	1.2	5.5	54	135
15-30	6.82	0.66	6.3	1.5	1.3	2.3	13	36.0
30-60	7.22	0.45	3.1	0.3	0.2			
60-90	7.25	0.47	4.5	0.9	0.3			
90-120	6.90	0.54	5.8	1.3	0.4			
7-A 0-15 cm	6.87	1.29	8.7	1.5	0.7	7.3	55	64.9
15-30	7.05	0.64	4.2	1.1	0.6	2.2	11	6.4
30-60	7.33	0.46	3.7	1.0	0.9			
60-90	7.25	0.44	4.9	0.4	0.3			
90-120	7.00	0.44	5.1	1.1	0.3			
Significance	N.S.	(*)	N.S.	N.S.	N.S.	N.S.	*	N.S.
L.S.D.		0.60					42	

Statistics only apply to the 0-15 cm. depth

Table 13. .... Continued)

		pH	Cond.	H_2O	Mineral nitrogen		P	K	SO_4-S
			mmhos/cm	%	NH_4-N	NO_3-N			
					ppm		ppm		
1-B	0-15 cm	7.00	0.68	25.3	2.4	3.7	4.6	25	37.1
	15-30	6.87	0.49	5.0	0.5	0.4	2.0	7	4.4
	30-60	7.02	0.47	5.6	0.5	0.4			
	60-90	7.48	0.39	5.5	0.9	0.6			
	90-120	7.25	0.44	5.1	0.3	0.1			
2-B	0-15 cm	7.52	0.81	30.9	1.2	5.8	1.9	24	154
	15-30	7.10	0.59	13.2	0.9	0.8	2.3	9	111
	30-60	7.33	0.46	4.5	0.2	0.1			
	60-90	7.48	0.39	5.3	0.1	0.3			
	90-120	7.40	0.46	5.9	0.5	0.3			
3-B	0-15 cm	7.03	0.63	17.1	0.8	4.4	3.1	25	69.1
	15-30	7.30	0.44	4.7	0.8	0.1	2.0	7	3.0
	30-60	7.45	0.41	5.2	0.9	0.4			
	60-90	7.18	0.41	5.7	0.1	0.3			
	90-120	7.17	0.51	6.7	0.3	0.3			
4-B	0-15 cm	6.68	0.94	44.2	2.5	5.3	3.0	29	52.7
	15-30	6.85	0.78	16.9	0.3	0.9	1.4	8	12.0
	30-60	7.33	0.55	6.1	0.4	0.1			
	60-90	7.28	0.64	5.3	0.5	0.6			
	90-120	7.48	0.50	5.4	0.1	0.0			
5-B	0-15 cm	6.58	1.73	15.7	3.8	17.3	5.2	120	203
	15-30	6.65	0.85	6.2	1.5	1.4	1.3	9	33.5
	30-60	7.03	0.49	3.5	0.6	0.0			
	60-90	6.80	0.49	4.4	0.7	0.1			
	90-120	7.22	0.58	4.4	0.7	0.6			
6-B	0-15 cm	7.02	1.69	24.7	1.8	13.8	3.4	91	207
	15-30	6.50	1.24	13.5	3.0	3.7	2.1	20	211
	30-60	7.08	0.48	4.1	1.1	0.8			
	60-90	7.33	0.44	4.2	0.7	0.2			
	90-120	7.47	0.46	4.7	3.0	0.6			
7-B	0-15 cm	7.25	1.03	9.8	1.8	2.4	7.1	29	59.2
	15-30	7.40	0.50	3.3	1.1	0.3	1.5	7	3.4
	30-60	7.53	0.43	4.5	0.5	0.2			
	60-90	7.33	0.40	5.0	1.1	0.4			
	90-120	7.73	0.42	5.8	0.9	0.1			
Significance		N.S.	***	N.S.	N.S.	N.S.	N.S.	**	N.S.
L.S.D.			0.58					58	

Statistics only apply to the 0-15 cm. depth

Table 13. ....Continued)

		pH	Cond. mmhos/cm	H_2O %	Mineral nitrogen NH_4-N	NO_3-N	P	K	SO_4-S
					ppm		ppm		
1-C	0-15 cm	6.58	1.75	46.4	3.3	107	13.1	121	172
	15-30	6.60	0.85	7.1	0.4	7.3	2.6	13	8.2
	30-60	6.83	0.53	4.7	0.5	1.8			
	60-90	7.05	0.58	5.3	0.2	2.2			
	90-120	7.18	0.46	5.5	1.0	0.7			
2-C	0-15	6.48	1.54	39.8	1.2	113	20.4	218	41.7
	15-30	6.32	1.05	10.7	1.5	14.3	7.6	19	7.3
	30-60	7.18	0.40	3.6	1.1	0.6			
	60-90	7.13	0.35	4.4	0.3	0.7			
	90-120	7.28	0.47	5.9	1.4	0.8			
3-C	0-15	6.57	1.65	31.1	2.5	121	25.0	136	87.7
	15-30	6.85	0.72	8.4	0.1	6.0	3.7	12	7.6
	30-60	7.45	0.60	6.1	0.5	2.4			
	60-90	7.35	0.44	5.7	1.0	1.5			
	90-120	7.02	0.51	6.0	0.1	0.8			
4-C	0-15 cm	6.98	1.64	12.9	1.9	67.6	12.3	104	120
	15-30	7.27	0.69	6.0	10.2	8.3	4.4	14	57.3
	30-60	7.22	0.46	4.4	0.6	1.8			
	60-90	6.90	0.51	5.2	1.1	1.0			
	90-120	7.35	0.44	5.4	1.8	1.2			
5-C	0-15 cm	6.77	3.00	9.1	12.2	86.3	17.7	180	116
	15-30	6.83	1.13	3.6	1.2	9.2	5.8	18	13.3
	30-60	7.37	0.55	4.4	0.5	2.8			
	60-90	7.07	0.54	4.6	1.4	4.1			
	90-120	7.22	0.49	5.1	1.3	2.1			
6-C	0-15 cm	7.03	2.60	13.2	3.1	85.3	25.6	161	103
	15-30	6.72	1.20	11.4	2.2	19.5	8.0	28	34.5
	30-60	6.82	0.72	3.1	2.4	22.6			
	60-90	7.03	0.55	4.0	1.6	1.4			
	90-120	7.27	0.55	4.1	1.0	1.7			
7-C	0-15 cm	6.82	2.00	28.8	6.3	65.6	16.1	124	106
	15-30	6.70	0.95	10.2	2.0	10.8	3.3	14	49.5
	30-60	7.05	0.67	4.4	1.0	1.6			
	60-90	7.63	0.48	4.9	1.0	1.3			
	90-120	7.48	0.46	4.8	1.9	1.4			
Significance		N.S.	***	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
L.S.D.			0.46						

Statistics only apply to the 0-15 cm. depth
For statistical analysis between treatments A, B and C see Appendix

Conservation. The opposite seems to be true for treatments where overburden was used as a surface amendment.

In these treatments, the soil seemed to dry out to a depth of about 30 cm. Field observations indicated that, when the overburden dried out, the soil surface became very hard.

Addition of the lower rate of fertilizer (treatment A) resulted in a slight lowering in pH in the 0-15 cm depth, but did not significantly affect the salt concentration. The pH at greater depths was slightly less alkaline than in July, but the conductivity was about the same. As before, treatments 5, 6, and 7, which involved the addition of mine overburden, had higher conductivities than those where only peat had been added.

The medium fertilizer rate (treatment B) generally showed a slight increase in soil pH due to the counteraction of fertilizer acidification by the added lime. Conductivity values were not significantly different in the 0-15 cm depth from the July values. With treatment C, the acidifying effect of two large additions of fertilizer was generally offset by the addition of the lime. Surface pH values were, on the whole, unaltered from the July results. Soil conductivity had increased quite sharply. The highest values were again recorded for the overburden treated soils. Treatment 5C had a conductivity of 3.00 mmhos/cm in the 0-15 cm depth. A conductivity of 4 mmhos/cm would be expected to affect the growth of many salt sensitive plants.

The pH of the soil below 30 cm was slightly reduced while conductivities were marginally higher than in July.

Mineral nitrogen values between sub-treatments within each different fertilizer treatment were not significantly different. Plots that had received the low rate of fertilizer (Treatment A) were all very low in both ammonium and nitrate throughout the soil profile. With treatment B, the pattern was similar although there was some indication that nitrate values were higher overall than in treatment A. Results with treatment C indicated that, despite the recent application of fertilizer, the levels of ammonium were low. Nitrate concentrations were high in the surface 15 cm. The results gave little evidence to suggest that nitrate was being leached to below the 30 cm depth. In treatment C the concentration of nitrate-N varied between 65.6 ppm and 121.1 ppm in the surface 0-15 cm. Ammonium-N was below 12.2 ppm.

Phosphorus, potassium and sulfate were only measured in the 0-15 cm depths. Available phosphorus was still very low in treatments A and B. Most was in the surface 15 cm (1.9 ppm to 7.3 ppm). No differences could be found at the sub-treatment level. Some residual available-P was present in treatment C. There were again no significant differences between sub-treatments. Phosphorus contents varied between 12.3 ppm and 25.6 ppm in the 0-15 cm depth and between 2.6 ppm and 8.0 ppm in the 15-30 cm depth. Most of the added phosphorus seemed to be held in the surface peat and overburden layers.

Potentially available potassium levels were similar to those recorded in July for the surface 15 cm. Values were again generally higher in those treatments that had been amended with mine overburden (treatments 5, 6 and 7). Concentrations of potassium were very low below the 15 cm depth. Potassium was significantly higher in treatment C than in treatment

A and B.

The concentrations of sulfate-S were quite variable between replicates. As was found in July, all the plots contained adequate supplies of sulfur to supply plant needs.

3.6.2 Surface Water Runoff

Runoff water was collected on August 4 and 15 and on September 14 and 28, 1976. Table 14 shows the amounts of water collected and the nutrient losses in runoff during this time period. Table 15 gives comparative data for rainwater collected at the site at identical times.

Between July 15, when the collectors were set up, and August 4, a total of 31.6 mm of rainfall was recorded at the G.C.O.S. Meterological station. All rainfall during this period was light.

Between August 4 and 15, 32.5 mm of rainfall was recorded. Some 97 percent fell as heavy intensity rainfall during the 13th and 14th.

During the third collection period, two days of high intensity rainfall occurred. On August 27, 36.8 mm was recorded while on September 6, 39.9 mm fell. During this period a total of 86.2 mm of rainfall was recorded.

From September 14 to 28, no records were available for rainfall from the G.C.O.S. station. However, a total of 28.2 mm were recorded in the collector on the plot.

The only problem encountered with the collection of runoff water concerned the tendency for some of the funnels to become clogged up with fine material. When this occurred, some overflow of water may have occurred. One of the traps was especially problematical (4-C rep # 3) due to the erosion of tailings sand from a treatment #8 plot above. However, this was an exception and, although the variation in the amount of runoff water

Table 14. Volume and analysis of water runoff from plots at each collection period during 1976- Experiment II.

	Volume	pH	Cond.	Mineral nitrogen		P	K	SO_4-S
	l/m^2		mmhos/cm.	NH_4-N	NO_3-N			
				mg/m^2			mg/m^2	
8/4/76								
1-C	0.19	6.36	1.32	4.2	11.0			26.4
2-C	0.33	6.54	0.55	0.6	7.4			21.6
3-C	0.25	7.23	0.65	2.5	8.4			16.8
4-C	0.40	7.11	1.14	3.1	11.0			38.1
5-C	0.45	6.48	1.70	8.0	21.6			96.5
6-C	0.36	7.01	1.90	6.1	21.5			87.5
7-C	0.19	7.05	1.43	3.0	9.9			32.7
Significance	N.S.		*	N.S.	N.S.			**
L.S.D.			0.89					51.0
8/15/76								
1-C	0.22	6.61	0.26	1.3	1.5	0.4	6.3	3.7
2-C	0.14	6.41	0.79	7.3	4.6	1.1	17.1	4.4
3-C	0.48	6.67	0.36	5.0	3.5	1.8	18.7	12.6
4-C	0.20	6.67	0.80	5.0	14.9	0.2	20.2	4.9
5-C	0.92	6.30	1.44	64.2	56.1	36.8	159	68.1
6-C	0.74	6.79	0.66	24.2	26.8	1.8	62.5	17.7
7-C	0.49	6.60	0.88	19.6	21.3	4.3	51.0	18.6
Significance	N.S.		N.S.	***	***	***	**	**
L.S.D.				17.4	18.0	17.4	81.4	33.4
9/14/76								
1-C	0.32	6.38	0.18	1.2	0.8	x	3.2	3.1
2-C	0.27	5.96	0.79	4.0	5.6	0.3	26.8	4.6
3-C	0.33	6.18	0.21	0.2	0.5	0.1	5.3	8.5
4-C	0.24	6.07	0.46	1.4	2.6	0.2	20.7	4.7
5-C	1.74	6.06	0.94	30.6	45.6	2.6	206	34.8
6-C	2.00	6.24	0.63	17.8	20.2	1.9	193	82.9
7-C	0.68	5.92	0.96	10.4	52.2	1.1	106	65.5
Significance	N.S.		N.S.	*	N.S.	**	(*)	N.S.
L.S.D.				18.9		1.6	163	
9/28/76								
1-C	0.44	6.44	1.99	1.5	16.6	x	46.2	52.5
2-C	0.45	6.54	0.85	1.1	14.8	x	6.1	23.1
3-C	0.21	6.77	1.54	0.2	9.5	x	17.8	40.5
4-C	0.38	6.79	1.61	0.2	23.5	x	23.4	34.3
5-C	0.68	6.45	1.67	3.9	28.8	x	45.8	103
6-C	1.42	6.52	1.51	0.8	21.4	x	90.8	150
7-C	0.63	6.68	1.63	1.5	24.6	0.1	36.6	81.5
Significance	N.S.		N.S.	N.S.	N.S.		N.S.	***
L.S.D.								64.9

x less than 0.1 mg/m^2

Table 15. Analysis of rainfall collected during 1976- Experiment II.

Date	Amount Collected		pH	Cond.	Mineral nitrogen		P	K	SO_4-S
	mm.	l/m^2		mmhos/cm	NH_4-N	NO_3-N			
					mg/m^2		mg/m^2		
8/4/76	31.6*	38.3**	6.87	0.057	0.00	7.66			91.9
8/15/76	32.5*	50.7**	7.15	0.036	0.00	6.05	0.00	0.00	50.7
9/14/76	86.2*	128.1**	7.14	0.057	0.00	67.33	0.00	0.00	206
9/28/76	28.2**	28.2**	6.05	0.070	0.00	24.19	0.00	28.22	68.54

* G.C.O.S. met station records
** Plot measurements

Total nutrients in rainfall:

Nitrogen (as nitrate)	1.05 Kg/ha
Phosphorus	0.00 Kg/ha
Potassium	0.28 Kg/ha
Sulfate sulfur	4.46 Kg/ha

collected was quite large, the modifications to the traps seemed to have improved the method of collection over last year. It would be difficult to improve runoff collection further on the small plot scale without devoting one whole experimental area to water erosion problems.

Some trends were evident in this study. Treatments amended with mine overburden (5, 6 and 7) caused on average, more water runoff than those with a pure peat/tailings sand surface (Table 14). This was most evident where mine overburden was left untilled at the surface (treatment 5) and where a high rate had been added and tilled into the surface (treatment 6). In relation to the total rainfall intercepted by the plot surface it was estimated that from between 0.2 percent and 7.1 percent was collected as runoff. The rest was assumed to be absorbed by the soil surface. The greatest percentages were recorded for treatments 5 and 6.

Treatments 2, 3, and 4 which involved contour trenching, Aquatain stabilizer and Bitumuls stablizer respectively did not produce significantly different runoff values from the control treatment 1. Runoff from treatments 1, 2, 3, and 4 was considered slight and, under the rainfall conditions encountered in 1976, was not thought serious enough to cause serious erosion problems once plants were established. Runoff from treatments 5 and 6 was at times considered quite serious in relation to potential erosion. It should be noted that only a 5 m slope length was used.

The results with treatment 7 were generally similar to treatment 1. This seemed to indicate that once the low rate of overburden was incorporated into the peat layer the surface characteristics of the plot were dominated by the peat.

The pH of runoff water ranged from mildly acidic to neutral. No significant differences were apparent. Rain water pH was generally within the range encountered for the plot runoff water.

Conductivity of runoff water varied widely between the different collection periods (see Table 14). The first runoff collection had relatively high conductivity values. This was probably due to the small amounts of water collected and the recent addition of fertilizer to the plots. Conductivity of water collected from the second and third samplings were considerably lower. The second addition of fertilizer to treatment C later in August seemed to be reflected in the high conductivity of runoff water collected on September 28th. More washoff of the fertilizer appeared to occur at that time than during the third collection period. A comparison between treatments indicates that conductivities were generally high where overburden had been incorporated as an amendment. This was most noticeable where collection periods were not close to the times when fertilizers were added. This presumably reflects a certain amount of natural leaching of surface salts from the overburden which has considerably higher conductivity than the peat amendment on the tailings sand.

The conductivity of runoff water never reached values that would be considered likely to cause direct damage to vegetation.

Rainwater always had much lower conductivity than runoff water (see Table 15). This indicated that very low concentrations of soluble salts were coming down in the rainfall itself.

Table 14 shows the amount of different nutrients in runoff water. In general smaller amounts of plant nutrients (N, P, K, and S)were present in the total runoff from the plots that had only been amended with peat (treatments 1, 2, 3, and 4) than in treatments that included overburden (treatments

5, 6 and 7). However when compared to the total amounts of fertilizer added the amounts lost in runoff were rather insignificant (see Table 16).

A minimum equivalent to 0.3 Kg-N/ha was lost from treatment 3 (Aquatain stabilizer) while a maximum of 2.6 Kg-N/ha was lost from treatment 5 (overburden on the surface). A total of 300 Kg-N/ha was added to treatment C during 1976.

Phosphorus was not particularly mobile. A minimum estimated to be 0.01 Kg-P/ha was lost from treatment 1 (peat tilled in) and treatment 4 (Bitumuls stabilizer) while 0.39 Kg-P/ha was lost from treatment 5.

Potassium was the most readily surface leached nutrient. Values ranged from 0.42 Kg-K/ha with treatment 3 to 4.11 Kg-K/ha with treatment 5.

The sulfate anion was lost quite readily from all plots. A minimum value of 0.54 Kg-SO_4-S/ha was lost from treatment 2 (contour trenching) and a maximum of 3.38 Kg-SO_4-S/ha was lost from treatment 6 (high rate of overburden tilled in).

It should be noted that the mine overburdens are naturally quite rich in potassium and sulfate so that a certain amount of the losses may not have arisen from the fertilizers added.

The results seem to agree with the less comprehensive studies on Experiment (I) last year. Only mineral nitrogen losses were studied on the vegetated part of the dike during 1975. Results indicated that between 0.002 and 0.255 lb-N/acre (or 0.002 - 0.230 Kg-N/ha) were lost in runoff from areas that received up to 320 lb-N/acre (285 Kg-N/ha). In Experiment (II), where the first year of cover was in the process of being established, values were up to 10 times higher.

Table 16. Total nutrient losses in surface runoff water, Experiment II- 1976.

	Nutrient losses (Kg/ha)			
	N	P	K	SO_4-S
1-C	0.4	*	0.6	0.9
2-C	0.5	*	0.5	0.5
3-C	0.3	*	0.4	0.8
4-C	0.6	*	0.6	0.8
5-C	2.6	0.4	4.1	3.0
6-C	1.4	*	3.5	3.4
7-C	1.4	*	1.9	2.0

Averages of three replicates for four collection periods

* less than 0.1 Kg/ha

Table 17. Germination and plant heights, Experiment II- 1976.

	Germination* (%)	Average plant height (cm) 8/4/76	 8/27/76
1-A		21.8	54.5
2-A		17.1	44.3
3-A		21.9	58.3
4-A		18.9	51.0
5-A		21.5	50.5
6-A		21.7	58.9
7-A		21.3	60.3
Significance & L.S.D.		N.S.	N.S.
1-B		20.1	53.9
2-B		15.2	36.3
3-B		16.8	43.8
4-B		22.0	60.8
5-B		21.6	62.2
6-B		22.2	59.3
7-B		20.2	57.1
Significance & L.S.D.		** 4.1	N.S.
1-C	40.9	20.9	57.7
2-C	32.6	17.8	46.0
3-C	40.0	17.4	44.3
4-C	40.5	20.1	57.9
5-C	29.4	20.1	53.4
6-C	26.0	21.8	57.6
7-C	46.1	18.6	45.1
Sig. & L.S.D.	N.S.	N.S.	N.S.

* Germination estimated by counting number of seeds germinated within 10 random 20 cm x 20 cm areas in each plot.

** Plant height determined by measuring plant height in 20 random locations within each plot.

Total amounts of nutrients added in rainwater were very small (see Table 15). Approximately 1.1 Kg-N/ha as nitrate, 0.3 Kg-K/ha and 4.5 Kg-SO_4-S/ha were added during the July 15th 1976 to September 28th monitoring period. Over the whole year probably enough sulfur is brought down in rainfall to satisfy the sulfur nutrition of the vegetation on the dike.

3.6.3 Vegetative Growth

(a) Germination and Early Growth

Most of the plots showed adequate germination and good early growth. Plate 3 gives a general view of the experimental area about three weeks after seeding.

The germination of seed was best on treatments 1, 3, 4, and 7. The percentage germination recorded for those treatment at the high fertilization rate (C) varied from 40.0 percent to 46.1 percent (see Table 17). With treatments 5 and 6 germination was poorer (29.4% and 26.0% respectively) and overall growth of the plots appeared quite patchy. The poorer performance seemed to be related to the hard soil surface that developed from the presence of overburden and the greater amount of surface water runoff that resulted. Seeds were probably washed off more easily and, if germination was initiated, roots would not be able to penetrate beneath the surface as easily as on the peat surfaced plots.

Visual observations seemed to suggest that the Bitumuls treatment was most effective in producing a uniform cover of plants.

Average germination of treatment 2-C was slightly lower than on the other treatments that were amended with only peat rather than peat and overburden. The results were possibly due to the drier surface moisture produced by the scattering of tailings sand spoil material from the trenches over the plot surface.

Average plant heights were measured twice during the early phases of plant establishment on the plots. The first measurement was made on August 4th, 20 days after seeding, and the second on August 27th, 43 days after seeding. The results are presented on Table 17. There were no consistently significant differences between fertilizer treatments. Average plant heights were often lower with treatment 2. However, the low results were normally due to one low value recorded for one replicate.

Although indentification of all the species seeded was difficult at this early stage due to morphological similarities, it appeared that most if not all of the types seeded had germinated successfully.

Six weeks after seeding, plant growth had become well established on most plots (see Plate 4). Oats provided most of the cover but the growth of the grasses and legumes was also good. Heavy rainfall on August 13th and 26th had caused some damage. The most severe damage to seeded plots ocurred where channels had developed and the foliage had become beaten down. Nowhere on the seeded parts of the area could the effect be classed as serious. On treatment 8, which was not seeded at this time, quite deep undercutting had occurred in places. This was serious enough to require some repair work at this time.

Nutrient deficiencies did not become evident until plants were about 3 - 4 weeks old. Deficiencies of nitrogen were most common while potassium and phosphorus deficiency symptoms were noticeable on some plots. There did not appear to be any correlation between any specific fertilizer or surface amendment treatment and the occurrence of nutrient deficiency. Of the plant species sown it was generally the fast growing Pendek Oats that was most affected.

(b) Plant Productivity and Cover

Between September 26th and 28th plant samples were taken from each plot for the assessment of productivity and for nutrient analysis. By this time the Oats had headed out and were beginning to ripen. The legumes and other grasses were not as fully developed. A meter square area was harvested and the exact location marked with small plastic tags. The growth of Oats seemed to dominate the plots. On selected treatment Oats, other grasses and legumes were harvested separately.

On average Oats made up 85.1 to 92.7 percent of the weight yield while grasses made up 5.8 to 13.2 percent and legumes only 1.3 - 2.4 percent (see Table 18). However, the cover provided by the perennial plants was in most cases considerable. Plates 5 and 6 give a visual comparison with treatment 1-A of the total cover and that due to the grasses and legumes once the oats had been clipped off. The total cover provided by plant growth was good on all treatments. Cover by grasses and legumes on treatments 5 and 6 was not as uniform as with other treatments. It remains to be seen whether the growth will be adequate next year. Two areas southwest of Experiment (I), that had been seeded in 1971 were studied to provide a comparison with the vegetative cover on Experiment (II). The first area was considered to have an adequate vegetative cover in relation to erosion protection. It had an average of 375 - 500 plants per m^2. The second vegetated area was rated as fair to poor and had an average of 125 - 250 plants per m^2. The density of plants in Experiment II on the high fertilizer treatment varied between 580 and 1030 plants per m^2 when germination success was assessed. A proportion of these were Oat plants

Table 18. Comparison of yields of oats, legumes and other grasses from selected treatments, Experiment II- 1976

	Dry weight yield (Kg/m^2)														
	Oats					Grasses					Legumes				
	R1	R2	R3	Ave.	SD	R1	R2	R3	Ave.	SD	R1	R2	R3	Ave.	SD
1-A	.204	.244	.321	.256	.059	.020	.019	.051	.030	.018	.004	.004	.012	.007	.005
1-C	.189	.269	.317	.258	.065	.040	.053	.028	.040	.013	.003	.008	.004	.005	.003
4-C	.249	.285	.247	.260	.021	.026	.035	.049	.037	.012	.003	.002	.006	.004	.003
5-C	.250	.280	.423	.318	.092	.014	.017	.028	.020	.007	.003	.001	.011	.005	.005
6-C	.271	.361	.360	.331	.052	.013	.026	.039	.026	.013	.002	.004	.008	.005	.003
Significance				N.S.					N.S.					N.S.	

which would largely die out next year.

The yield of above ground vegetation was relatively variable from replicate to replicate. The complete data is given in Table 19. About seven plots had very low dry matter yields (ie. less than 0.1 Kg/m^2) in relation to the rest. Four of these were from treatment 2. The reasons for the poor yield here was thought to be due to the instability and low fertility of the tailings material dug up from the trenches and spread on the plot. However, the remainder of the low yielding plots were randomly distributed over the area and were not related to particular main treatments or sub-treatments.

Average yields varied from 0.147 Kg/m^2 to 0.393 Kg/m^2 (about 0.8 to 2.2 tons/acre).

Root cores were taken from selected treatments in a similar way as was described for Experiment (I). Yields at different depths are given in Table 20. Most of the root growth was restricted to the surface 15 cm. As was found for top yields, the results were quite variable. Average total yields varied from 0.157 to 0.281 Kg/m^2. There was some evidence that deeper root penetration occurred in treatments where overburden had been added. Possibly the roots passed through the drier overburden layer quite readily and into the moist peat layer below.

At this early stage in the program, the data gave little evidence of much root penetration below the surface peat and overburden. Only the surface 0-15 and 15-30 cm depths were analyzed for roots this year. The legume species (Alfalfa, Lupine, Cicer Milk Vetch and Sanfoin) put down quite deep roots into the tailings layer. These plants may play a signific-

Table 19. Dry weight yield of plant tops, Experiment II- 1976.

	Dry weight yield	(Kg/m^2)			
	R1	R2	R3	Average	St. Dev.
1-A	0.228	0.267	0.384	0.293	0.081
2-A	0.201	0.045	0.415	0.220	0.186
3-A	0.240	0.296	0.317	0.284	0.040
4-A	0.272	0.415	0.096	0.261	0.160
5-A	0.150	0.403	0.472	0.341	0.170
6-A	0.300	0.207	0.389	0.393	0.091
7-A	0.259	0.284	0.434	0.326	0.095
Significance				N.S.	
1-B	0.261	0.320	0.318	0.300	0.034
2-B	0.342	0.029	0.069	0.147	0.170
3-B	0.208	0.017	0.329	0.185	0.157
4-B	0.373	0.309	0.393	0.358	0.044
5-B	0.335	0.363	0.410	0.369	0.073
6-B	0.263	0.290	0.400	0.318	0.073
7-B	0.206	0.269	0.301	0.259	0.040
Significance				N.S.	
1-C	0.232	0.330	0.349	0.304	0.063
2-C	0.345	0.388	0.056	0.263	0.181
3-C	0.243	0.041	0.300	0.195	0.136
4-C	0.278	0.322	0.302	0.301	0.022
5-C	0.267	0.298	0.462	0.343	0.105
6-C	0.286	0.391	0.407	0.361	0.066
7-C	0.265	0.048	0.424	0.246	0.189
Significance				N.S.	

Statistical analysis between treatments A, B and C may be found in the Appendix.

Table 20. Distribution and yield of plant roots, Experiment II- 1976.

	Yield (Kg/m^2)												
	0–15 cm.					15–30 cm.					Total	Distribution (%)	
	R1	R2	R3	Ave.	SD	R1	R2	R3	Ave.	SD	Mean	0–15 cm.	15–30 cm.
1–A	.405	.181	.209	.265	.132	.013	.008	.026	.016	.009	0.281	94.3	5.7
5–A	.236	.133	.089	.153	.077	.010	.009	.030	.016	.012	0.169	90.5	9.5
6–A	.119	.198	.261	.193	.071	.031	.016	.036	.028	.010	0.221	87.3	12.7
1–C	.076	.271	.101	.149	.106	.010	.006	.009	.008	.002	0.157	94.9	5.1
5–C	.087	.127	.242	.152	.080	.021	.006	.011	.013	.008	0.165	92.1	7.9
6–C	.228	.147	.128	.168	.053	.016	.031	.019	.022	.008	0.190	88.4	11.6
Significance											N.S.		

ant role in the stabilization of the soil surface at this time.

3.6.4 Plant Analysis

Plant tops and roots were analyzed for total N, P, K, S and Ca. Nitrate content of the above ground material was also determined. The results are presented in Tables 21 - 23.

Nitrogen content of top material grown on plots which had received the low or medium rates of fertilizer were approximately the same. With treatment C, which had been fertilized in August as well as in July, nitrogen contents of the plant tops were significantly higher. In all treatments in which oats, grasses and legumes had been harvested separately the grass and legume material had higher total nitrogen contents than oats.

A similar trend was observed with phosphorus contents. Treatment A and B produced above ground plant material with a lower phosphorus content than treatment C. Application of phosphorus in August resulted in an increase of about 50 percent in phosphorus content in the plant material. The results were more variable than had been found with total nitrogen values.

Oats and other grasses had higher total phosphorus contents than legumes. Addition of extra fertilizer in treatment C seemed to result in a reduction in the final total phosphorus content of the top material of legumes.

Differences between experimental subtreatments within each main fertilizer treatment were slight. Total phosphorus contents varied from 0.46 percent P for oats produced in treatment 4-C to 0.12 percent P in treatments 2-B and legumes in treatment 6-C.

Potassium contents in treatment A were slightly lower than with

Table 21. Analysis of plant tops, Experiment II– 1976.

		Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulfur (%)	Calcium (%)	Nitr (%
1–A	Oats	1.93	0.29	1.90	0.23	0.36	0.
	Grasses	2.70	0.27	2.86	0.19	0.56	0.
	Legumes	2.60	0.20	1.96	0.27	2.34	0.
2–A		2.08	0.19	1.84	0.19	0.36	0.
3–A		1.92	0.31	2.36	0.21	0.43	0.
4–A		1.91	0.23	1.79	0.10	0.31	0.
5–A		2.03	0.22	2.06	0.18	0.34	0.
6–A		2.05	0.24	2.02	0.15	0.30	0.
7–A		2.07	0.30	2.23	0.21	0.32	0.
Sig. & L.S.D.		N.S.	N.S.	N.S.	N.S.	N.S.	N
1–B		2.15	0.30	2.69	0.17	0.42	0.
2–B		1.87	0.12	1.73	0.12	0.32	0.
3–B		2.03	0.26	2.43	0.15	0.43	0.
4–B		2.16	0.27	2.39	0.15	0.40	0.
5–B		2.20	0.27	2.26	0.14	0.38	0.
6–B		1.96	0.23	2.44	0.16	0.39	0.
7–B		2.18	0.26	2.50	0.16	0.35	0.
Sig. & L.S.D.		N.S.	* 0.11	* 0.52	N.S.	N.S.	N
1–C	Oats	2.29	0.31	2.75	0.13	0.46	1.
	Grasses	3.85	0.38	3.94	0.25	0.48	0.
	Legumes	3.70	0.20	2.61	0.22	2.29	0.
2–C		2.81	0.42	3.88	0.21	0.49	1.
3–C		3.15	0.41	4.03	0.23	0.45	1.
4–C	Oats	2.83	0.46	3.38	0.19	0.47	1.
	Grasses	3.78	0.43	4.19	0.24	0.50	0.
	Legumes	3.63	0.21	2.97	0.24	1.85	0.
5–C	Oats	2.51	0.31	2.73	0.15	0.42	1.
	Grasses	3.29	0.30	3.38	0.16	0.47	0.
	Legumes	3.30	0.13	2.67	0.20	2.42	0.
6–C	Oats	2.27	0.28	3.02	0.15	0.38	0.
	Grasses	3.47	0.24	3.40	0.18	0.53	0.
	Legumes	3.14	0.12	2.23	0.18	2.59	0.
7–C		2.73	0.38	3.31	0.16	0.45	1.

Values are means of three replicates.
Analysis of varience was performed on treatments A and B. The results where oats, grasses and legumes were measured separately were excluded. Complete results of statistical treatments are given in the Appendix.

Table 22. Analysis of plant roots, Experiment II- 1976.

	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulfur (%)	Calcium (%)
1-A	1.14	0.88	0.95	0.24	1.10
5-A	1.20	0.70	0.81	0.19	1.03
6-A	0.92	0.63	1.35	0.19	0.74
1-C	1.41	1.09	0.79	0.26	1.60
5-C	1.51	1.19	1.25	0.31	1.04
6-C	1.19	0.90	1.33	0.21	1.09
Significance	N.S.	*	N.S.	N.S.	N.S.
L.S.D.		0.35			

Results are means of three replicates

Table 23. Total nutrient uptake by plant tops and roots- Experiment (II), 1976.

	Nutrient Uptake (Kg/ha)									
	Tops					Roots				
	N	P	K	S	Ca	N	P	K	S	Ca
1-A	59.3	8.3	58.6	6.6	12.5	32.0	24.7	26.7	6.7	30.9
2-A	45.8	4.2	40.5	4.2	7.9					
3-A	54.5	8.8	67.0	6.0	12.2					
4-A	49.9	6.0	46.7	2.6	8.1					
5-A	69.2	7.5	70.2	6.1	11.6	20.3	11.8	13.7	3.2	17.4
6-A	80.6	9.4	79.4	5.9	11.8	20.3	13.9	29.8	4.2	16.3
7-A	67.4	9.8	72.7	6.8	10.4					
1-B	64.5	9.0	80.7	5.1	12.6					
2-B	27.5	1.8	24.4	1.8	4.7					
3-B	37.6	4.8	45.0	2.8	8.0					
4-B	77.3	9.7	85.6	5.4	14.3					
5-B	81.8	10.0	83.4	5.2	14.0					
6-B	62.3	7.3	77.6	5.1	12.4					
7-B	56.4	6.7	64.8	4.1	9.1					
1-C	76.4	9.6	88.1	4.5	14.9	22.1	17.1	12.4	4.1	25.1
2-C	73.9	11.0	102.0	5.5	12.9					
3-C	61.4	8.0	78.6	4.5	8.8					
4-C	88.9	13.7	104.6	5.9	14.8					
5-C	88.1	10.6	94.9	5.2	15.5	24.9	19.6	20.6	5.1	17.2
6-C	85.7	10.0	109.9	5.6	15.3	22.6	17.1	25.3	4.0	20.7
7-C	67.2	9.3	81.4	3.9	11.1					

Results calculated from the mean of three replicates. For statistical analysis see Appendix treatment B. Values for plants receiving treatment C were considerably higher than the low and medium fertilizer treatment. Where comparisons were made, grasses had significantly higher total potassium contents in the tops than either legumes or oats. Contents varied between 1.73 percent for treatment 2-B to 4.18 percent for grass samples from treatment 4-C.

The total sulfur of tops was relatively constant and varied between 0.10 percent for treatment 4-A to 0.27 percent in legumes produced under treatment 1-A. No significant differences existed between main treatments, subtreatment or different plant types.

Legumes had between 4-5 times higher calcium contents than grasses or oats. Calcium contents of the legumes were no higher where lime had been added (treatments B and C). However, plant top material, as a whole, had higher calcium contents at the highest fertilizer rate (treatment C).

Chemical analysis of roots from selected treatments are presented in Table 22. Material from the 0-15 cm and 15-30 cm depths are combined for each treatment before analysis.

Nitrogen and potassium contents of root materials were lower than in the tops while phosphorus, sulfur and calcium were higher.

Nitrogen contents were higher in treatment C. In treatment 6-C the nitrogen content of the roots was considerably lower than was found in treatment 1-C and 5-C. The reason for this is not known.

Phosphorus contents within treatment C were also higher than treatment A. No significant differences were found at the subtreatment level.

In contrast to phosphorus contents, when additional potassium fertilizers were added (treatment C), there was no increase in the potassium content of roots.

Total sulfur contents were slightly greater where additional sulfur had been added in treatment C.

Similarly calcium contents of root tissues were greater in treatment C than treatment A. The difference was attributed to the addition of lime in treatment C.

Calculation of the total nutrient uptake on an area basis is presented in Table 23. From 27.5 to 88.9 Kg-N/ha were converted into top material. On average higher amounts were taken up by treatments that were fertilized at the high rate than at the two lower rates. Uptake of potassium was generally slightly higher (25.4 to 104.6 Kg/ha) but showed a similar trend in relation to the rate of fertilizer addition. Phosphorus uptake by top material was quite variable. Values ranged between 1.8 and 6.8 Kg/ha. The total calcium incorporated into the above ground material was between 4.7 and 15.5 Kg/ha. The ratios of the different nutrient elements were generally quite similar. The approximate ratio was 10: 1.2 : 11 : 0.8 : 1.8 of N: P: K: S: Ca.

Less total nitrogen was incorporated into the root tissues than into top material. The amount varied between 20.3 and 32.0 Kg-N/ha in the limited number of treatments studied. This was between one quarter to one third the amount found in plant tops. Phosphorus was taken up to a greater extent by roots. Values ranged between 11.8 and 24.7 Kg-P/ha. Potassium accumulated in the root accounted for between 12.4 and 29.8 Kg-K/ha. This was considerably less than occurred in the tops. Sulfur uptake by the roots was about the same as was found in the above ground parts. Calcium uptake by roots was significantly greater than for the tops. Amounts between

16.3 and 30.9 Kg Ca/ha were found with the treatments studied.

In very approximate terms a total of 90-110 Kg-N; 20-30 Kg-P; 85-135 Kg-K; 10 Kg-S and 30-40 Kg-Ca per hectare were taken up in vegetative growth during the period between seeding and September, 1976. Generally the amounts taken up by plants on treatment C were slightly higher than in treatment A. In the first year the nutrients added in fertilizer amendments amounted to 80 Kg-N, 35 Kg-P, 75 Kg-K and 20 Kg-S per hectare in treatment A. With treatment C the annual addition was 300 Kg-N, 80 Kg-P, 300 Kg-K and 40 Kg-S per hectare. With treatment A there seemed to have been considerable incorporation of available soil nutrients in addition to those supplied as fertilizer.

The nitrate content of plant tops was generally above the level considered to be undesirable in animal feeds (0.5% is considered undesirable and 1.5% toxic). The highest levels occurred in the Oat plants. Nitrate contents of legumes were quite low. Values recorded with fertilizer treatments A and B were on average similar. Nitrate contents at the higher rate C were significantly greater.

3.6.5 Estimation and observations of plot erosion

Estimations of particulate movement down the slope were made in conjunction with water runoff measurements. When runoff water was collected, the soil deposited in the chute was also recovered. If the quantity of soil material deposited in the trap was relatively small, the entire sample was retained. If the chute was quite full, then the amount collected was estimated from the volume that it occupied and a sub-sample was retained. Samples were analyzed for aggregate size distribution and mineral nitrogen content.

After the rainfall on the 26th of August the trap on treatment 4-C of replicate 3 became completely filled with tailings sand. It was likely that on this plot the collection of runoff water was not efficient either. The remainder of the traps seemed to work moderately well during the year.

Tables 24 and 25 show the amount of soil collected from down-slope movement and the amount of mineral nitrogen that the soil contained on the basis of slope area.

The contour trenching treatment gave the lowest soil erosion measurements and the lowest losses of mineral nitrogen (0.19 cm of soil removed and 0.51 Kg-N lost per hectare). The two treatments which involved the soil stabilizers (treatments 3 and 4) gave the worst problems. What seemed to occur with the Bitumuls conditioner was that initially the asphalt cover stabilized the soil surface but once it became punctured water became able to channel underneath the surface. On average treatment 4 gave a 1.77 cm loss of soil surface and movement of 6.3 Kg-N/ha.

Treatments 5 and 6 which involved overburden application were quite susceptible to downslope movement of soil. The same treatments also yielded high amounts of runoff water.

With treatment 7 where only a low rate of overburden had been incorporated, erosion problems were not as serious.
The plot surface tended to assume similar surface characteristics to peat when the overburden amendment was tilled in.

Analysis of the aggregate size of material washing down the slope did not show any clear evidence that any size fractionation was occurring (see Table 26). Tailings sand has particles that are predominantly between 20

Table 24. Total amount of soil erosion and mineral nitrogen lost in eroded materials- Experiment (II), 1976.

	Soil movement (Kg/m^2)	Mineral nitrogen (mg/m^2)		
		NH_4-N	NO_3-N	Total
August 4th				
1-C	0.009	0.1	0.0	0.1
2-C	0.051	0.2	0.2	0.4
3-C	0.006	0.0	0.1	0.1
4-C	0.026	0.1	0.0	0.1
5-C	0.047	0.2	0.2	0.4
6-C	0.034	0.2	0.1	0.3
7-C	0.024	0.1	0.0	0.1
August 15th				
1-C	2.000	21.0	51.6	72.6
2-C	1.167	13.1	21.1	34.2
3-C	7.000	86.0	173.5	259.5
4-C	12.300	181.3	242.4	423.7
5-C	5.800	23.9	46.3	70.2
6-C	6.667	35.6	44.8	80.4
7-C	2.000	13.0	21.9	34.9
September 14th				
1-C	0.400	10.3	17.8	28.1
2-C	0.700	8.9	6.4	15.3
3-C	1.067	33.8	87.5	121.3
4-C	5.333	123.2	87.2	210.4
5-C	1.000	28.4	21.3	49.7
6-C	1.333	15.3	45.5	60.8
7-C	1.167	18.5	14.4	32.9
September 28th				
1-C	0.027	0.1	0.2	0.3
2-C	0.016	0.2	0.7	0.9
3-C	0.011	0.0	0.3	0.3
4-C	0.070	0.3	0.4	0.7
5-C	0.039	0.2	0.8	1.0
6-C	0.021	0.1	0.7	0.8
7-C	0.041	0.1	0.1	0.2

Results are means of three replicates.
Within each sampling period, the means were not statistically different at the 5% level of significance.

Table 25. Cumulative soil erosion and mineral nitrogen losses- Experiment (II

	Soil loss (cm)	Total mineral nitrogen (Kg/ha)
1-C	0.24	1.01
2-C	0.19	0.51
3-C	0.81	3.81
4-C	1.77	6.35
5-C	0.69	1.21
6-C	0.81	1.42
7-C	0.32	0.68

Calculated from the means of three replicates for four collection periods.

Table 26. Aggregate size distribution of soil collected in runoff traps - 1976.

	Aggregate size distribution (%) mesh size							Description
	>10	10-20	20-40	40-60	60-80	80-100	<100	
8/4/76								
1-C	17.2	11.8	12.6	20.0	19.2	8.2	10.9	peat & some tailings
2-C	11.3	6.9	9.5	41.2	18.4	6.3	6.4	mainly tailings
3-C	15.1	9.6	10.6	22.6	20.9	9.6	11.6	peat & tailings
4-C	7.5	8.1	11.1	37.6	20.7	7.4	7.6	peat & tailings
5-C	14.6	8.7	13.6	39.7	11.5	4.1	8.1	mainly overburden
6-C	19.5	9.6	13.8	36.2	10.7	4.3	5.9	mainly overburden
7-C	12.2	10.1	12.6	36.6	14.6	5.2	8.7	peat/sand/overb'dn
8/15/76								
1-C	34.6	17.0	13.5	15.9	9.0	3.8	6.2	mainly peat
2-C	15.6	8.4	9.7	36.2	19.0	5.0	6.1	tailings
3-C	33.6	18.1	13.4	15.6	8.9	3.7	6.7	mainly peat
4-C	25.6	16.8	11.8	26.4	11.5	3.7	4.2	tailings
5-C	100							fused overburden
6-C	100							fused overburden
7-C	32.7	18.0	12.8	22.2	6.8	2.6	4.9	tailings & overb'dn
9/14/76								
1-C	26.7	5.0	15.4	24.7	10.6	4.8	12.8	mainly fine peat
2-C	6.9	8.3	9.4	47.0	17.4	5.6	5.6	tailings
3-C	26.9	9.0	10.2	19.0	14.0	6.6	14.3	mainly peat
4-C	7.9	5.1	11.3	56.7	12.2	3.4	3.4	mainly tailings
5-C	14.8	11.2	18.9	35.2	9.8	3.9	6.2	tailings & overb'dn
6-C	41.6	7.8	10.2	17.3	10.7	4.4	8.0	tailings & overb'dn
7-C	16.8	8.2	12.0	38.1	9.7	5.1	10.1	tailings & some overburden
Tailings sand	2.7	1.5	19.2	56.7	10.4	4.5	5.0	
Peat	12.5	10.4	9.9	19.2	22.0	9.9	16.1	

Results are means of three replicates.

and 80 mesh in size. Most are between 40 and 60 mesh. Where tailings sand appeared from visual observation to be the main material moving down the slope, much of the material collected fell between 20 and 80 mesh in size. When peat was the predominant material washed down, proportionally more smaller and larger aggregates were collected (for example 1-C and 3-C of the 9/14/76 collection period). Overburden behaved rather differently. After being washed down the slope into the collector it seemed to dry out and aggregate into larger sized units. The material collected after the high intensity rainfall on the 26th of August had fused into a large mass in the collector when it was examined the next day.

The results indicated that the downslope erosion of soil could be serious where undercutting and channeling below the surface amendments were able to develop. From measurements of mineral nitrogen, the nutrient losses in the eroded soil seemed likely to be low in relation to the amounts of fertilizer amendment added. Visual observations of the plot confirmed that the rapid root development was most important in controlling erosion. Erosion was serious where the added peat was sparse or where insufficient fertilizer had been applied to maintain adequate plant growth. On areas on the dike, once deep erosion channels become established even the vegetated areas are easily damaged.

3.6.6 Lysimeter Studies

(a) Plant Growth

Plant growth in the lysimeters was considerably inferior to that on the main experimental plots. There was large variation between different treatments and replicates of the same treatment. Table 27 shows the average number of plants that developed with each lysimeter treatment. Growth

Table 27. Total number of plants in lysimeters, Experiment II - 1976.

	Number of plants per lysimeter			
	Oats	Grasses	Legumes	Total
1-A	3	15	5	23
3-A	0	1	0	1
4-A	0	1	0	1
5-A	2	12	4	18
6-A	0	8	2	10
7-A	2	14	4	18
1-B	0	12	2	14
3-B	0	1	0	1
4-B	2	11	3	16
5-B	1	4	2	7
6-B	1	3	2	6
7-B	3	5	1	9
1-C	2	18	4	24
3-C	0	1	0	1
4-C	0	0	0	0
5-C	1	3	1	5
6-C	1	7	1	9
7-C	1	4	2	7

A total number of 134 seeds were sown in each lysimeter.
Results are means of three replicate lysimeters.

with treatment 1 was normally adequate to provide a good soil cover. The overburden treatments were much poorer (5, 6, and 7). Lysimeters that were treated with Aquatain (treatment 3) and Bitumuls Stabilizers (treatment 4) gave very low germination of seed. Many lysimeters had no plants in them at all.

The reasons for the poor performance of plants in relation to the main plot area are probably related to the ease with which the exposed and relatively small containers were able to dry out.

No measurements of plant biomass production were made in 1976.

(b) Leachate Analysis

Leachate was collected from the lysimeters on August 4th and 5th and on September 14th and 28th. These were the same dates when runoff water was sampled. The amount of sample collected during the first period was quite small. Only pH, conductivity and mineral nitrogen was determined. With the three other sets of leachate, potassium, phosphorus and sulfate were also determined. The results are shown in Tables 28-31. Total water movement and nutrient losses may be found in Table 32.

The amount of leachate collected would be expected to vary depending upon the amount of rainfall, soil moisture content and infilitration characteristics, the degree of uptake and transpiration of moisture by plants, and the surface evaporation rate. Generally the volume of leachate collected was greater with treatments 3 and 4. The lowest quantity of leachate was an average collected from treatments 1 and 7. However, the results were quite variable between replicates. Observations showed that the movement of the containers that was necessary to remove leachate samples, could cause cracking of the soil surface. A high leaching rate could have resulted

Table 28. Analysis of lysimeter leachate collected August 4th, 1976.

	Volume l/m^2	pH	Cond. mmhos/cm	Mineral nitrogen NH_4-N mg/m^2	Mineral nitrogen NO_3-N mg/m^2
1-A	0.54	6.40	0.16	3.2	5.1
3-A	1.55	6.61	0.26	13.3	14.6
4-A	1.09	6.88	0.25	7.1	8.9
5-A	1.04	6.49	0.37	5.2	11.6
6-A	0.58	6.68	0.29	5.4	11.0
7-A	0.72	6.25	0.46	8.1	10.5
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.
1-B	0.55	6.56	0.19	3.3	7.1
3-B	1.21	6.76	0.28	6.7	9.7
4-B	1.24	6.70	0.25	5.0	15.5
5-B	0.55	6.35	0.59	10.2	39.5
6-B	1.69	6.60	0.89	10.3	79.9
7-B	1.12	6.83	0.59	10.8	24.5
Sig. & L.S.D.	N.S.	N.S.	***0.35	N.S.	N.S.
1-C	0.71	7.00	0.41	4.5	18.7
3-C	0.45	7.01	0.27	5.8	9.1
4-C	1.32	6.64	0.36	8.9	31.4
5-C	0.96	6.64	1.46	21.2	67.1
6-C	1.24	6.75	0.72	5.0	44.4
7-C	1.15	6.93	0.48	4.9	30.6
Sig. & L.S.D.	N.S.	N.S.	***0.56	N.S.	N.S.

Values are means of three replicates

Table 29 Analysis of lysimeter leachate collected on August 15th, 1976.

	Volume	pH	Cond.	Mineral nitrogen		P	K	SO_4-S
	l/m^2		mmhos/cm	NH_4-N	NO_3-N	mg/m^2		
				mg/m^2				
1-A	16.7	6.19	0.26	52.1	58.3	0.9	70	683
3-A	30.3	5.69	0.49	6.4	279	0.9	137	1943
4-A	28.5	6.16	0.47	17.2	414	1.1	137	1917
5-A	14.1	6.28	0.62	1.3	69.6	1.3	90	1217
6-A	16.8	6.09	0.23	0.2	67.2	0.7	63	287
7-A	13.0	6.23	0.26	0.0	49.8	0.7	13	327
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	**220	N.S.	N.S.	N.S.
1-B	19.5	6.25	0.67	0.7	638	1.1	273	953
3-B	20.4	6.54	0.75	15.9	598	1.0	87	1703
4-B	22.2	6.61	0.67	7.7	857	1.0	247	1097
5-B	18.2	6.20	0.50	0.0	273	3.4	230	810
6-B	11.1	6.70	0.45	6.6	167	1.1	157	257
7-B	17.2	6.85	0.34	2.5	115	0.7	140	367
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
1-C	13.2	6.72	0.50	13.0	179	0.6	123	467
3-C	28.1	6.61	0.78	3.8	930	2.8	443	973
4-C	28.9	6.64	0.94	0.0	1412	1.3	527	2093
5-C	15.8	6.61	0.55	0.0	229	2.2	313	727
6-C	11.0	6.71	0.40	0.0	152	1.7	207	250
7-C	21.5	6.78	0.33	8.7	171	1.6	140	693
Sig. & L.S.D.	**11.5	N.S.	**0.32	N.S.	***700	N.S.	***140	*1620

Values are means of three replicates

Table 28. Analysis of lysimeter leachate collected August 4th, 1976.

	Volume	pH	Cond.	Mineral nitrogen	
	l/m^2		mmhos/cm	NH_4-N	NO_3-N
				mg/m^2	
1-A	0.54	6.40	0.16	3.2	5.1
3-A	1.55	6.61	0.26	13.3	14.6
4-A	1.09	6.88	0.25	7.1	8.9
5-A	1.04	6.49	0.37	5.2	11.6
6-A	0.58	6.68	0.29	5.4	11.0
7-A	0.72	6.25	0.46	8.1	10.5
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.
1-B	0.55	6.56	0.19	3.3	7.1
3-B	1.21	6.76	0.28	6.7	9.7
4-B	1.24	6.70	0.25	5.0	15.5
5-B	0.55	6.35	0.59	10.2	39.5
6-B	1.69	6.60	0.89	10.3	79.9
7-B	1.12	6.83	0.59	10.8	24.5
Sig. & L.S.D.	N.S.	N.S.	***0.35	N.S.	N.S.
1-C	0.71	7.00	0.41	4.5	18.7
3-C	0.45	7.01	0.27	5.8	9.1
4-C	1.32	6.64	0.36	8.9	31.4
5-C	0.96	6.64	1.46	21.2	67.1
6-C	1.24	6.75	0.72	5.0	44.4
7-C	1.15	6.93	0.48	4.9	30.6
Sig. & L.S.D.	N.S.	N.S.	***0.56	N.S.	N.S.

Values are means of three replicates

Table 29 Analysis of lysimeter leachate collected on August 15th, 1976.

	Volume l/m^2	pH	Cond. mmhos/cm	Mineral nitrogen NH_4-N mg/m^2	NO_3-N	P	K	SO_4-S
						mg/m^2		
1-A	16.7	6.19	0.26	52.1	58.3	0.9	70	683
3-A	30.3	5.69	0.49	6.4	279	0.9	137	1943
4-A	28.5	6.16	0.47	17.2	414	1.1	137	1917
5-A	14.1	6.28	0.62	1.3	69.6	1.3	90	1217
6-A	16.8	6.09	0.23	0.2	67.2	0.7	63	287
7-A	13.0	6.23	0.26	0.0	49.8	0.7	13	327
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	**220	N.S.	N.S.	N.S.
1-B	19.5	6.25	0.67	0.7	638	1.1	273	953
3-B	20.4	6.54	0.75	15.9	598	1.0	87	1703
4-B	22.2	6.61	0.67	7.7	857	1.0	247	1097
5-B	18.2	6.20	0.50	0.0	273	3.4	230	810
6-B	11.1	6.70	0.45	6.6	167	1.1	157	257
7-B	17.2	6.85	0.34	2.5	115	0.7	140	367
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
1-C	13.2	6.72	0.50	13.0	179	0.6	123	467
3-C	28.1	6.61	0.78	3.8	930	2.8	443	973
4-C	28.9	6.64	0.94	0.0	1412	1.3	527	2093
5-C	15.8	6.61	0.55	0.0	229	2.2	313	727
6-C	11.0	6.71	0.40	0.0	152	1.7	207	250
7-C	21.5	6.78	0.33	8.7	171	1.6	140	693
Sig. & L.S.D.	**11.5	N.S.	**0.32	N.S.	***700	N.S.	***140	*1620

Values are means of three replicates

Table 30. Analysis of lysimeter leachate collected on September 14th, 1976.

	Volume l/m^2	pH	Cond. mmhos/cm	Mineral nitrogen		P	K	SO_4-S
				NH_4-N	NO_3-N			
				mg/m^2		mg/m^2		
1-A	2.9	5.91	0.45	0.0	0.0	x	3.3	250
3-A	12.8	5.84	0.64	6.7	320		60.0	883
4-A	15.7	5.93	0.84	3.3	653		93.0	997
5-A	14.3	6.14	0.90	23.3	40.0		73.3	1487
6-A	11.7	6.36	0.34	16.7	6.7		10.0	330
7-A	13.5	6.36	0.40	10.0	16.7		30.0	330
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	***80		***50.0	N.S.
1-B	6.1	6.11	0.88	3.3	100		30.0	376
3-B	20.5	6.10	0.94	6.7	1003		200	1137
4-B	11.4	5.94	0.52	3.3	173		20.0	290
5-B	8.7	6.12	0.62	13.3	100		137	280
6-B	8.4	6.17	0.48	0.0	190		190	170
7-B	2.4	6.32	0.21	0.0	10.0		16.7	30
Sig. & L.S.D.	N.S.	N.S.	N.S.	N.S.	***350		N.S.	N.S.
1-C	11.1	6.24	0.49	6.7	107		36.7	357
3-C	2.9	6.35	0.70	0.0	180		30.0	110
4-C	21.5	6.20	1.01	3.3	1093		330	543
5-C	13.8	6.50	0.43	10.0	153		167	540
6-C	13.0	6.37	0.42	6.7	187		167	303
7-C	23.2	6.41	0.35	13.3	34.7		63.3	433
Sig. & L.S.D.	***9.7	N.S.	**0.39	N.S.	***310		***150	N.S.

x- all less than 1.0 mg-P/m^2

Values are means of three replicates

Table 31. Analysis of lysimeter leachate collected on September 28th, 1976

	Volume	pH	Cond.	Mineral nitrogen		P	K	SO_4-S
	l/m^2		mmhos/cm	NH_4-N	NO_3-N			
				mg/m^2		mg/m^2		
1-A	3.8	5.44	0.21	30.0	16.7	x	40.0	43.3
3-A	10.7	5.46	0.69	6.7	340		43.3	367
4-A	8.5	5.73	0.78	3.3	270	3.3	50.0	697
5-A	4.8	6.09	0.91	6.7	43.3		66.7	410
6-A	3.0	6.30	0.42	3.3	23.3		63.3	133
7-A	6.6	6.28	0.32	3.3	30.0		70.0	117
Sig. & L.S.D.	N.S.	** 0.44	N.S.	N.S.	*230		N.S.	N.S.
1-B	5.3	6.16	0.82	6.7	210		110	573
3-B	13.0	6.13	0.72	13.3	743		183	973
4-B	3.1	6.29	0.75	0.0	180		50.0	220
5-B	6.6	6.37	0.92	20.0	130		213	1223
6-B	3.2	6.45	0.52	0.0	50.0		46.7	147
7-B	4.0	6.61	0.41	0.0	20.0		46.7	80
Sig. & L.S.D.	N.S	*** 0.19	N.S.	N.S.	**370		N.S.	N.S.
1-C	3.1	6.51	0.84	0.0	170		30.0	157
3-C	10.2	6.41	1.08	0.0	353		183	490
4-C	9.2	6.41	1.10	0.0	573		150	547
5-C	3.2	6.57	0.72	6.7	66.7		80.0	293
6-C	5.3	6.54	0.82	0.0	180		130	637
7-C	5.6	6.64	0.41	3.3	70.0		80.0	113
Sig. & L.S.D.	N.S.	** 0.14	* 0.43	N.S.	N.S.		N.S.	N.S.

x rest of the values are less than 1.0 mg-P/m^2

Values are means of three replicates

Table 32. Total water leaching and nutrient loss from lysimeters, July 15th to September 28th, 1976.

	Total water leached mm.	Nutrient Losses (Kg/ha)					
		NH_4-N	NO_3-N	Total	P	K	SO_4-S
1-A	23.9	0.9	0.8	1.7	*	1.1	9.8
3-A	55.4	0.3	9.5	9.8		2.4	31.9
4-A	53.8	0.3	13.5	13.8		2.8	36.1
5-A	34.2	0.4	1.6	2.0		2.3	31.1
6-A	32.1	0.3	1.1	1.4		1.4	7.5
7-A	33.8	0.2	1.1	1.3		1.1	7.7
1-B	31.5	0.1	9.6	9.7		4.1	19.1
3-B	55.1	0.4	23.5	23.9		4.7	38.1
4-B	37.9	0.2	12.3	12.5		3.2	16.1
5-B	34.1	0.4	5.4	5.8		5.8	23.1
6-B	24.4	0.2	4.8	5.0		3.9	5.7
7-B	24.7	0.1	1.7	1.8		2.0	4.8
1-C	28.1	0.2	4.7	4.9		1.9	9.8
3-C	41.7	0.1	14.7	15.8		6.6	15.7
4-C	60.9	0.1	31.1	31.2		10.1	31.8
5-C	33.8	0.4	5.2	5.6		5.6	15.6
6-C	30.5	0.1	5.6	5.7		5.0	11.9
7-C	51.5	0.3	3.1	3.4		2.8	12.4

* All losses much less than 0.1 Kg-P/ha

P, K and SO_4-S not determined in the first set of leachate.

Total precipitation from July 15th to September 28th = 178.5 mm.

All values are calculated from the means of three replicates for each sampling period.

from the rapid drainage of water through the cracks that developed around the edge of the pail.

The total amount of water that was leached during the July 15th to September 28th study period was equivalent to between 23.9 mm and 60.0 mm of rainfall in different treatments studied (Table 32). The total rainfall during this period was 178.5 mm. Therefore it seems likely that, on newly revegetated areas on the dike, a significant proportion of the total precipitation will readily leach to below the rooting depth. However, once a dense root mat develops the leaching pattern may be entirely different.

The reaction of the leachate water was neutral to slightly acidic. The water from the first collection period was a little more alkaline than were the later samples. This seemed to reflect the trend shown with soil samples from the main plot experiment where the samples became more acidic as the year progressed.

Conductivity of the leachate water varied from 0.16 to 1.46 mmhcs/cm. The only trend observed was that the values with the high fertilizer rate (B and C) were generally greater than those recorded for the lower rate (treatment A).

Where leaching of water was most intense the losses of mineral nitrogen were found to be quite high. Much less ammonium in relation to nitrate was lost in the leachate water. The losses of mineral nitrogen during the summer study period was equivalent to between 1.3 and 31.2 Kg-N/ha. Within the same fertilization treatment the losses for treatments 1, 5, 6 and 7 were not significantly different. Between 1.3 and 2.0 Kg-N/ha were lost at the low fertilizer rate (treatment A, 80 Kg-N/ha added) while equivalent to between 1.8 and 9.7 Kg-N/ha were lost at the higher rate (eg. treatments B and C

150 Kg-N/ha added). Nitrogen losses incurred with treatments 3 and 4, which involved the soil stabilizers, were significantly higher (9.8-13.8 Kg-N/ha at rate A; 12.5-31.2 Kg-N/ha at rate B and C). The majority was lost as the nitrate ion.

The rate of loss of nitrate will depend upon many factors. Some of the more important ones are:

(i) Water flux through the soil
(ii) Rate of nitrification ($NH_4 \rightarrow NO_3$)
(iii) Rate of uptake by plants and micro-organisms
(iv) Denitrification losses
(v) Accompanying cations

As was noted previously, the growth of plants in lysimeters that had been treated with the soil stabilizers was extremely poor. The negligible plant uptake of mineral nitrogen could have contributed to the large amount of nitrate lost by leaching. It also seems possible that the adhesive property of the stabilizer materials caused the soil to pull away from the sides of the pail and increase the amount of water leaching through the soil. To a certain extent this might increase the downward movement of nitrate in the soil.

If the results noted with the lysimeters are representative of the main plot area, it seems that relatively large amounts of nitrogen applied as fertilizer are leached below the rooting depth. The process seems more serious where large single applications of nitrogen are made (e.g. 150 Kg-N/ha).

Losses of other nutrients were generally less serious. Phosphate in particular was practically immobile in the soil. Leaching losses over the summer were less than 0.1 Kg-P/ha.

Between 1.1 and 10.1 Kg/ha of potassium was leached below the 30 cm depth in the lysimeters. Generally the amount lost in each treatment was quite similar to that found for nitrogen. However, with the soil stabilizer treatments loss of potassium was considerably less than for nitrogen.

Sulfate was very readily leached from the lysimeter soils. The total amounts lost during the summer were on average only slightly greater at the higher fertilizer application rate. It therefore seems that a large proportion of the sulfur leached came from native sources present in the tailings sand, peat and overburden. The soil mixes are sufficiently rich in available sulfur that the losses are of little consequence in relation to plant nutrition. However, it is of some concern that there is probably a high rate of leaching of sulfate to depth in the dike which could result in salt seepages towards the base of the dike. Average losses of sulfate-S from the lysimeters were equivalent to between 4.8 and 38.1 Kg-S/ha over the period studied.

(c) Soil Samples

Soil samples were taken from each lysimeter during October 1976. Only two cores were taken from each pail. Samples were divided into two depths; 0-15 cm and 15 cm to the bottom (about 30 cm). The results are presented in Table 33.

The soil pH in the surface 15 cm was normally about 0.5 to 0.6 units higher where lime had been added (treatments B and C). The pH of the lower depth was always slightly lower than in the surface.

Soluble salts were highest where the tailings sand had been amended

Table 33. Analysis of lysimeter soil samples- October, 1976.

		pH	Cond.	Mineral nitrogen		P	K	SO_4-S
			mmhos/cm	NH_4-N	NO_3-N			
				ppm			ppm	
1-A	0-15 cm	6.22	0.60	1.9	0.6	6.8	18.2	50.1
	15-30	6.33	0.50	5.7	1.7	4.4	9.8	26.1
3-A	0-15 cm	6.12	0.84	3.6	25.5	0.2	40.5	50.8
	15-30	6.60	0.58	1.4	5.5	2.0	9.2	17.8
4-A	0-15 cm	6.12	0.68	2.4	18.5	1.6	39.0	30.1
	15-30	6.62	0.61	2.2	7.5	1.9	11.3	15.6
5-A	0-15 cm	6.43	1.90	1.6	0.7	18.2	48.0	133
	15-30	6.78	1.39	1.2	1.3	4.8	17.3	64.5
6-A	0-15 cm	6.58	2.47	2.6	2.5	5.5	48.3	305
	15-30	6.65	1.72	3.3	2.3	4.5	25.5	146
7-A	0-15 cm	6.37	2.27	4.6	4.3	3.8	47.0	181
	15-30	6.65	0.88	4.1	3.3	4.4	24.7	43.0
1-B	0-15 cm	6.88	1.20	3.3	27.8	2.2	47.3	55.4
	15-30	6.95	0.73	3.4	7.4	2.1	30.3	39.9
3-B	0-15 cm	6.77	1.17	4.3	41.5	7.1	65.3	50.0
	15-30	6.93	0.75	2.1	10.4	2.8	48.7	22.2
4-B	0-15 cm	6.88	1.16	5.0	28.1	0.9	117	48.4
	15-30	7.07	0.57	4.0	8.8	0.9	37.3	13.4
5-B	0-15 cm	6.27	2.07	4.8	14.8	7.0	54.0	212
	15-30	6.57	1.00	1.8	3.7	3.1	12.0	50.9
6-B	0-15 cm	7.12	2.43	3.6	12.2	4.0	56.3	281
	15-30	7.52	2.01	1.3	6.8	3.6	38.7	106
7-B	0-15 cm	6.85	2.25	2.8	8.4	4.7	52.7	294
	15-30	7.62	1.09	4.3	5.1	3.6	17.7	50.0
1-C	0-15 cm	6.72	1.13	3.1	13.5	7.6	31.7	72.4
	15-30	7.12	0.54	3.0	3.3	1.0	10.3	18.4
3-C	0-15 cm	6.72	1.13	5.6	39.8	10.8	57.0	46.8
	15-30	7.13	0.74	1.9	9.4	2.9	15.3	25.9
4-C	0-15 cm	7.15	0.79	7.5	24.1	0.4	55.3	22.2
	15-30	6.85	0.66	3.7	11.6	1.4	15.3	16.5
5-C	0-15 cm	6.37	1.74	4.1	15.6	8.4	64.3	155
	15-30	6.87	1.20	8.7	7.8	4.5	24.0	65.5
6-C	0-15 cm	7.12	2.33	3.3	11.8	8.6	55.0	276
	15-30	7.57	1.80	4.6	7.5	3.9	39.0	107
7-C	0-15 cm	6.93	2.47	8.0	17.2	9.3	60.0	287
	15-30	7.55	1.28	2.0	8.4	6.1	49.7	59.4

Treatments B and C received the same amount of fertilizer in 1976.

Values are means of three replicates.

For statistical analysis of the 0-15 cm. depth see Appendix.

with overburden. At the higher fertilizer rate with the non overburden treated soils the conductivity also increased. Overall values ranged from 0.60 to 2.47 mmhos/cm in the 0-15 cm depth to 0.50 to 2.01 mmhos/cm in the soil below 15 cm. These are higher than would be expected to be found for most virgin or cultivated soils but they are not high enough to cause concern to plant growth.

Amounts of ammonium nitrogen were low throughout. Nitrate concentrations were quite variable but were much higher. The high rate of fertilizer addition generally produced the highest amounts of residual nitrate. In treatments 3 and 4, where the plant growth was the poorest, NO_3-N values were higher than was found for other treatments.

Available phosphorus contents were moderately low. No consistent differences were found between either main treatments or subtreatments. The results of leaching losses and of soil analysis seem to indicate that much of the phosphorus added in fertilizers becomes fixed in the soil since uptake by the vegetation was probably quite small.

Potassium contents were also quite low in the surface 15 cm especially at the low fertilization rate. Surface soil values ranged from 18.2 to 117 ppm while in the lower depth concentrations were considerably lower.

Sulfate-S on the other hand was quite abundant. Concentrations were greatest in the overburden treatments (5, 6, and 7). Here values were between 133 and 305 ppm in the surface 0-15 cm. All soils contained adequate amounts of available sulfur for plant needs.

Even though isotopically tagged fertilizers were not used in this study we can make some approximate statements concerning the fate of added fertilizer nutrients. An estimate of fertilizer losses in water runoff has already been discussed (see Section 3.6.2) and the lysimeter study provides data related to possible leaching losses (see Section 3.6.6). However, several assumptions must be made if the lysimeter results are used in conjunction with results from the main plot experiment. Firstly the soil mixes in the lysimeters are not precisely the same as occur on the main experimental area. Plant growth in the lysimeters was not as extensive as on the main plot and consequently nutrient uptake was likely less and the potential for nutrient leaching was greater. Finally, due to the generally poor growth in the lysimeters, treatment C did not receive an addition of fertilizer in August, 1976, as was the case in the main experiment.

The tabulation below gives a rough comparison of nitrogen use for all three fertilization regimes on treatment 1 (peat on the surface) and treatment 5 (overburden over peat). Due to the preliminary nature of these results a more complete discussion of nitrogen, phosphorus and potassium cycling will be delayed until two years of data are at hand.

	Soil Nitrogen (Kg-N/ha)			Plant Nitrogen (Kg-N/ha)		Fertilizer (Kg-N/ha)	Estimated Losses (Kg-N/ha)		
	Total*	Available**		Tops	Roots		Runoff		Leaching***
		Jul/76	Sept/76				Soil	Water	
1A	840	25	4	59	32	80	nd	nd	1.7
5A	1860	43	7	69	20	80	nd	nd	2.0
1B	1770	39	4	65	nd	150	nd	nd	9.7
5B	1815	57	14	82	nd	150	nd	nd	5.8
1C	1410	74	61	76	22	300	1.0	0.4	4.9
5C	1635	43	60	88	25	300	1.2	2.6	5.2

* July data, does not include subsequent root production

** for 0 - 3C cm depth. Assumed bulk densities for the 0 - 15 and 15 - 30 cm depths were 0.3 and 1.0 g/cm^3 respectively

*** Leaching losses below 30 cm. Estimates for treatments B and C involved the addition of 150 Kg-N/ha

nd- not determined

Again it should be noted that the addition of peat provides large amounts of organic nitrogen. A small percentage of this will become available through natural microbial mineralization reactions. Unfortunately without using tagged fertilizers it is not possible to determine the natural rate of mineralization or the effect of the added fertilizer on the release of native soil nitrogen in a form available to plants.

Except where additional fertilizer was added in August, there was a gradual depletion in available nitrogen between July and September, 1976.

In the first year of growth there was little variation in the amount of nitrogen taken up into tops and roots. Total amounts varied between 89 and 113 Kg-N/ha in relation to a range of 80 to 300 Kg-N/ha added as fertilizer. It can be seen that, in terms of efficiency of fertilizer use, an addition as large as 300 Kg-N/ha is probably not needed during the first year. However, a definite pronouncement can not be made since the area was seeded much later than would be considered normal and therefore the growing season was short.

Nitrogen losses in runoff water and eroded soil materials were insignificant in relation to the amount added in fertilizers (total of 1.4 to 3.8 Kg-N/ha lost in relation to 80 to 300 Kg-N/ha added). Leaching losses, as estimated from the lysimeter study, were greater. However, values much less than the 1.7 to 9.7 Kg-N/ha would probably been found on the main experiment where plant growth was better.

3.7 Summary Conclusions

(1) A bare peat surface over the tailings sand was not able to prevent water channeling and erosion without the rapid establishment of a dense plant cover.

(2) In view of the slope involved, the extent of soil movement down slope was not rated serious on any of the vegetated plots. Losses were greatest where the highest rates of mine overburden had been incorporated into the tailings surface or where a layer of overburden was placed at the surface. Significant soil movement occurred where "Aquatain" and "Bitumuls" soil stabilizers had been used. If peat formed the soil surface, down slope movement of soil was slight. Contour trenching seemed to reduce the particulate movement down slope but it had no significant advantage over the incorporation of peat without trenching.

(3) Water infiltration rates were high. Lysimeter studies indicated that between 13 percent and 34 percent of the intercepted rainfall readily leached below a depth of about 30 cm.

(4) The highest volumes of surface water runoff occurred in treatments where mine overburden incorporation had been studied. The results indicated that, in relation to the total rainfall intercepted by the soil surface, the amount in runoff was quite small.

(5) In comparison to the amounts of nutrients supplied in fertilizer, the

losses in runoff water and eroded soil were very small. Leaching losses were greater. Nitrate, potassium and sulfate were leached more readily than phosphate and ammonium ions.

(6) Plot surfaces where mine overburden was added to the surface or was tilled in at a high rate became dry and hard. The percentage moisture held in the surface 30 cm was significantly less than with plot surfaces that had only been amended with peat.

(7) Soil pH and soluble salt concentrations were within the range acceptable for plant growth. Overburden treated plots had the highest surface conductivities.

(8) Soils contained moderate amounts of available plant nutrients before the plots were seeded and fertilized in July. By September depletion of mineral nitrogen, phosphorus and to a certain extent potassium had occurred.

(9) Sulfate sulfur analysis indicated that no further additions of sulfur containing fertilizers would be necessary in the immediate future.

(10) Seed germination and growth was adequate to protect the soil surface from erosion.

(11) Oat dry weight production was considerably greater than that for grasses and legumes. The cover produced by grasses and legumes alone was considered adequate in terms of erosion protection in all treatments except those that involved application of overburden to the surface or where a high rate of overburden was tilled into the surface.

(12) Dry weight yields were not significantly different between the different fertilizer regimes studied. Applications of 150 Kg-N per hectare and

over did not seem to help in the initial establishment of plant cover in comparison to a rate equivalent to 80 Kg-N per hectare.

(13) Plant uptake of nutrients was not significantly different at the two lower fertilizer application rates which were made in June. However, an additional application in August significantly increased uptake into plant tissues. The total plant uptake amounted to 90-110 Kg-N; 20-30 Kg-P; 85-135 Kg-K and 10 Kg-S per hectare.

(14) Dry weight production of root and shoot material was approximately equivalent.

(15) Root growth was largely limited to the surface 15 cm.

(16) Plant growth in the lysimeters was poor and highly variable. Extensive reseeding will be required next year.

(17) Commercial soil stabilizers demonstrated little advantages over other forms of surface amendments. The "Bitumuls" conditioner seemed to produce a more uniform plant cover, possibly by reducing seed water wash off.

(18) Symptoms of plant nutrient deficiencies were not widespread or related to any specific experimental treatment. Of those observed, nitrogen deficiencies seemed to be most common.

(19) Nitrate contents in plant tops reached levels that would cause some concern if plant material were used as livestock feed.

4. EXPERIMENT TO STUDY WAYS OF INCREASING THE ROOTING DEPTH OF PLANTS GROWN ON A TAILINGS SAND SLOPE (EXPERIMENT III).

4.1 Introduction

The previous years study on a vegetated area of the tailings pond dike indicated that grass root growth was restricted to the peat layer which had been added to the tailings sand surface. It was estimated that about 86 percent by weight of the roots were concentrated in the peat layer (3). Deeper penetration of roots should improve the stability of the dike through reducing the likelihood of erosion. It was initially hoped to study two possible approaches to promoting favorable conditions for deeper rooting. One aspect involved the deep incorporation of different surface amendments such as peat and mine overburdens. The second approach concerned the deep placement of fertilizer to stimulate the spread of root systems. In the first year it was decided to limit studies to assessing the incorporation of different surface soil amendments.

4.2 Objectives

To examine means by which rooting depth of plants can be encouraged to extend below the immediate surface of tailings material.

4.3 Experimental Design

An unvegetated area was selected immediately downslope of Experiment II (see Figure 2). Four different treatments were studied, each treatment was replicated three times.

Treatment:

1. Overburden added at 750 Tonnes/ha and tilled into the peat - tailings sand surface to a depth of 30 cm.
2. Additional peat added to give a depth of about 20 cm on the surface and incorporated in with the tailings sand to a depth of 30 cm.

3. Overburden added at 1500 Tonnes/ha and tilled into the peat surface to a depth of 30 cm.
4. Peat (about 10-15 cm) tilled into the tailings sand surface to a depth of about 15 cm

Fertilizer Amendment:

Treatments 1, 2, and 3

150 Kg-N/ha (58.3 Kg NO_3-N/ha; 91.7 Kg NH_4-N/ha)

40 Kg-P/ha

150 Kg-K/ha

20 Kg-S/ha

Lime at 5 Tonnes/ha

Treatment 4

80 Kg-N/ha (23.3 Kg NO_3-N/ha; 56.7 Kg NH_4-N/ha)

35 Kg-P/ha

75 Kg-K/ha

20 Kg-S/ha

Fertilizer applied in June as 21-0-0, 34-0-0, 11-55-0 and 0-0-62

Lime added as finely powdered feed grade limestone.

Plot size: 5m x 4m

Replicates: 3

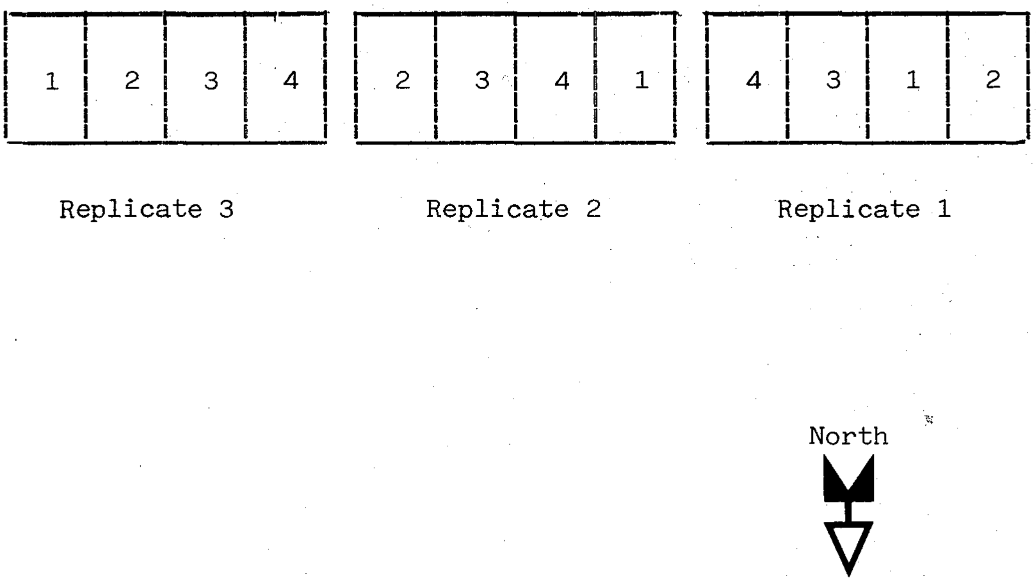
Total number of plots: 12

The experiment was set out in a randomized design as shown in Figure 5.

4.4 Plot Establishment

The plots were staked out and the original peat that was added by

Figure 5. Field plan of experiment on an unvegetated area on a tailings sand dike at the GCOS plant site at Fort McMurray, Alberta (Experiment [III]).



(slope 15–18°)

G.C.O.S. was raked evenly over the plots. Soil samples were taken on June 22, 1976. Starting on June 29, 1976 the overburden and extra peat was added. The amendments were tilled in with a rototiller to a depth of about 25 cm. Final mixing to 30 cm was completed by hand spading. Lime was added to plots 1, 2, and 3 and the lime incorporated by raking to a depth of about 7.5 cm. Fertilizer was added individually to each plot by hand, and also raked in to a depth of about 7.5 cm. About a week later, on July 10, the plots were seeded with the same seed mix and at the same rate as was used with Experiment II. Seed was lightly raked in and the soil surface packed down.

4.5 Work Plan

Visual and semi-quantitative measurements of germination and plant growth were made throughout the summer. Plant samples from one meter square areas were taken from each plot on 15 September. At the same time root samples and soil samples were taken. Root cores were taken for 0-15 cm, 15-30 cm and 30-60 cm depths.

Soil samples were taken at 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm and 90-120 cm.

4.6 Results

4.6.1 Soil Samples

(a) June 28th, 1976

Each plot was sampled to a depth of 120 cm before the addition of extra surface amendments. At this time the tailings material was covered by the peat that had been added by G.C.O.S. personnel. The results would provide baseline values and would show the uniformity of the peat addition and the tailings sand in the area.

The analysis indicated that the plot area chosen was more uniform than the larger area used for Experiment II. Visual observations showed that the peat layer was not as deep as on many parts of experiment II and that spreading had been more even.

The results of soil analysis are given in Table 34. Soil pH values ranged from 6.03 to 6.62 in the surface 15 cm. This reflected the mildly acidic nature of the peat used. Soil reaction became slightly more alkaline with depth. In the 90-120 cm depth pH values of 6.97 to 7.20 were found.

Soluble salt concentrations were highest in the surface peat layer. Conductivity values of between 0.57 and 0.84 mmhos/cm were recorded in the 0-15 cm depth while a range of 0.14 to 0.25 mmhos/cm was found in the tailings sand regions between 30 cm and 120 cm in depth.

Calcium was the dominant extractable cation (exchangeable + soluble). Surface values were quite variable. Concentrations within the 15 cm peat layer varied from 459 ppm to 1271 ppm. Smaller concentrations of sodium and magnesium were found. Concentrations of cations in the surface 15 cm were higher than in the lower depths. Surface concentrations of sodium were variable and ranged from 9.4 ppm with treatment 4, to 51.3 ppm in treatment 1. Less variability was encountered with magnesium. Concentrations were between 72.9 and 103 ppm in the surface 15 cm.

Organic carbon, total nitrogen and total exchange capacities were all

Table 34. Analysis of soil samples from an experiment to examine rooting of plants on a tailings sand dike at the GCOS plant site at Fort McMurray, Alberta - June 28th, 1976 (Experiment [III]).

		pH	Cond.	Mineral nitrogen		H_2O	P	K	SO_4-S	Acetate extractable			Org. C	Tot. N	T.E.C.
				NH_4-N	NO_3-N					Na	Ca	Mg			
			mmhos/cm	ppm		%		ppm			ppm		%	%	meq/100g
1	0-15 cm	6.60	0.76	16.8	6.9	16.8	2.2	73	93.3	51.3	559	96.9	2.6	0.22	11.2
	15-30	6.42	0.37	9.3	2.0	5.0	1.8	21	28.1	10.3	163	22.5	0.4	0.06	2.7
	30-60	7.12	0.22	17.8	1.2	4.3	1.2	21	8.6	5.5	71	19.1		0.03	
	60-90	7.03	0.21	8.9	0.3	5.0	1.7	12	9.7	8.0	63	19.2			
	90-120	7.17	0.25	14.8	0.0	5.0	1.3	15	8.5	6.8	58	18.6			
2	0-15 cm	6.17	0.57	15.8	3.1	25.6	0.3	27	76.9	21.7	1271	98.3	4.4	0.27	19.7
	15-30	6.53	0.27	16.6	0.3	7.4	1.5	14	16.6	7.4	250	32.9	1.0	0.07	3.2
	30-60	6.85	0.20	11.0	0.0	5.0	1.0	8	6.3	5.8	102	26.7		0.03	
	60-90	7.12	0.14	11.5	0.0	5.4	1.0	7	5.4	6.5	49	17.7			
	90-120	6.95	0.17	13.4	0.0	6.0	0.8	7	6.9	7.3	79	20.7			
3	0-15 cm	6.62	0.84	20.7	5.5	19.1	2.8	73	108	47.5	550	103	3.6	0.24	12.9
	15-30	6.55	0.40	19.6	0.6	8.8	2.0	16	26.1	8.4	150	22.5	1.0	0.13	2.8
	30-60	9.97	0.23	13.1	0.1	4.8	1.5	15	12.9	6.4	71	22.3		0.05	
	60-90	7.12	0.20	11.2	0.0	4.9	1.3	13	8.1	6.3	48	19.0			
	90-120	7.20	0.23	14.9	0.0	5.1	1.5	13	12.5	7.9	75	12.7			
4	0-15 cm	6.03	0.63	14.5	4.6	19.2	1.2	21	68.4	9.4	459	72.9	3.2	0.27	12.7
	15-30	6.38	0.26	13.6	0.6	8.1	1.3	14	14.7	5.3	125	22.5	0.9	0.06	2.4
	30-60	6.82	0.22	14.8	0.3	4.5	1.3	13	6.8	7.0	74	17.0		0.06	
	60-90	6.90	0.19	14.0	0.3	4.6	1.3	9	7.1	6.9	73	20.4			
	90-120	6.97	0.18	8.6	0.0	5.0	1.0	8	7.4	8.5	61	20.1			
Significance		***	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*			N.S.	N.S.	N.S.
L.S.D.		0.32								30.2					

Values are means of three replicates. Statistical analysis of the 0-15 cm. depth only.

highest in the 0-15 cm depth. This reflected the presence of the peat amendment at the surface of the plots. Organic carbon was between 2.6 percent and 4.4 percent in the 0-15 cm depth and between 0.4 and 1.0 percent in the 15-30 layer.

Exchange capacity was related to organic carbon contents and hence also to the amount of peat present. Values between 11.2 and 19.7 meq/100g indicated a good ability to hold nutrient cations in the surface 15 cm. Cation exchange capacity of the 15-30 cm depth was much less (2.4 - 3.2 meq/100g). Tailings sand had a very low cation exchange capacity (3).

Total nitrogen contents showed a similar pattern to organic carbon. Most of the organic nitrogen would be expected to be derived from the peat. Concentrations in the surface 15 cm varied from 0.22 - 0.27 percent. Organic nitrogen can be slowly converted into potentially available mineral forms such as ammonium and nitrate by microbial activity in the soil.

(b) <u>September 15th, 1976</u>

A similar set of core samples were taken on September 15, 1976, for the determination of moisture, pH, conductivity and available nutrients. In contrast to the June samples, they show differences due to the incorporation of overburden and extra peat. The results are shown in Table 35.

Surface pH was slightly higher than had been found with the initial samples. In the surface 0-15 cm values ranged from 6.65 to 7.10 with treatments 1, 2, and 3 which had received lime. Treatment 4, which was not limed had a significantly lower pH of 6.30 in the surface 15 cm.

Treatments 1 and 3 which involved the incorporation of overburden, had the highest conductivities. Even so the surface values of 1.65 mmhos/cm and 2.09 mmhos/cm for treatments 1 and 3 respectively were not high enough to

Table 35. Analysis of soil samples from an experiment to examine rooting of plants on a tailings sand dike at the GCOS plant site at Fort McMurray, Alberta - September 15th, 1976 (Experiment [III]).

		pH	Cond.	Mineral nitrogen		H_2O	P	K	SO_4-S
			mmhos/cm	NH_4-N	NO_3-N	%	ppm		
				ppm					
1	0-15 cm	6.93	1.65	1.9	2.7	11.9	15.4	72	61.6
	15-30	6.62	0.70	0.7	1.2	7.7	1.4	19	34.6
	30-60	6.62	0.44	0.3	1.1	5.1	0.8	12	20.5
	60-90	6.77	0.34	0.2	0.3	5.5	0.2	10	13.5
	90-120	7.02	0.30	0.6	0.5	5.0	0.8	10	10.1
2	0-15 cm	6.65	1.04	2.0	9.3	23.8	7.4	46	43.5
	15-30	6.47	0.68	1.4	3.5	10.3	1.0	15	36.0
	30-60	6.88	0.41	1.1	0.6	6.0	1.2	12	14.0
	60-90	6.95	0.35	0.8	2.5	6.0	1.0	11	9.9
	90-120	7.05	0.31	0.6	0.9	6.4	1.2	10	8.6
3	0-15 cm	7.10	2.09	2.8	17.1	17.2	25.6	118	122
	15-30	6.67	1.12	1.2	4.1	9.8	3.6	33	46.7
	30-60	6.53	0.48	0.4	0.4	4.5	2.0	12	24.6
	60-90	6.67	0.37	0.6	0.2	4.9	1.0	11	17.0
	90-120	6.93	0.36	0.8	0.3	5.3	1.6	11	14.4
4	0-15 cm	6.30	0.54	1.7	1.9	27.8	5.7	28	51.4
	15-30	6.20	0.53	0.7	0.4	6.6	1.2	12	33.2
	30-60	6.45	0.35	0.5	1.0	5.7	1.4	10	16.3
	60-90	6.85	0.29	0.5	0.3	6.1	0.8	10	10.6
	90-120	6.88	0.27	0.3	0.5	5.7	0.6	11	9.0
ignificance		*	***	N.S.	**	N.S.	***	***	*
.S.D.		0.56	0.48		9.8		10.0	33	56.9

Values are means of three replicates. Statistical analysis of the 0-15 cm. depth only.

restrict the growth of plants. Treatment 2 (extra peat added) had a conductivity of 1.04 mmhos/cm in the surface 15 cm. The control treatment 4 had the lowest conductivity, 0.54 mmhos/cm.

Available mineral nitrogen was generally low. Most of the nitrogen applied as fertilizer had been lost from the soil. Nitrogen could have been taken up by plants, microbial cells or lost through leaching and denitrification reactions. Generally nitrate was the predominate form of mineral nitrogen. Ammonium-N values were low and ranged from 1.7 to 2.8 ppm in the surface 15 cm and were less than 2 ppm in the lower hoisons. Nitrate-N in the 0-15 cm depth varied from 17.1 ppm with treatment 3 to 1.0 ppm with treatment 4. Values were quite variable between replicates.

There was evidence to suggest that sulfate was being leached in the soil. Values recorded in September for the lower depths (eg. 30-60, 60-90 and 90-120 cm) were generally higher than had been found in June. Sulfate concentrations were still highest in the surface 15 cm. The high rate of overburden addition (treatment 3) had 122 ppm SO_4-S in the surface 15 cm. Both overburden treatments (1 and 3) had higher levels of SO_4-S in the surface than the peat-only treatments. The overburden was naturally quite rich in sulfate (see Appendix).

The moisture content of the surface 15 cm was higher for treatments 2 and 4 which involved amendment with peat only. The overburden material has a lower capacity to retain moisture and seems to dry out more easily than the peat.

4.6.2 Vegetative Growth

A lower germination rate was recorded here than was found on the

Experiment II plot area which was seeded later. Germination was between 19.2 percent and 21.7 percent (see Table 36). There were no significant differences between treatments. Although complete identification of the plant species was not possible at this time, it seemed that most of the types that had been seeded had shown some germination. Growth was dominated by the rapidly growing Oat plants. The early growth was healthy in appearance. Later in the summer some deficiency symptoms of nitrogen in particular were evident. Plants showing nutrient deficiency were not widespread and did not appear to be specifically related to any particular treatment.

Average plant heights were measured on August 4th and again on August 27th (see Table 36). On August 4th, 25 days after seeding, there were no differences between the four experimental treatments. By August 27th, 48 days after seeding, the Oat plants on the overburden treated plots were not quite as high as those on the peat-only treatments. When the plants were sampled, Oats had headed out but few legumes or grasses had flowered or produced seed. At this time there did not seem to be any differences between the experimental treatments in respect to general plant growth or to erosion damage. Some plots had more patchy growth than others. Runoff water from higher up the slope had produced small channels on some plots. Erosion was assessed as very mild in relation to the extent of erosion on some areas bordering the experimental site or on the unseeded treatment in Experiment II.

(b) Plant Productivity

The methods used to take plant top and root samples were similar to that described in Experiments I and II. Dry weight yields are shown in Table 37. No significant differences could be found between the treatments

Table 36. Seed germination and plant height in the deep rooting experiment.

	Germination (%)		Plant height (cm.)			
	Average	SD	Aug. 4, 1976		Aug. 27, 1976	
			Average	SD	Average	SD
1	18.0	2.35	31.0	1.2	55.9	3.4
2	18.2	2.02	31.2	0.3	61.3	1.6
3	16.1	0.84	30.2	1.1	59.4	4.6
4	17.2	0.66	30.9	0.6	61.0	3.3
Significance	N.S.		N.S.		N.S.	

Vales are means of three replicates.

Table 37. Dry weight yield of plant tops and roots and the root:shoot ratio (Experiment III)- 1976.

	Top yield (Kg/m^2)		Root yield (Kg/m^2)								Root/shoot
			0–15 cm.		15–30 cm.		30–60 cm.		Total		
	Ave.	SD	Ave.	SD	Ave.	SD	Ave.	SD	Ave.	SD	
1	0.211	0.044	0.122	0.043	0.037	0.017	0.0013	0.0011	0.161	0.058	0.76
2	0.277	0.028	0.203	0.009	0.028	0.009	0.0015	0.0003	0.264	0.055	0.84
3	0.258	0.042	0.163	0.043	0.037	0.020	0.0011	0.0009	0.201	0.060	0.80
4	0.238	0.031	0.156	0.060	0.017	0.013	0.0008	0.0015	0.174	0.072	0.73
Signif.	N.S.		N.S.		N.S.		N.S.		N.S.		

Values are means of three replicates.

imposed for either total root or top production. The results were quite variable between replicates. The yield of above ground material varied between 0.211 and 0.277 Kg/m^2. Root yields were between 0.161 and 0.233 Kg/m^2. With the deep tilling treatments, between 75.8 and 87.1 percent of the root material was in the surface 15 cm. Where peat was only tilled to 15 cm, 90.1 percent was located in the surface 15 cm. Most of the roots were confined to the regions that were amended with peat or overburden. On average the overburden treated plots had a higher percentage of root weight in the 15-30 cm depth than the other treatments. However, this may not be due to the presence of overburden but rather to the tillage of the initial peat amendment to a greater depth than in other treatments. Root production in the 30-60 cm depth was very small during the first year of growth (0.008 to 0.0015 Kg/m^2 or from 0.1 percent to 1.2 percent of the total weight).

4.6.3 Plant Analysis

The root material isolated from each depth was combined to give a bulk sample for each treatment. The results of top and root analysis are shown in Table 38.

(a) Plant Tops

Plant tops had slightly higher total nitrogen content where the higher rate of fertilizer addition had been made. Plant top material in treatment 4 had a total nitrogen content of 1.92 percent. The contents of total phosphorus, potassium, sulfur and calcium were not significantly different between the four different treatments.

Nitrate content of the above ground material varied from 0.66 percent to 0.84 percent. It is considered that nitrate contents of livestock feeds

Table 38. Analysis of plant material (Experiment [III]) - 1976.

		N (%)	P (%)	K (%)	S (%)	Ca (%)	Nitrate (%)
TOPS	1	2.35	0.39	2.73	0.22	0.33	0.66
	2	2.25	0.39	3.11	0.18	0.44	0.84
	3	2.36	0.39	3.28	0.19	0.39	0.66
	4	1.92	0.33	2.50	0.21	0.38	0.66
	Significance	*	N.S.	N.S.	N.S.	N.S.	*
	L.S.D.	0.32					0.14
ROOTS	1	1.63	0.82	1.17	0.20	0.66	
	2	1.14	0.83	1.23	0.18	0.81	
	3	1.26	0.89	1.45	0.18	0.53	
	4	1.05	0.62	0.57	0.16	0.70	
	Significance	N.S.	*	N.S.	N.S.	N.S.	
	L.S.D.		0.17				

All values are means of three replicates.

that are between 0.5 and 1.5 percent are potentially toxic but are more likely to cause decreased performance in animals. Over 1.5 percent nitrate is considered to be toxic.

Total nitrogen content of roots was quite variable and ranged from 1.05 percent to 1.63 percent. No significant differences existed between treatments. Root contents were significantly lower than was found in the top growth.

Phosphorus contents were higher in the roots than in the shoots. Addition of the higher rate of fertilizer produced a slightly higher content of total phosphorus in the roots. A total of 40 Kg-P/ha was added as fertilizer to treatments 1, 2 and 3 while treatment 4 received 35 Kg-P/ha.

Potassium levels were significantly lower in the roots than in the shoots. Average values in treatment 4 were considerably lower (0.57 percent) in comparison to treatments 1, 2, and 3 (1.17 to 1.45 percent total-K). The large differences in the content of root potassium and the results of soil analysis seem to indicate that the deeper tillage in treatment 1, 2, and 3 helped to increase the uptake of potassium. The deeply tilled treatment also received more fertilizer-K than the control treatment 4.

The sulfur content of roots was approximately the same in the different experimental treatments imposed.

The calcium content of the roots was approximately twice that found in the top material.

Calcium uptake was not significantly higher where lime had been added.

Table 39 shows the total amounts of nitrogen, phosphorus, potassium, sulfur and calcium that was taken up into plant material during the first year of revegetation of the area.

Table 39. Total uptake of nutrients by plant tops and roots (Experiment [III]) - 1976.

	Nutrient content (Kg/ha)														
	Tops					Roots					Total				
	N	P	K	S	Ca	N	P	K	S	Ca	N	P	K	S	Ca
Treatment-1	49.6	8.2	57.6	4.6	7.0	25.9	13.2	18.8	3.2	10.6	75.5	21.4	76.4	7.8	17.6
Treatment-2	62.3	10.8	86.1	5.0	12.2	26.6	19.3	28.7	4.2	18.9	88.9	30.1	114.8	9.2	31.1
Treatment-3	60.9	10.1	84.6	4.9	10.0	25.3	17.9	29.1	3.6	10.7	86.2	28.0	113.7	8.5	20.7
Treatment-4	45.7	7.9	59.5	5.0	9.0	18.3	10.8	9.9	2.8	12.2	64.0	18.7	69.4	7.8	21.2

Fertilizer added- Treatments 1,2, and 3 150 Kg-N; 40 Kg-P; 150 Kg-K and 20 Kg-S per hectare.
Treatment 4 80 Kg-N; 35 Kg-P; 75 Kg-K and 20 Kg-S per hectare.

All values are calculated from the means of three replicates.

Greater amounts of total nutrients were taken up with treatments 2 (high rate of peat tilled to 30 cm). Treatment 1 (lower rate of overburden tilled to 30 cm) gave a higher uptake of N, P, and K than the control treatment 4.

At the low fertilization rate (treatment 4), 64 Kg-N; 18.7 Kg-P; 69.4 Kg-K; 7.8 Kg-S and 21.2 Kg-Ca per hectare were taken up into plant tissues. Potassium uptake in the roots only accounted for 9.9 Kg-K/ha.

With the treatments that received the higher rate of fertilizer amendment, 75.5 - 88.9 Kg-N; 21.4 - 30.1 Kg-P; 76.4 - 114.8 Kg-K; 7.8 - 9.2 Kg-S and 17.6 - 31.1 Kg-Ca per hectare were incorporated into plant tissues.

The level of available sulfur in the soil in relation to plant uptake suggests that there is little need to add sulfur containing fertilizers in the foreseeable future.

4.7 Summary Conclusions

(1) Deep tillage of overburden and peat resulted in a greater proportion of root mass in the 15-30 cm depth. Root penetration below the 30 cm depth was slight.

(2) Initial soil sampling prior to the implementation of the experimental treatments showed that the area was generally more uniform with respect to soil properties than the Experiment II area.

(3) Amounts of available phosphorus and potassium were low at this time.

(4) Plant growth on the plots was adequate to prevent erosion.

(5) Average top and root dry weight yields were within the range encountered in Experiment II. Plant uptake of nutrients were similar in comparison to the same fertilizer treatment.

5 GENERAL STUDIES

5.1 Microbial Numbers and Soil Respiration

A comparison was made of biological activity of the older experiment (I) area and the newly established experiment (II) site. Soil respiration was measured in the laboratory and in the field. The results are presented in Tables 40 and 41. The measurement of soil respiration during September indicated that on average the biological activity in the soils in experiment (I) were higher than in experiment (II). However, the differences were quite slight. No significant differences could be found between the treatments studied. Laboratory measurements showed larger differences. The rates recorded with soils from the older experimental area were considerably greater than those from experiment (II). The increased production in carbon dioxide was thought to be due to the greater decomposition of plant root and top residues or possibly to higher numbers of organisms. The results showed that "baseline" respiration rates for a peat or peat/overburden amended site were between 0.06 and 0.13 mg CO_2-C/100g/hr at 20°C. Values for an "established" plot seemed to be about 0.19 to 0.29 mg CO_2-C/100g/hr. There were no differences between the experimental treatments studied.

The tailings sand samples had very low microbial activities. The fresh sample had a higher activity than the older one, possibly since there may have still been a certain amount of degradable bitumen in the fresh material. The pH and conductivity of both samples were quite different (see Appendix).

The numbers of different organisms generally showed a relationship to the laboratory soil respiration rate. Experiment (I) soil contained between

Table 40. Microbial numbers and soil respiration for selected treatments in Experiment (I), 1976.

Treatment	Microbial numbers/g			Soil respiration	
	Bacteria ($x\ 10^7$)	Actinomycetes ($x\ 10^7$)	Fungi ($x\ 10^4$)	Field* (mg CO_2-C/ m^2/hr)	Laboratory** (mg CO_2-C/ 100g/hr)
To	27.2	2.1	8.8	29.5	0.191
T2	54.5	2.2	20.2	31.9	0.294
T4	45.9	0.5	10.6	35.8	0.219
T5	30.1	1.6	12.4	30.0	0.251
Significance	N.S.	N.S.	N.S.	N.S.	N.S.

Values are means of three replicates.

* Soil respiration was measured on September 15, 1976

Mean air temperature = 17.4 C

Mean soil temperature	To 13.1 C
(at 4 cm depth)	T1 13.3 C
	T2 12.9 C
	T5 13.3 C

** Constant temperature of 20 C.

Table 41. Microbial numbers and soil respiration from selected treatments in Experiment (II) and for two samples of tailings sand

Treatment	Microbial numbers/g			Soil respiration	
	Bacteria ($x 10^7$)	Actinomycetes ($x 10^7$)	Fungi ($x 10^4$)	Field* (mg CO_2-C/ m^2/hr)	Laboratory** (mg CO_2-C/ 100g/hr)
1-A	5.77	0.230	9.33		0.072
5-A	3.61	0.068	8.20		0.073
6-A	2.92	0.090	4.00		0.058
7-A	5.69	0.079	7.92		0.069
1-C	13.1	0.194	21.7	22.4	0.128
5-C	6.26	0.211	5.65	21.8	0.070
6-C	8.30	0.104	8.94	25.9	0.070
7-C	7.87	0.177	6.76	32.3	0.070
Sig. & L.S.D.	*5.47	N.S.	** 7.28	N.S.	
Fresh T.S.	0.24	0.010	0.10		0.016
Old T.S.	0.015	0.001	0.18		0.008

Fresh tailings sand taken from the edge of the tailings pond
Old tailings taken from the 30-45 cm depth near Experiment III

* Mean air temperature 18°C

Mean soil temperature (at 4 cm depth)
1-C 13.4°C
5-C 14.1°C
6-C 14.1°C
7-C 13.8°C

** Constant temperature of 20°C

Values are means of three replicates except for tailings sand samples.

2.7 and 5.5 x 10^8 bacteria per gram while the experiment (II) soils contained 2.9 to 5.8 x 10^7 bacteria per gram. A similar trend was observed with actinomycetes which were over an order of magnitude lower than the bacteria. Differences between experiment (I) and (II) were not as noticeable where fungal counts were concerned. Between 8.3 and 12.4 x 10^4 per gram were found with experiment (I) soils and 4.0 to 9.3 x 10^4 per gram with experiment (II) soils.

Numbers of bacteria, actinomycetes and fungi were much lower in the tailings sand samples. The variety of different types of bacteria was much less than had been found with peat and overburden amended sands. Quite high numbers of organisms were found in the tailings sand samples that were studied last year. It seems possible that the samples of tailings that were taken last year had been contaminated with other soil materials that contained much higher numbers of micro-organisms.

The addition of peat and overburden to the tailings sand surface leads to an increase in microbial numbers, diversity of microbial types and a higher overall soil respiration rate. High microbial activity is important in ensuring efficient recycling of nutrient elements from organic forms into those that are available to plants.

5.2 Water Infiltration Rates

Table 42 shows the water infiltration measurements made in the field. All the surfaces studied had very high water infiltration rates. The surface of the Tc treatment in experiment (I) had the lowest infiltration rate (16.6 cm/hr). This is probably due to the dense surface cover of Creeping Red Fescue and the root mat that develops below. The bare tailings sand

Table 42. Water infiltration rates - 1976

Treatment	Infiltration rate (cm/hr)
Bare tailings	21.6
Expt (I) To	16.6
Expt (II) 1-A	24.1
Expt (II) 3-A	25.8
Expt (II) 4-A	27.3
Expt (II) 5-A	24.0
Expt (II) 6-A	30.5
Significance	N.S.

Measurements were taken in June, 1976 while Experiment (II) was not vegetated

Values are means of three replicates.

surface had a slightly lower infiltration rate than the remaining treatments on experiment (II). The values recorded for subtreatments 1, 3, 4, 5 and 6 on main treatment A were not significantly different and varied between 24.0 and 30.5 cm/hr.

The data indicate that rainfall will be rapidly taken up by tailings sand, peat and overburden surfaces. This conclusion is largely substantiated by the results of the lysimeter studies.

6 GENERAL CONCLUSIONS AND RECOMMENDATIONS

Since this was the first year of study involving experiments (II) and (III) many of the recommendations and conclusions are tentative.

(a) The results and observations of experiment (I) this year indicate that although a permanent plant cover has been established and the site is physically fairly stable, it cannot be considered biologically stable yet. Mineralization reactions were able to supply good amounts of available plant nutrients early in the year. Additions of fertilizer the previous year produced higher early plant biomass yields. However, continued good plant growth was dependent upon the addition of extra fertilizers during 1976. Even large additions of fertilizers in June of 1975 did not seem to promote plant growth later in the summer of 1976.

If good plant top production is required, annual addition of fertilizers preferably twice during the summer, should be made. The amounts added should be at the minimum 80 Kg-N, 20 Kg-P and 80 Kg-K per hectare per year to produce adequate results.

(b) The addition of sulfur containing fertilizers is not needed on the areas of the dike that were studied.

(c) Liming does not seem to be needed for several years where adequate amounts of peat with a slightly acidic reaction has been added.

(d) In newly vegetated areas peat seems to be the best surface amendment to add. It has good moisture holding characteristics, high cation exchange capacity and produces a good plant cover. It is however, often low in available plant nutrients and will decompose quite rapidly. S. 132

(e) Overburden materials studied seem to be useful surface amendments. Their long term use is still being assessed. They have good buffering properties, add some clay to the soil and contain good reserves of potassium. They are more erodable than peat, do not produce as uniform a plant cover, develop tough surfaces and may contain undesirable amounts of salts. Application costs in relation to peats will likely be higher.

(f) Soil conditioners, stabilizers and contouring methods do not seem to be economically advantageous in most situations in view of the success with the use of peats.

(g) During the first year of revegetation the following fertilization scheme is tentatively recommended.

May: With seed - 75 Kg-K/ha
75 Kg-N/ha
40 Kg-P/ha
As 34-0-0, 11-55-0, 0-0-60

Late July: 150 Kg-K/ha
150 Kg-N/ha
40 Kg-P/ha

(h) Surface amendments of peat and overburden should be tilled into the tailings sand layer as deeply as possible. Deep root penetration seems to be more limited by lack of nutrients at depth than by lack of available moisture.

(i) The use of a quick growing nurse crop such as Oats is recommended especially where areas are seeded late in the spring and summer. Rapid soil stabilization by root and top growth is essential to prevent soil erosion even where peat and overburden amendments have been added.

(j) Tailings sands have low numbers of microorganisms in relation to cultivated soils. The addition of peat and overburden adds microorganisms. The ability of the soils to develop good microbial populations capable of decomposing dead plant tissues should be studied in more detail. It is by efficient cycling of added nutrients that a stable plant cover will be rapidly established.

7 BIBLIOGRAPHY

1. Methods of soil analysis, Part I and II. Agronomy Monograph No. 9, American Society of Agronomy Inc., Madison, Wisc. (1965).
2. Manual on soil sampling and methods of analysis. Prepared by the Subcommittee of the Canada Soil Survey Committee on Methods of Analysis. Edit. J.A. McKeague, (1975).
3. Takyi, S.K., M.J. Rowell, W.B. McGill and M. Nyborg. Reclamation and vegetation of surface mined areas in the Athabasca tar sand. Environmental research monograph 1977-1, Syncrude Canada Ltd.

8 APPENDIX

8.1 Properties of soils used in the study

Table 43 shows the analysis of physical and chemical properties of the soils used in this study. The tailings sands 'B' and 'C' were the 'fresh' and 'old' tailings samples used in the microbiological studies. The fresh sample had a high pH and a relatively high concentration of soluble salts which would indicate the presence of residual sodium hydroxide. The old sample had a lower pH and salt content. Apparently much of the soluble salt had leached out. Similar properties were shown by the tailings material that was used in the lysimeter studies (Tailings sand A). Contents of available plant nutrients were very low in the tailings samples. There were measurable amounts of residual bitumen present. Tailings sands were low in organic carbon and total nitrogen and contained from 93-96 percent sand.

The different peat samples that were used were all acidic. Soluble salt contents were quite low. The original peat that was added to areas (II) and (III) contained moderate amounts of mineral nitrogen when sampled in June. Peats B and C which were used as extra amendments and in lysimeter studies were low in mineral nitrogen. All peats had low amounts of available phosphorus. Potassium was high in samples A and C but low in sample B. Peat A was less decomposed than either sample B or C. This was reflected in the higher organic carbon content of peat A. The ratios of carbon to nitrogen were about the same.

Overburden materials were typified by neutral to mildly alkaline pH values and relatively high conductivities. Levels of mineral nitrogen and

Table 43. Analysis of soil involved in the revegetation of steep tailings sand slopes at the G.C.O.S. plant site at Fort McMurray, Alberta - Experiments (II) and (III).

	pH	Cond.	Mineral nitrogen		P	K	SO_4-S	Tot. N	Org. C	C:N	Extractable hydrocarbon
		mmhos/cm	NH_4-N	NO_3-N	ppm			%	%		%
			ppm								
Tailings sand-A	6.23	0.46	1.5	1.3	2.3	9	7.0	0.03	0.33	11.0	0.18
Tailings sand-B	9.70	1.17						0.01	0.28	28.0	
Tailings sand-C	6.90	0.40						0.01	0.29	29.0	
Peat-A	5.40	0.29	41.6	53.8	2.8	233	10.4	1.82	44.7	24.6	
Peat-B	6.08	0.42	3.3	1.0	0.0	298	19.6	0.89	23.8	26.7	
Peat-C	6.63	0.54	1.0	1.0	0.0	34	17.2	0.67	18.5	27.6	
Overburden-A	7.75	2.66	14.0	2.2	1.8	205	107	0.08	1.1	13.8	0.15
Overburden-B	7.00	3.52	6.8	1.0	9.8	85	97.0	0.03	1.1	36.7	0.57

Tailings sand-A : Taken from below the peat layer added to experimental sites (II) and (III).
Tailings sand-B : Fresh tailings sand taken from the side of the tailings pond, G.C.O.S site.
Tailings sand-C : Old tailings sand from the 30-45cm depth below site (III).
Peat-A : Original peat added to experimental sites (II) and (III).
Peat-B : Extra peat added to certain areas in site (II) and (III).
Peat-C : Peat added to lysimeters.
Overburden-A : Overburden added to experimental areas (II) and (III).
Overburden-B : Overburden added to lysimeters.

Table 43. (Continued)

	Particle size distribution			Soluble cations				Sol + Exch. cations		
	% sand	% silt	% clay	Na	K	Ca	Mg	Na	Ca	Mg
				ppm				ppm		
Tailings sand-A	96	1	3	6.0	1.1	8.0	3.2	6.3	96.0	22.0
Tailings sand-B	94	4	2							
Tailings sand-C	93	2	5							
Peat-A				97.6	88.4	343	74.4	168	10550	1200
Peat-B				13.0	3.5	108	28.3	22.3	5800	925
Peat-C				27.7	2.3	41.1	12.9	115	4600	635
Overburden-A	79	12	9	164	19.7	102	32.4	635	1675	260
Overburden-B				148	11.4	44.5	16.3	515	410	145

available phosphorus were quite low. However, overburdens were relatively rich in sulfate. Potassium was also quite high. The overburden added to the main plots of experiments II and III contained more potassium than that used in the lysimeter studies. Overburden B contained 0.57% extractable hydrocarbon while overburden A contained 0.15%. These levels would not be expected to affect seed germination or plant growth to any great extent. The overburdens were quite sandy. Overburden A contained 79% sand, 12% silt and 9% clay. Texturally it would be classified as a loamy sand.

Table 44 shows the moisture holding characteristics of different soils and mixes. The tailings sand had the poorest ability to hold moisture. Overburden was also quite poor reflecting its high content of sand. Peat had the best moisture holding characteristics. When the materials were mixed together, the moisture retention tended to be related to the amount of peat that the mix contained.

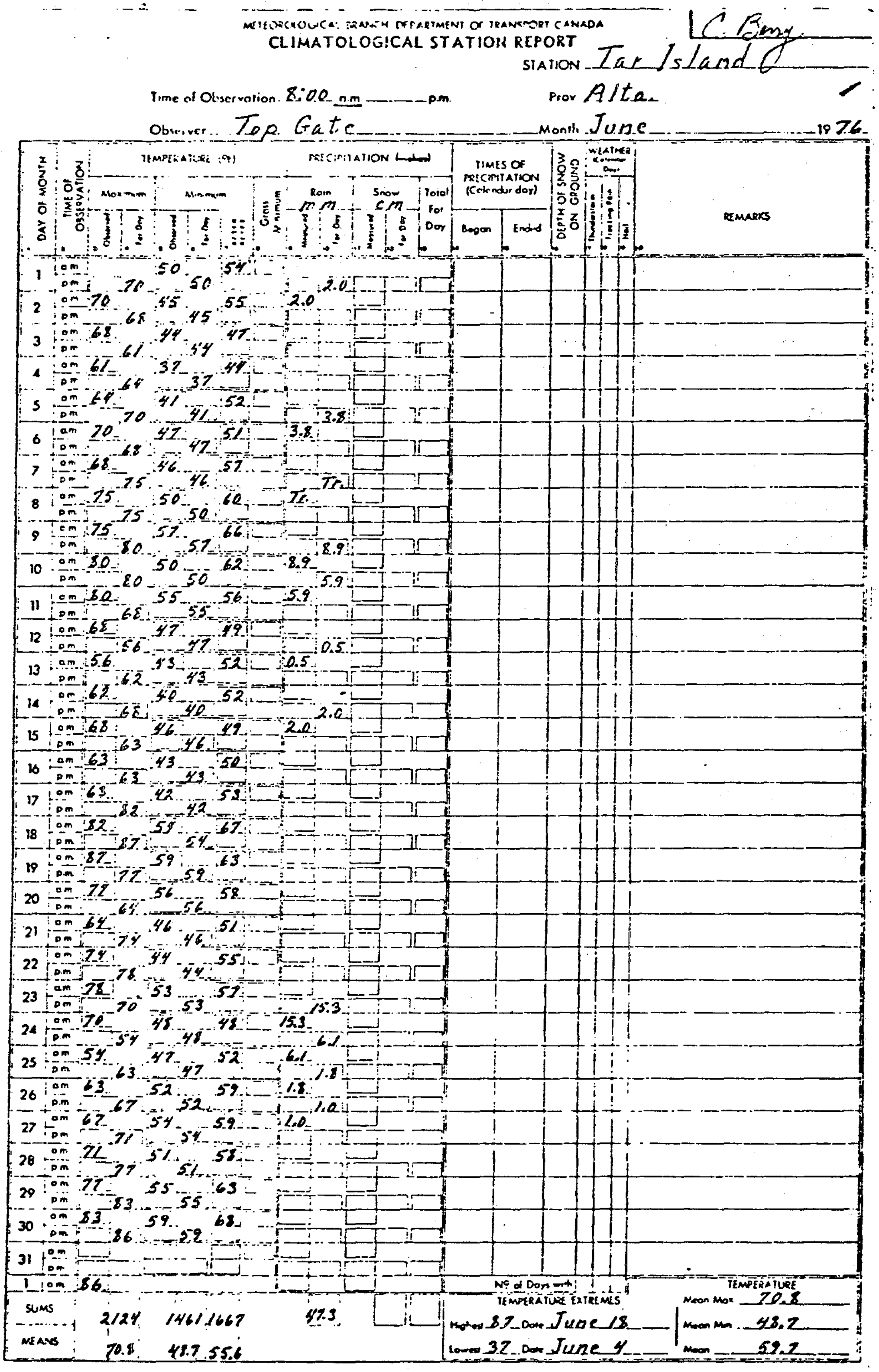
8.2 Rainfall data

Tables 45–48 shows rainfall data collected from the G.C.O.S. Top Gate station between June and September 1976.

Table 44. Moisture holding capacities of different soils and mixes

Soil or mix	Moisture content (%)	
	1/3 atmos.	15 atmos.
Peat	72.0	43.6
Overburden	9.9	4.1
Tailings sand	1.8	0.8
Tailings:peat (1:1)	15.8	12.5
Tailings:peat:overburden (1:1:1)	10.7	4.9

Table 45. Rainfall data - June, 1976.



METEOROLOGICAL BRANCH DEPARTMENT OF TRANSPORT CANADA

CLIMATOLOGICAL STATION REPORT

C. Bery

STATION Tar Island

Time of Observation 8:00 a.m ______ p.m.

Prov Alta.

Observer Top Gate

Month June 1976

DAY OF MONTH	TIME OF OBSERVATION	TEMPERATURE (°F)					PRECIPITATION						TIMES OF PRECIPITATION (Calendar day)		DEPTH OF SNOW ON GROUND	WEATHER (Calendar Day)			REMARKS
		Maximum		Minimum			Grass Minimum	Rain mm		Snow cm		Total For Day							
		Observed	For Day	Observed	For Day	[illegible]		Measured	For Day	Measured	For Day		Began	Ended		Thunderstorm	Freezing Rain	Hail	
1	am			50		54													
	pm		70		50				2.0										
2	am	70		45		55		2.0											
	pm		68		45														
3	am	68		44		47													
	pm		61		44														
4	am	61		37		44													
	pm		64		37														
5	am	64		41		52													
	pm		70		41				3.8										
6	am	70		47		51		3.8											
	pm		68		47														
7	am	68		46		57													
	pm		75		46				Tr.										
8	am	75		50		60		Tr.											
	pm		75		50														
9	am	75		57		66													
	pm		80		57				8.9										
10	am	80		50		62		8.9											
	pm		80		50				5.9										
11	am	80		55		56		5.9											
	pm		68		55														
12	am	68		47		49													
	pm		56		47				0.5										
13	am	56		43		52		0.5											
	pm		62		43														
14	am	62		40		52													
	pm		68		40				2.0										
15	am	68		46		49		2.0											
	pm		63		46														
16	am	63		43		50													
	pm		63		43														
17	am	63		42		53													
	pm		82		42														
18	am	82		53		67													
	pm		87		54														
19	am	87		59		63													
	pm		77		59														
20	am	77		56		58													
	pm		64		56														
21	am	64		46		51													
	pm		74		46														
22	am	74		44		55													
	pm		78		44														
23	am	78		53		57													
	pm		70		53				15.3										
24	am	70		48		48		15.3											
	pm		54		48				6.1										
25	am	54		47		52		6.1											
	pm		63		47				1.8										
26	am	63		52		59		1.8											
	pm		67		52				1.0										
27	am	67		54		59		1.0											
	pm		71		54														
28	am	71		51		58													
	pm		77		51														
29	am	77		55		63													
	pm		83		55														
30	am	83		59		68													
	pm		86		59														
31	am																		
	pm																		
1	am	86																	
SUMS			2124		1461	1667			47.3				Nº of Days with						
MEANS			70.8		48.7	55.6													

TEMPERATURE EXTREMES

Highest 87 Date June 18

Lowest 37 Date June 4

TEMPERATURE

Mean Max 70.8

Mean Min 48.7

Mean 59.7

Table 46. Rainfall data - July, 1976.

METEOROLOGICAL BRANCH DEPARTMENT OF TRANSPORT CANADA

C. Berry

CLIMATOLOGICAL STATION REPORT

STATION Tar Island

Time of Observation 8:00 a.m. ________ p.m.

Prov. Alta.

Observer Top Gate

Month July 1976

DAY OF MONTH	TIME OF OBSERVATION	TEMPERATURE (°F) Maximum Observed	Maximum For Day	Minimum Observed	Minimum For Day	[illegible]	Grass Minimum	PRECIPITATION (~~inches~~) Rain mm Measured	Rain mm For Day	Snow cm Measured	Snow cm For Day	Total For Day	TIMES OF PRECIPITATION (Calendar day) Began	Ended	DEPTH OF SNOW ON GROUND	WEATHER (Calendar Day) Thunderstorm	Freezing Rain	Hail	REMARKS
1	a.m.			66		69													
	p.m.		79		66														
2	a.m.	79		63		64													
	p.m.		79		63														
3	a.m.	79		51		60													
	p.m.		80		51														
4	a.m.	80		55		61													
	p.m.		78		55														
5	a.m.	78		60		63													
	p.m.		81		60														
6	a.m.	81		55		67													
	p.m.		85		55				6.3										
7	a.m.	85		58		67		6.3											
	p.m.		80		58				12.4										
8	a.m.	80		61		63		12.4											
	p.m.		65		61				3.0										
9	a.m.	65		57		60		3.0											
	p.m.		71		57				1.3										
10	a.m.	71		51		51		1.3											
	p.m.		59		51														
11	a.m.	59		50		55													
	p.m.		75		50				2.0										
12	a.m.	75		54		61		2.0											
	p.m.		74		54				3.0										
13	a.m.	74		57		58		3.0											
	p.m.		58		57				1.9										
14	a.m.	58		48		51		1.9											
	p.m.		66		48														
15	a.m.	66		46		53													
	p.m.		75		46				1.9										
16	a.m.	75		54		59		1.9											
	p.m.		82		54				4.3										
17	a.m.	82		58		69		4.3											
	p.m.		78		58														
18	a.m.	78		55		64													
	p.m.		74		55														
19	a.m.	74		47		57													
	p.m.		64		47														
20	a.m.	64		46		50													
	p.m.		76		46				5.3										
21	a.m.	76		50		55		5.3											
	p.m.		67		50				2.5										
22	a.m.	67		53		58		2.5											
	p.m.		73		53														
23	a.m.	73		54		58													
	p.m.		79		54				4.6										
24	a.m.	79		53		61		4.6											
	p.m.		75		53														
25	a.m.	75		52		58													
	p.m.		78		52				0.5										
26	a.m.	78		54		56		0.5											
	p.m.		61		54				3.0										
27	a.m.	61		50		53		3.0											
	p.m.		67		50				5.3										
28	a.m.	67		52		53		5.3											
	p.m.		68		52				Tr.										
29	a.m.	68		53		58		Tr.											
	p.m.		67		53				0.6										
30	a.m.	67		56		57		0.6											
	p.m.		71		56														
31	a.m.	71		51		55													
	p.m.		78		51														
1	a.m.	78																	
SUMS			2263		1670	1759			57.9										
MEANS			73.0		53.9	56.7													

No. of Days with

TEMPERATURE EXTREMES

Highest 85 Date July 6

Lowest 46 Date July 20

TEMPERATURE

Mean Max. 73.0

Mean Min 53.9

Mean 63.4

Table 47. Rainfall data - August, 1976.

METEOROLOGICAL BRANCH · DEPARTMENT OF TRANSPORT · CANADA

CLIMATOLOGICAL STATION REPORT

C. Bray

STATION Tar Island

Time of Observation 8:00 am ______ p.m.

Prov. Alta

Observer Top Gate

Month August 1976

DAY OF MONTH	TIME OF OBSERVATION	TEMPERATURE (°F) Maximum Observed	Maximum For Day	Minimum Observed	Minimum For Day	Minimum	Grass Minimum	PRECIPITATION ~~inches~~ m.m. Rain Measured	Rain For Day	Snow Measured	Snow For Day	Total For Day	TIMES OF PRECIPITATION (Calendar day) Began	Ended	DEPTH OF SNOW ON GROUND	WEATHER			REMARKS
1	a.m.			54		62													
	p.m.		81		54				2.8										
2	a.m.	81		61		68		2.8											
	p.m.		84		61				0.5										
3	a.m.	84		62		64		0.5											
	p.m.		80		62				0.3										
4	a.m.	80		53		57		0.3											
	p.m.		78		53														
5	a.m.	78		54		58													
	p.m.		84		54														
6	a.m.	84		57		61													
	p.m.		81		57				0.6										
7	a.m.	81		57		58		0.6											
	p.m.				57														
8	a.m.																		
	p.m.																		
9	a.m.																		
	p.m.																		
10	a.m.																		
	p.m.		82			63			0.5										
11	a.m.	82		58				0.5											
	a.m.		80		58														
12	a.m.	80		59		63													
	p.m.		85		59														
13	a.m.	85		59		63													
	p.m.		83		59				31.2										
14	a.m.	83		60		68		31.2											
	p.m.		85		60														
15	a.m.	85		67		73													
	p.m.		86		67														
16	a.m.	86		66		73													
	p.m.		85		66														
17	a.m.	85		59		75													
	p.m.		74		59				Tr.										
18	a.m.	74		54		62		Tr.											
	p.m.		78		54														
19	a.m.	78		53		58													
	p.m.		73		53														
20	a.m.	73		51		54													
	p.m.		71		51														
21	a.m.	71		50		52													
	p.m.		70		50				Tr.										
22	a.m.	70		49		51		Tr.											
	p.m.		72		49														
23	a.m.	72		49		52													
	p.m.		73		49														
24	a.m.	72		47		48													
	p.m.		67		47														
25	a.m.	67		47		56													
	p.m.		66		47				Tr.										
26	a.m.	66		53		54		Tr.											
	p.m.		55		53				36.8										
27	a.m.	55		42		45		36.8											
	p.m.		58		42														
28	a.m.	58		42		45													
	p.m.		69		42				1.3										
29	a.m.	69		45		49		1.3											
	p.m.		70		45				0.3										
30	a.m.	70		43		45		0.3											
	p.m.		68		43				1.3										
31	a.m.	68		45		50		1.3											
	p.m.		68		45														
1	a.m.	68																	
SUMS			2106		1496	1627			75.6										
MEANS			75.2		53.4	58.1													

No. of Days with

TEMPERATURE EXTREMES

Highest 86 Date Aug. 15

Lowest 42 Date Aug. 27 & 28

TEMPERATURE

Mean Max 75.2

Mean Min 53.4

Mean 64.3

Table 48. Rainfall data - September, 1976.

CLIMATOLOGICAL STATION REPORT

STATION Tar Island

Time of Observation 8:00 am ______ p.m.

Prov. Alta

Observer Top Gate

Month September 1976

DAY OF MONTH	TIME OF OBSERVATION	TEMPERATURE (°F) Maximum Observed	Maximum For Day	Minimum Observed	Minimum For Day		Grass Minimum	PRECIPITATION m Rain mm Measured	Rain mm For Day	Snow cm Measured	Snow cm For Day	Total For Day	TIMES OF PRECIPITATION (Calendar day) Began	Ended	DEPTH OF SNOW ON GROUND	WEATHER (Calendar Day) Thunderstorm	Freezing Rain	Hail	REMARKS
1	a.m			50		54													
	p.m		65		50				5.1										
2	a.m	65		51		53		5.1											
	p.m		65		51														
3	a.m	65		45		48													
	p.m		77		45														
4	a.m	77		45		50													
	p.m		70		45				1.5										
5	a.m	70		50		53		1.5											
	p.m		69		50														
6	a.m	69		50		51													
	p.m		54		50				39.9										
7	a.m	54		45		46		39.9											
	p.m		54		45				Tr.										
8	a.m	54		37		42		Tr.											
	p.m		65		37														
9	a.m	65		47		51													
	p.m		70		47														
10	a.m	70		46		53													
	p.m		62		46														
11	a.m	62		42		44													
	p.m		56		42														
12	a.m	56		34		36													
	p.m		59		34														
13	a.m	59		35		49													
	p.m		69		35														
14	a.m	69		47		49													
	p.m		71		47														
15	a.m	71		50		52													
	p.m		74		50														
16	a.m	74		52		58													
	p.m		72		52														
17	a.m	72		50		54													
	p.m		57		50														
18	a.m	57		36		43													
	p.m		67		36														
19	a.m	67		43		47													
	p.m		75		43														
20	a.m	75		42		45													
	p.m		71		42														
21	a.m	71		39		41													
	p.m		70		39														
22	a.m	70		40		42													
	p.m		63		40														
23	a.m	63		34		36													
	p.m		69		34														
24	a.m	69		36		45													
	p.m		67		36														
25	a.m	67		37		39													
	p.m		58		37														
26	a.m	58		36		41													
	p.m		72		36														
27	a.m	72		41		51													
	p.m		80		41														
28	a.m	80		43		46													
	p.m		80		43				Tr.										
29	a.m	80		45		61		Tr.											
	p.m		68		45														
30	a.m	68		40		47													
	p.m		62		40														
31	a.m																		
	p.m																		
1	a.m	62											Nº of Days with						
SUMS			2011		1288	1427			46.5										
			[illegible]		42.9	47.6													

TEMPERATURE EXTREMES

Highest 80 Date Sep. 27+28

" " Sep 12 + 23

TEMPERATURE

Mean Max 67.3

Mean Min. 42.9

Mean 55.

8.3 Statistical treatments

The following notations are used in the tables of statistical treatments.

Significance :

***	Significant at the 1% level
**	Significant at the 2.5% level
*	Significant at the 5% level

SS	Total sum of squares
TSS	Treatment sum of squares
ESS	Error sum of squares
EMS	Error mean square
Sig.	Significance
L.S.D	Least significant difference at the 5% level
DF	Degrees of freedom

1. Experiment I- June soil samples

(a) Analysis of varience

Parameters	Treatments	F	SS	TSS	ESS	EMS	Sig.	L.S.D.
pH 0-15 cm	T1,T1A,T2,T2A	4.13	0.879	0.534	0.345	0.043	*	0.39
pH 0-15 cm	T3,T3A,T4,T4A	12.83	1.414	1.171	0.243	0.030	NS	
P 0-15 cm	T0,T2,T4,T5	0.77	900	426	1474	184.3	NS	
NH4-N 0-15 cm	T0,T1A,T3A,T5	1.35	888	973	1915	239.4	NS	
NH4-N 0-15 cm	T0,T2,T4,T5	0.99	2983	805	2178	272.2	NS	
K 0-15 cm	T0,T2,T4,T5	4.09	55578	33634	21945	2743	(*)	98.7
S04-S 0-15 cm	T0,T2,T4,T5	9.86	1999	1574	425	53.2	***	13.7
Org.-C 0-15 cm	T0,T2,T4,T5	0.84	9.76	40.87	31.12	3.89	NS	

DF1 = 3

DF2 = 8

$F_{5\%} = 4.07$

(b) Correlation

x	y	Treatments	r^2	DF	Slope	Interc.	t	$t_{5\%}$	Sig.
Org.-C	T.E.C	all, 0-15 cm	0.82	9	3.06	2.54	5.65	2.26	***
Org.-C	T.E.C	all to 60 cm	0.95	33	3.62	- 0.87	24.3	2.04	***
Org.-C	T.E.C	15-60 cm	0.97	21	3.55	- 1.03	24.8	2.08	***

(c) t-tests

Parameter	Treatment	t	DF	$t_{5\%}$	Sig.
pH	T1/T2	2.71	4	2.13	*
	T1A/T2A	2.00	4	2.13	NS
	T3/T3A	6.09	4	2.13	***
	T4/T4A	3.22	4	2.13	**
NH4-N	T3,T3A,T4,T4A/T0,T5	0.66	16	1.75	NS
NO3-N	" " "	1.80	16	1.75	(*)
P	T2,T4/T0,T5 0-15 cm	0.22	10	1.81	NS
K	T2,T4/T0,T5 0-15 cm	2.46	10	1.81	*
S	T2,T4/T0,T5 0-15 cm	1.16	10	1.81	NS
S	0-15 cm/90-120 cm	7.46	22	7.46	***

2. Experiment I- September soil samples

(a) Analysis of varience

Parameters	Treatments	F	SS	TSS	ESS	EMS	Sig.	L.S.D.
pH 0-15 cm	T1,T1A,T2,T2A	11.1	1.295	1.045	0.250	0.031	***	0.33
	T3,T3A,T4,T4A	3.13	0.63	0.34	0.29	0.036	NS	
NH4-N 0-15 cm	T0,T2,T4,T5	1.27	82.1	26.6	55.5	6.95	NS	
NO3-N 0-15 cm	" "	1.87	368	152	216	27.0	NS	
P 0-15 cm	" "	0.50	1293	204	1089	136.1	NS	
K 0-15 cm	" "	1.97	55805	23727	32078	4009	NS	
S 0-15 cm	" "	0.62	28696	5427	23269	2909	NS	
	DF1 = 3	DF2 = 8		$F_{5\%}$ = 4.07				
NH4-N 0-15 cm	T0,T0A,T3,T3A,T4,T4A, and T1,T1A,T2,T2A	1.23	183.6	65.4	118.2	5.91	NS	
NO3-N 0-15 cm	" " "	3.10	992.8	578.7	414.1	20.7	**	7.75
	DF1 = 9	DF2 = 20		$F_{5\%}$ = 2.39				

(b) t-test

Parameter	Treatment	t	DF	$t_{5\%}$	Sig.
NH4-N	T0,T0A,T3,T3A,T4,T4A/ T1,T1A,T2,T2A	2.93	28	1.701	***
NH4-N	as above + T5,T5A	3.20	34	1.697	***
NO3-N	as above	2.85	28	1.701	**
NO3-N	as above	2.16	34	1.697	**

3. Experiment I- Top production and root production

(a) Analysis of varience

Parameters	Treatments	DF1	DF2	F	SS	TSS	ESS	EMS	$F_{5\%}$	Sig.	L.S.D.
June top yield	All	11	24	2.88	.0736	.0418	.0317	.0013	2.27	**	0.061
Sept top yield	All	11	24	4.52	.1365	.0920	.0444	.0019	2.27	***	0.073
Sept root yield	T0,T2,T4,T5	3	8	0.20	2.727	.191	2.536	.317	4.07	NS	
June top yield	T vs TA means	1	10	11.09	.0141	.0074	.0067	.0007	4.96	***	0.033
Sept top yield	" "	1	10	0.27	.0308	.0008	.0300	.0030	4.96	NS	
Sept top yield	T0,T3,T4/T1,T2 means	1	8	22.2	.0232	.0170	.0062	.0077	5.32	***	0.036
Sept top yield	T0,T3,T4/T1,T2, T5 - means	1	10	35.2	.0308	.0239	.0068	.0068	4.96	***	0.034

(b) t-test

Parameter	Treatments	t	DF	$t_{5\%}$	Sig.
June top yield	T0/T0A	1.15	4	2.13	NS
	T1/T1A	1.39	4	2.13	NS
	T2/T2A	1.20	4	2.13	NS
	T3/T3A	2.37	4	2.13	*
	T4/T4A	1.82	4	2.13	NS
	Total/total	3.24	28	1.71	***
Sept. top yield					
	0/38 lbs-N/ac in 1976	4.14	22	1.71	***
	0/80 lbs-N/ac in 1976	5.85	28	1.70	***
	38/80lbs-N/ac in 1976	0.72	16	1.75	NS

4. Experiment I - Nutrient contents of tops and roots

(a) Analysis of varience

Parameters		Treatments	DF1	DF2	F	SS	TSS	ESS	EMS	$F_{5\%}$	Sig.	L.S.D.
Top spring	N	All	11	24	3.53	3.77	2.33	1.44	0.0600	2.59	***	0.41
	P				1.75	0.181	0.080	0.101	0.0042		NS	
	K				4.28	4.42	2.93	1.49	0.0622		***	0.42
	S				1.45	0.048	0.019	0.029	0.0012		NS	
	Ca				1.15	0.230	0.079	0.151	0.0063			
	NO3				4.87	1.044	0.720	0.324	0.0131		***	0.20
Top fall	N	All	11	24	4.84	15.79	10.88	4.91	2.045	2.59	***	0.76
	P				2.42	0.0746	0.0392	0.0354	0.00148		*	0.06
	K				3.01	9.66	5.60	4.06	0.1692		**	0.69
	S				1.52	0.049	0.020	0.029	0.0012		NS	
	Ca				1.48	0.171	0.069	0.102	0.0043		NS	
	NO3				0.66	7.95	1.85	6.10	0.2541		NS	
Root	N	T0,T2,T4,T5	3	8	2.08	0.129	0.056	0.073	0.0090	4.07	(*)	0.18
	P				0.25	0.126	0.011	0.115	0.0145		NS	
	K				0.96	0.808	0.214	0.594	0.0742		NS	
	S				0.25	0.0072	0.0006	0.0066	0.00082		NS	
	Ca				0.17	0.516	0.034	0.526	0.0658		NS	

(b) t-test

Parameter	Treatment	t	DF	$t_{5\%}$	Sig.
N	June/Sept	3.51	11	1.796	***
P	June/Sept	3.77	11	1.796	***
K	June/Sept	2.48	11	1.796	**
S	June/Sept	3.99	11	1.796	***

5. Experiment II - July soil samples

(a) Correlation

x	y	Treatments	r^2	DF	Slope	Interc.	Sig.
Org.-C	T.E.C	all, 0-15 cm	0.87	47	2.37	1.47	***

(b) Analysis of varience

Parameters	Treatments	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
pH 0-15 cm.	Var. in means A,B,C	2	21	0.12	3.47	NS	
NH4-N 0-15 cm.				0.67		NS	
NO3-N 0-15 cm.				0.53		NS	
P 0-15 cm.				0.29		NS	
K 0-15 cm.				0.25		NS	
S 0-15 cm.				1.28		NS	
H20 0-15 cm.				4.05		*	12.5
pH 0-15 cm.	Within treatment A	7	16	0.87		NS	
NH4-N 0-15 cm.				0.81		NS	
NO3-N 0-15 cm.				0.53		NS	
P 0-15 cm.				1.12		NS	
K 0-15 cm.				3.23		**	45.6
S 0-15 cm.				1.45		NS	
Cond. 0-15 cm.				5.70		***	0.47
Na 0-15 cm.				1.78		NS	
pH 0-15 cm.	Within treatment B	7	16	1.09		NS	
Cond. 0-15 cm.				12.0		***	0.44
NH4-N 0-15 cm.				1.57		NS	
NO3-N 0-15 cm.				1.14		NS	
P 0-15 cm.				3.39		**	1.6
K 0-15 cm.				5.60		***	78.7
S 0-15 cm.				0.99		NS	
Na 0-15 cm.				1.94		NS	
pH 0-15 cm.	Within treatent C	7	16	1.77		NS	
Cond. 0-15 cm.				10.2		***	0.34
NH4-N 0-15 cm.				0.76		NS	
NO3-N 0-15 cm.				0.76		NS	
P 0-15 cm.				0.44		NS	
K 0-15 cm.				3.89		**	54.0
S 0-15 cm.				0.90		NS	
Na 0-15 cm.				4.48		***	18.9

(b) t-test

All analyses are for the 0-15 cm. depth

Parameter	Treatment	t	DF	$t_{5\%}$	Sig.
pH	Means A v B	3.26	12	1.78	***
NH4-N		0.60			NS
NO3-N		2.22			**
P		1.25			NS
K		0.58			NS
S		0.66			NS
pH	Means A v C	2.03	12	1.78	*
NH4-N		1.00			NS
NO3-N		10.79			***
P		6.29			***
K		6.22			***
S		0.71			NS
pH	Means B v C	1.82	12	1.78	*
NH4-N		1.55			(*)
NO3-N		9.89			***
P		6.88			***
K		4.73			***
S		0.16			NS

6. Experiment II - September soil samples

(a) Analysis of varience

All analyses are for the 0-15 cm. depth

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
pH	Within treatment A	6	14	1.18	2.85	NS	
Cond.				2.68		(*)	0.60
NH4-N				0.90		NS	
NO3-N				0.59		NS	
P				0.89		NS	
K				3.30		*	42.1
S				0.49		NS	
pH	Within treatment B	6	14	1.35	2.85	NS	
Cond.				5.64		***	0.58
NH4-N				2.77		(*)	1.80
NO3-N				1.17		NS	
P				1.00		NS	
K				4.22		**	58.3
S				1.23		NS	
pH	Within treatment C	6	14	1.10	2.85	NS	
Cond.				13.44		***	0.46
NH4-N				2.30		NS	
NO3-N				0.60		NS	
P				0.68		NS	
K				0.63		NS	
S				0.22		NS	

7. Experiment II - Water runoff analysis

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Water r/o	All - period #1	6	14	1.59	2.85	NS	
	#2			2.05		NS	
	#3			2.27		NS	
	#4			3.63		**	0.60
Conduct.	All - period #1	6	14	2.93	2.85	*	0.89
	#2			2.90		*	0.69
	#3			1.97		NS	
	#4			2.35		NS	
NH_4-N	All - period #1	6	14	1.10	2.85	NS	
	#2			14.8		***	17.4
	#3			3.31		*	18.9
	#4			1.26		NS	
NO_3-N	All - period #1	6	14	1.83	2.85	NS	
	#2			10.5		***	18.0
	#3			1.51		NS	
	#4			0.30		NS	
P	All - period #1	6	14	-			
	#2			5.42		***	17.4
	#3			3.60		**	1.6
	#4			-			
K	All - period #1	6	14	-	2.85		
	#2			3.90		**	81.4
	#3			2.75		(*)	163
	#4			2.15		NS	
S	All - period #1	6	14	3.75	2.85	**	51.0
	#2			4.26		**	33.4
	#3			1.58		NS	
	#4			4.46		***	64.9

8. Plant height and germination - Experiment II

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Plant height	A #1	6	14	1.61	2.85	NS	
	B			3.94		**	4.14
	C			0.68		NS	
	A #2			0.70		NS	
	B			1.82		NS	
	C			0.64		NS	
Plant height #1	A-B-C Means	2	18	0.50	3.55	NS	
#2	A-B-C Means			0.18		NS	
Germination	C only	6	14	1.20		NS	

9. Experiment II - Dry weight yield and plant analysis

(a) Analysis of varience

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Dry weight	Within A	6	14	0.24	2.85	NS	
(Tops)	Within B			2.29		NS	
	Within C			0.65		NS	
	A-B-C Means			0.26		NS	
(Roots)	All			0.90		NS	
Plant analysis +							
N	A	5	12	0.14	3.11	NS	
	B	6	14	1.40	2.85	NS	
P	A	5	12	1.83	3.11	NS	
	B	6	14	2.73	2.85	(*)	0.11
K	A	5	12	1.58	3.11	NS	
	B	6	14	3.13	2.85	*	0.52
S	A	5	12	1.48	3.11	NS	
	B	6	14	1.10	2.85	NS	
Ca	A	5	12	0.84	3.11	NS	
	B	6	12	1.92	2.85	NS	
NO_3-N	A	5	12	0.84	3.11	NS	
	B	6	12	1.68	2.85	NS	
N	Oats/grass/legume 1-A	2	6	17.7	5.14	***	0.34
P				7.09		*	0.06
K				87.0		***	0.20
S				2.98		NS	
Ca				263.9		***	0.23
NO_3-N				15.2		***	0.31
N	Oats/grass/legume 1-C	2	6	41.2	5.14	***	0.20
P				4.95		NS	
K				16.5		***	0.62
S				7.82		***	0.08
Ca				260.3		***	0.23
NO_3-N				14.1		***	0.45
Root analysis							
N	A-C	1	4	4.96	7.71	NS	
P				8.18		*	0.35
K				0.14		NS	
S				2.56		NS	
Ca				1.86		NS	
N	A + C all reps.	5	12	2.33	3.11	NS	
P				2.00		NS	
K				1.14		NS	
S				6.01		***	0.57
Ca				2.26		NS	

+ Excluded are treatments where oats, grasses and legumes were separated.

10. Nutrient uptake - Experiment II

(a) t-test

Parameter	Treatment	t	DF	$t_{5\%}$	Sig.
N	A v B	0.40	6	1.94	NS
P		0.60			NS
K		0.46			NS
S		1.64			NS
Ca		0.064			NS
N	A v C	3.14	6	1.94	***
P		2.00			*
K		4.10			***
S		0.55			NS
Ca		2.06			*
N	B v C	3.70	6	1.94	***
P		2.98			**
K		3.16			***
S		1.44			NS
Ca		2.64			**

11. Soil movement downslope - Experiment II

(a) Analysis of varience

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Soil movement	All period #1	6	14	0.90	2.85	NS	
	#2			0.95		NS	
	#3			1.55		NS	
	#4			1.40		NS	
NH_4-N	#1			0.74		NS	
	#2			1.14		NS	
	#3			1.12		NS	
	#4			1.07		NS	
NO_4-N	#1			1.35		NS	
	#2			0.85		NS	
	#3			1.34		NS	
	#4			1.17		NS	

12. Lysimeter leachate water - Experiment II

(a) Analysis of varience

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Volume	Collection #1 - A	5	12	0.97	3.11	NS	
pH				1.06		NS	
Cond.				2.16		NS	
NH4N				1.29		NS	
NO3N				0.62		NS	
Volume	Collection #1 - B	5	12	0.41	3.11	NS	
pH				1.84		NS	
Cond.				5.72		***	0.35
NH4N				0.54		NS	
NO3N				1.35		NS	
Volume	Collection #1 - C	5	12	2.91	3.11	NS	
pH				1.16		NS	
Cond.				5.85		***	0.56
NH4N				1.30		NS	
NO3N				1.57		NS	
NH4N	Means A,B,C	2	15	0.12	3.68	NS	
NO3N				2.50		NS	

13. Lysimeter leachate analysis - Experiment II
Collection periods # 2,3, and 4.

(a) Analysis of varience

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Volume	Per. #2 A	5	12	1.30	2.31	NS	
pH				0.45		NS	
Cond.				1.51		NS	
NH4-N				1.09		NS	
NO3-N				4.42		**	0.22
P				0.32		NS	
K				2.37		NS	
S				2.78		NS	
Volume	Per. #2 B			0.64		NS	
pH				3.03		(*)	0.46
Cond.				1.66		NS	
NH4-N				1.05		NS	
NO3-N				1.81		NS	
P				1.96		NS	
K				0.36		NS	
S				1.89		NS	
Volume	Per. #2 C			4.19		**	11.51
pH				0.13		NS	
Cond.				5.19		***	0.32
NH4-N				0.20		NS	
NO3-N				54.4		***	0.70
P				0.62		NS	
K				13.4		***	0.14
S				3.82		*	1.02
NH4-N	Means A, B, C	2	15	0.81		NS	
NO3-N				1.82		NS	
P				1.83		NS	
K				5.53		**	188
S				0.30		NS	
Volume	Per. #3 A	5	12	1.11		NS	
pH				0.48		NS	
Cond.				C.88		NS	
NH4-N				1.10		NS	
NO3-N				5.81		***	0.08
P							
K				5.13		***	0.05
S				1.43		NS	

13. (Continued)

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Volume	Per. #3 B	5	12	2.19	3.11	NS	
pH				0.21		NS	
Cond.				1.80		NS	
NH4-N				0.62		NS	
NO3-N				10.5		***	0.35
P							
K				2.47		NS	
S				2.78		NS	
Volume	Per. #3 C			5.57		***	9.65
pH				0.86		NS	
Cond.				3.89		**	0.39
NH4-N				1.20		NS	
NO3-N				14.2		***	0.31
P							
K				5.76		***	0.15
S				0.85		NS	
NH4-N	Per. #3 A,B,C	2	15	1.15	3.68	NS	
NO3-N	Means			0.01		NS	
P							
K				1.29		NS	
S				1.56		NS	
Volume	Per. #4 A	5	12	1.16	3.11	NS	
pH				7.22		***	0.44
Cond.				1.74		NS	
NH4-N				1.40		NS	
NO3-N				3.87		*	0.23
P							
K				0.27		NS	
S				2.59		NS	
Volume	Per. #4 B			1.86		NS	
pH				8.73		***	0.19
Cond.				0.81		NS	
NH4-N				1.48		NS	
NO3-N				4.97		**	0.37
P							
K				0.98		NS	
S				1.23		NS	
Volume	Per. #4 C			0.93		NS	
pH				4.06		**	0.14
Cond.				3.27		*	0.43
NH4-N				0.84		NS	
NO3-N				1.71		NS	
P							
K				0.90		NS	
S				0.49		NS	

13. (Continued)

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
NH4-N	Per. #4 A,B,C	2	15	1.30	3.68	NS	
NO3-N	Means.			0.55		NS	
P							
K				1.92		NS	
S				0.82		NS	

14. Lysimeter soil analysis - Experiment II

(a) Analysis of varience - 0-15 cm. depth only

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
pH	A	5	12	14.9	3.11	***	0.15
Cond.				42.4		***	0.40
NH4-N				1.02		NS	
NO3-N				11.1		***	9.8
P				7.72		***	7.2
K				5.53		***	15.1
S				14.87		***	105
pH	B			11.2		***	0.26
Cond.				22.4		***	0.39
NH4-N				0.20		NS	
NO3-N				4.81		**	17.6
P				1.21		NS	
K				1.95		NS	
S				17.6		***	87.4
pH	C			22.7		***	0.19
Ccnd.				26.9		***	0.41
NH4-N				0.51		NS	
NO3-N				2.53		NS	
P				0.75		NS	
K				6.59		***	13.7
S				26.8		***	69.2

15. Experiment III - Soil analysis

(a) Analysis of varience (0-15 cm. depth only except where noted otherwise)

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
<u>June 1976</u>							
pH	1,2,3 and 4	3	8	9.10	4.07	***	0.32
Cond.				1.71		NS	
NH4-N				1.14		NS	
NO3-N				0.28		NS	
H20 0-15 cm				1.36		NS	
H20 15-30 cm				1.10		NS	
H20 30-60 cm				1.10		NS	
P				2.79		NS	
K				2.12		NS	
S				0.81		NS	
Na				4.76		*	30.2
% C				1.05		NS	
T.E.C.				1.93		NS	
% N				0.28		NS	
<u>Sept. 1976</u>							
pH				4.14		*	0.56
Cond.				21.1		***	0.48
NH4-N				0.70		NS	
NO3-N				5.55		**	9.8
H20 0-15 cm				1.26		NS	
H20 15-30 cm				0.40		NS	
H20 30-60 cm				1.68		NS	
P				8.81		***	10.0
K				15.3		***	32.9
S				4.17		*	56.9

16. Experiment III - Germination, plant height, yield, nutrient analysis.

(a) Analysis of varience

Parameter	Treatments	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Plant height	All #1	3	8	0.76	4.07	NS	
	All #2			1.56		NS	
Germination	All			0.98		NS	
Yields Tops	All			1.71		NS	
Yields Roots	All 0-15 cm			1.77		NS	
	15-30 cm			1.24		NS	
	30-60 cm			0.36		NS	
	Total			1.67		NS	
Tops analysis	All						
N				4.40		*	0.32
P				0.53		NS	
K				1.22		NS	
S				0.41		NS	
Ca				0.58		NS	
NO3-N				4.12		*	0.14
Root analysis							
N				1.61		NS	
P				4.96		*	0.17
K				3.07		NS	
S				0.40		NS	
Ca				2.68		NS	

(b) t-test

Parameter	Treatments	t	DF	$t_{5\%}$	Sig.
N	Root v Shoots	6.67	16	1.75	***
P		12.8			***
K		9.55			***
S		0.93			NS
Ca		4.97			***

All replicates of treatments 1,2, and 3.

17. Bacteria, fungi, actinomycetes, respiration and infiltration rates

(a) Analysis of varience

Parameter	Treatment	DF1	DF2	F	$F_{5\%}$	Sig.	L.S.D.
Bacteria	Expt. I	3	8	1.98	3.86	NS	
Actinomycetes				2.72		NS	
Fungi				1.20		NS	
CO2 field				2.24			
Bacteria	Expt. II	7	16	3.28	2.66	*	5.47
Actinomycetes				0.60		NS	
Fungi				5.41		**	7.28
CO2 field		3	8	1.79	3.86	NS	
Infiltration	All	6	14	2.12	2.85	NS	

Conditions of Use

Rowell, M.J., 1977. Continued studies of soil improvement and revegetation of tailings sand slopes. Syncrude Canada Ltd., Edmonton, Alberta. Environmental Research Monograph 1977-4. 156 pp.