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by G. L. Lesko

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ABSTRACT

Twenty-nine species, including trees, shrubs, herbs and grasses, were tested for reclamation of a tar sand tailings dyke at Fort McMurray, Alberta. All species were hydroseeded after three different soil preparations: (1) contour trenches on graded surface, (2) surface packed with a crawler tractor after grading, (3) no further treatment after grading.

Grass cover was achieved on the first and second treatments while the seeding on the third treatment failed. The successful grass species were: Agropyron cristatum, A. trichophorum, A. latiglume, A. riparium, Bromus inermis, Agrostis alba, Dactylis glomerata *and* Phleum pratense. *The seeding of trees, shrubs and herbs was unsuccessful.*

RÉSUMÉ

L'auteur essaya vingt-neuf espèces de plantes, incluant des arbres, des arbustes, des herbes et des graminées pour mettre en valeur un dyke de résidus de sables pétrolifères à Fort McMurray, Alberta. Toutes les espèces furent semées dans l'humidité après trois préparations de sol différentes: (1) tranchées suivant les lignes de niveau, sur surface nivelée, (2) surface tassée avec un tracteur à chenilles, après nivellement, (3) aucun autre traitement après nivellement.

Des graminées réussirent à pousser après les premier et deuxième traitements, mais aucune plante ne poussa par suite du troisième. Les graminées suivantes poussèrent: Agropyron cristatum, A. trichophorum, A. latiglume, A. riparium, Bromus inermis, Agrostis alba, Dactylis glomerata, *et* Phleum pratense. *Les herbes, les arbustes et les arbes ne poussèrent pas.*

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INTRODUCTION

Oil sand deposits in northern Alberta underlie 29,470 square kilometers (11,340 square miles), and 7.3% of this area is suitable for surface mining (Page *et al.*, 1972). The projected production level of one million barrels per day will require the mining of 700 million tons of tar sand annually, which will create 890 hectares (2,200 acres) of disturbed land every year (Page *et al.*, 1972).

The disturbed land surface will consist of areas of overburden, tailings sand and tailing ponds. Revegetation of the tailings sand is the must urgent because the clean, fine sands are easily eroded by wind or water. However, because revegetation of tar sand tailings is a new problem, existing information on suitable species and planting techniques is very limited.

Attempts at revegetation of the Great Canadian Oil Sands tailings dyke are described by Massey (1973). Growth room studies tested different mixtures of tailings sand, clay and/or peat with fertilizers. Test plants were Bromegrass (*Bromus inermis*), pubescent wheatgrass (*Agropyron trichophorum*), streambank wheatgrass (*A. riparium*), crested wheatgrass (*A. cristatum*), creeping red fescue (*Festuca rubra*), alsike clover (*Trifolium hybridum*) and sweet clover (*Melilotus alba*). Clay or peat mixed into the sand improved growth in all trials. Fertilization was necessary to maintain growth in pure sand.

Field trials on the tailings dyke tested the same soil treatments and plant species. The soil was prepared by mixing clay or peat into the top 12-15 centimeters (5-6 inches) of the sand. Grasses and legumes were hand-seeded and harrowed in. Seedings on untreated tailings sand failed but were successful on tailings with clay or peat.

Hydroseeding was also tested by Massey on 1:1 sand-peat mixture with fertilizers. Germination was slow in this trial but enough growth was produced, with and without irrigation, to prevent wind erosion and reduce water erosion on the dyke.

In the following study, hydroseeding was tried on tailings without clay or peat treatment. The surface was prepared by contour trenchings or bulldozer packing to improve the chances for germination and survival.

DESCRIPTION OF STUDY AREA

The study area is in the Athabasca River valley about 35 kilometers (22 miles) north of Fort McMurray in northeastern Alberta at 57°02' north and 111°29' west (Figure 1). The topography of the surrounding area is rolling, between 300 and 360 meters (1000-1200 feet), with elevations. The valley of the Athabasca River cuts through the land with elevations below 244 meters (800 feet). The terrain rises from the river valley to the northwest towards Birch Hills, where the elevation reaches 773 meters (2600 feet). U-shaped and longitudinal sand dunes are common. Muskeg covers 20%-50% of the area outside of the river valley. Soils in the muskeg are organic and in the well-drained sand areas are podsols (Lindsay, Pawluk and Odinsky, 1962).

Short, cool summers and long, cold winters characterize the climate of the study area. The length of frost-free season ranges between 8 and 115 days at the Fort McMurray airport (Canada Department of Transport, 1968). The mean annual precipitation is 421 millimeters (16.58 inches) and the average yearly water deficit at 101 millimeters

(4 inches) storage is between 101 and 152 millimeters (4 and 6 inches) (Government and University of Alberta, 1969). Monthly temperature and precipitation data for Fort McMurray are summarized in Table 1.

Wheeler and Vaartnou (1973) divided the vegetation of the tar sand area into the following habitat types:

Pure aspen (*Populus tremuloides*) community

Jack pine (*Pinus banksiana*) community

Pure white spruce (*Picea glauca*) community

White spruce - aspen boreal mixed wood community

Black spruce (*Picea mariana*) treed muskeg community

Riverine community

Jack pine communities occur on dry sands, the soil most similar to the well-drained tar sand tailings. The most important understory species in this community are *Cladonia* sp., bear berry (*Arctostaphylos uva-ursi*), blueberry (*Vaccinium myrtilloides*), bog cranberry (*V. vitis-idaea*), club mosses (*Lycopodium* sp.) and rice grass (*Oryzopsis pungens*).

The site of the revegetation experiments was the second berm of the tailings dyke of the Great Canadian Oil Sands Company Ltd. (Figure 2). The section of the dyke with the sample plots faces southeast at an elevation of 249 meters (830 feet) and has a 3:1 slope. The material of the dyke is tailings: fine, angular to subangular quartz sand with particle size ranging between 44 and 1000 microns (Creighton, 1972). This sand contains small amounts of bitumin and fine material (silt and clay) but is very low in nutrients and waterholding capacity.

METHODS

The performance of 29 species including trees, shrubs, herbs and grasses was tested in 11 seed mixtures (Table 2) under three surface treatments. Seeding rates and germination capacities are shown in Table 3.

SURFACE TREATMENTS

The face of the berm was smoothly graded in preparation for the following surface treatments:

A. Hand-made contour trenches, about 7.5 centimeters (3 inches) high and 15 centimeters (6 inches) between ridges.

B. Seeds packed in with a crawler tractor after hydroseeding and before hydromulching.

C. No treatment after grading.

SEEDING

All species used in the experiment were hydroseeded in the spring of 1972 and hydromulched after seeding with the slurry mixture described in Table 4. Additional fertilizer was applied in the spring of 1973 (15-15-15, 450 kilograms/hectare or 400 pounds/acre).

PLOT LAYOUT

The 24 sample plots, each 6 x 18 meters (20 x 60 feet), were laid out in a continuous block on the tailings dyke without replication (Figure 3). Ten of the sample plots received surface treatment A, a further 10 received surface treatment B, and 4 received surface treatment C. Seed mixtures 1-10 were used with surface treatments A and B, while seed mixture 11 was used on all four sample plots receiving surface treatment C.

Slurry mix 'a' (Table 4) was used with surface treatments A and B while slurry mixes 'a' to 'c' were used with surface treatment C.

ELECTRICAL CONDUCTIVITY AND pH MEASUREMENTS

Tailings samples were collected from each berm of the dyke at depths of 0-10, 10-20, 20-30 and 30-40 centimeters (0-4, 4-8, 8-12 and 12-16 inches). The samples were analyzed for pH and electrical conductivity in a 1:1 soil water mixture.

EVALUATION OF THE RESULTS

Results were evaluated in terms of (a) vegetation cover, (b) biomass production and (c) establishment rate. Evaluations were made on one-square-meter quadrats located in uneroded portions of the main plots. From one to four quadrats were evaluated, depending on the size of undisturbed areas.

The percentage of vegetative cover was estimated both for the one-square-meter quadrats and for the entire sample plot, including the eroded areas.

Biomass production was measured by digging up all plants in one quarter of the quadrats. The plants were washed, separated into roots and tops, oven-dried and weighed.

The establishment rates of different species were calculated as the number of individual plants in the one-meter-square quadrats expressed as a percentage of the total possible germination per square meter.

All field observations were carried out in September 1973, two seasons after seeding.

RESULTS

The experimental area (Figure 4) was severely eroded. Treatments A2, A3 and B1 were completely washed out and others were partially damaged (Figures 5 and 6) because the berm was newly constructed and seepage developed along its toe, and also because the upper half of the berm was not protected with vegetation.

Figures 7 and 8 compare the effects of surface treatments A and B on plant cover by different seed mixtures. Figure 7 shows the estimated plant cover on the entire sample plot, while Figure 8 compares the cover on the one-square-meter quadrats. Differences between the two figures illustrate the extent of erosion damage in the study area.

Surface treatment A provided better plant cover on the average (52.8%) than surface treatment B (30.2%). Grasses germinated and grew along the contour trenches in distinct rows in surface treatment A (Figure 9).

Surface treatment C failed completely (Figure 10) and will not be considered further.

Grasses alone contributed significantly to the plant cover. Only two examples of *Caragana arborescens* and one each of *Medicago sativa*, *Rosa woodsii* and *Linaria dalmatica* took root on the sample plots; and none of the following plants were found: *Picea engelmannii*, *Picea glauca*, *Pinus contorta* var. *latifolia*, *Amelanchier alnifolia*, *Prunus virginiana*, *Lonicera tatarica*, *Cornus stolonifera*, *Elasagnus commutata*, *Aster conspicuus, Epilobium angustifolium, Melilotus alba, Phacelia sericea, Vicia americana.*

The most successful grasses were *Agropyron cristatum, A. trichophorum, Bromus inermis* and *Agrostis alba.* The performance of *Agropyron riparium, Dactylis glomerata, Elymus junceus, Festuca rubra* and *Phleum pratense* was mediocre, while that of *Koleria aristata* and *Poa pratensis* was poor.

BIOMASS PRODUCTION

The pattern of biomass production was similar to that of the vegetation cover. Grasses under surface treatment A produced about twice as much biomass as grasses under treatment B (Figure 11).

The best producing species were *Agropyron cristatum, Agrostis alba, Bromus inermis* and *Dactylis glomerata.* Biomass production of *Agropyron latiglume, A. riparium, A. trichophorum, Festuca rubra* and *Phleum pratense* was medium.

Table 6 shows the biomass production divided into tops and roots. The average top/root ratio was 1.3:1 under surface treatment A, and 1:1 under treatment B. The wider top/root ratio is probably due to the better water conservation in the contour trenches.

Dactylis glomerata, Agrostis alba, Bromus inermis, Agropyron riparium and *Festuca rubra* developed the strongest root systems in relation to their tops.

ESTABLISHMENT RATES

Average establishment rates were less than 5% of the germination capacity (Figure 12). The highest rate, 16%,was attained by *Agropyron latiglume*. *Agropyron riparium*, *Bromus inermis* and *Agropyron trichophorum* had establishment rates over 5%, and the other species had rates of about 3% or less.

The difference between establishment rates in surface treatments A and B was negligible.

SALINITY AND pH

Table 6 shows the pH values in the berms at different depths. Tailings in berm 1 had been exposed for six years, while berms 2, 3 and 4 had been exposed for four, two, and one years, respectively. Berm 5 was freshly laid tailings (Figure 3), which are strongly alkaline (pH 8.4 - 8.7). The pH slowly decreased with time of exposure to the slightly acid values in berm 1.

Increasing pH values with depth also are indications of ongoing neutralization or acidification of the tailings. Tailings in berm 2, anomalously, were more alkaline than berms 3 and 4.

Salinity values found in the tailings were very low and would not interfere with the growth of any species. Salinity distribution in the tailings (Table 7) did not show a clear trend either with the time of exposure or with depth. Highest values were in berm 1, which had been exposed for the longest time. In some berms, values close to the surface were higher than those in deeper samples. This distribution pattern suggests little leaching and does not exclude a temporary accumulation of salts close to the surface.

DISCUSSION

Stabilization of the tar sand tailings dyke with vegetation is an urgent requirement because the loose sand is vulnerable to wind and water erosion (Figure 13). In reclamation experiments carried out by Great Canadian Oil Sands Ltd. (Massey 1973), grass seedings were successful in tailings mixed with peat (Figure 14). However, in areas without peat there were large gaps in the grass cover (Figures 15, 16).

The purpose of this study was to explore preparation methods and plant species in an attempt to stabilize tailings without having to mix peat into the sand.

The untreated, well-drained tailings do not appear toxic. A willow pole stuck into the edge of the third berm rooted well and produced vigorous new shoots (Figure 17). Grasses seeded into untreated sand also showed no signs of toxicity.

The alkalinity of fresh tailings is high but within two or three years pH values decrease to neutral or slightly acid, at least close to the surface (Table 6). Decreasing alkalinity is probably due to neutralization rather than leaching, because the salinity in the sand does not show the same pattern of decrease over time close to the surface. Neutralization of the alkalinity might be due to the SO_2 emission of the processing plant.

Existing salinity levels are far below toxic concentrations and there is very little likelihood they will reach toxic concentrations in the future. If salts do accumulate in the surface of well-drained tailings this will be only temporary because the system will not receive additional salts from ground water or other sources. The percolating or runoff water will slowly dilute the existing salt content.

Physical properties and low nutrient status seem to be the greatest problems with well-drained tailings. Untreated tailings provide very poor seedbeds and seeds are easily washed out by water or blown away by wind. Experimental results show that contour trenching, fertilizing and hydromulching can improve the tailings sufficiently for the establishment of vigourous grass growth without mixing peat into the sand (Figure 18).

Hydroseeding on graded tailings without further treatment failed to produce any grass cover. The failure was probably due to the lack of suitable microsites for seed germination.

Of the twenty-nine species tested for reclamation, which included trees, shrubs, herbs and grasses, only grasses produced significant plant cover. Other species failed entirely or produced only one or two individuals.

Observations on the tailing dyke revealed that native species may also be established by mixing organic matter collected from the surface soil into the sand. Great Canadian Oil Sands Ltd. mixed surface soil and organic matter into the tailings on the third berm, and the following species established from the mixture: *Chenopodium capitatum, C. prattericola, Urtica gracilis, Galium boreale, Crepis* cf. *tectorum, Salix* sp., *Rumex* cf. *orbiculatus, Potentilla* sp., *Fragaria virginianum, Ranunculus* spl. *Epilobium angustifolium, E.* cf. *glandulosum, Stellaria* sp., *Carex* sp., *Rubus strigosus, Calamagrostis* sp., and *Hordeum jubatum* (Figure 19).

CONCLUSIONS

It is concluded that:

1. Establishment of grasses is possible on well-drained tailings without

peat or other soil mixtures if the surface is contour trenched before hydroseeding.

2. Hydroseeding on smoothly graded tailings is not effective.
3. Direct seeding of trees, shrubs and herbs in well-drained tailings without peat or clay application is not effective.
4. Reclamation of well-drained tailings should be started with the establishment of grasses, followed by the introduction of trees and shrubs after the sand is stabilized and somewhat improved.
5. Successful grass species for reclamation of unimproved, well-drained tailings are: *Agropyron cristatum, A. trichophorum, Bromus inermis, Agrostis alba, Agropyron latiglume, A. riparium, Dactylis glomerata* and *Phleum pratense.*
6. Establishment rates of grasses were low, not exceeding 16% of the germination capacity for any species. The average rate was less than 5%.
7. Mixing the surface soil, clay or peat into the tailings greatly improved its seedbed qualities and may establish some native species from roots or dormant seeds.
8. Well-drained tailings that have aged for one to two years are not toxic to plants.
9. Alkalinity and salinity are not problems in well-drained tailings after one or two years' exposure.

ACKNOWLEDGMENTS

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The technical assistance of Mr. E.B. Robson and Mr. F.M. Dendwick is gratefully acknowledged.

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Table 1. Mean daily temperatures (C° and F°) and mean monthly precipitation (mm and inches) at Fort McMurray

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Temperature	-21.3	-17.2	-9.3	1.6	9.4	13.3	16.4	14.6	9.1	2.6	-8.6	-17.5	-0.6
	-6.3	1.0	15.3	34.8	48.9	55.9	61.6	58.3	48.3	36.7	16.5	0.5	31.0
Precipitation	22.4	16.5	22.4	19.0	59.9	59.9	74.4	59.9	49.0	26.2	23.6	22.4	428.0
	.88	.65	.88	.75	2.36	2.36	2.93	2.36	1.93	1.03	.93	.88	16.85

Canada Department of Transport, 1968.

Table 2. Seed mixture used in the experiment.

Mix 1	Mix 2	Mix 3	Mix 4
Agropyron cristatum Amelanchier alnifolia Aster conspicuus	Agropyron latiglume Prunus virginiana Lonicera tatarica	Agropyron riparium Poa pratensis Rosa woodsii	Pinus contorta, var. latifolia Agropyron trichophorum Caragana arborescens
Mix 5	Mix 6	Mix 7	Mix 8
Agrostis alba Medicago sativa	Bromus inermis Melilotus alba	Dactylis glomerata Vicia americana Cornus stolonifera	Picea engelmannii Elymus junceus Elaeagnus commutata
Mix 9	Mix 10	Mix 11	
Festuca rubra Phleum pratense Epilobium angustifolium	Koleria cristata Phacelia sericea Lunaria dalmatica	Picea glauca Agropyron cristatum Phleum pratense Caragana arborescens Epilobium angustifolium Lunaria dalmatica	Pinus contorta, var. latifolia Bromus inermis Rosa woodsii Medicago sativa Phacelis sericea

Table 3. Seeding rates, germination capacity and potential germinations per square meter of species seeded.

Botanical name	Seeding rates (grams/100 sq. meters)[a]	Seeds per gram[b]	Seeds per sq. meter	Germination capacity in percent	Max. potential germinants/sq. meter
Picea engelmanii Parry	11.9	503	55	75	41
Picea glauca (Moench) Voss	11.9	503	55	57	31
Pinus contorta, var. latifolia Engelm.	19.9	302	55	87	48
Agropyron cristatum (L.) Gaertn.	155.5*	386	545	83	452
Agropyron latiglume (Scribn. and Smith) Rydb.	177.9	337	545	24	131
Agropyron riparium Scribn. and Smith	195.4	307	545	94	512
Agropyron trichophorum (Link) Richt.	419.0	143	545	96	523
Agrostis alba L.	5.4	11,009	545	76	414
Bromus inermis Leyss.	200.1*	300	545	96	523
Dactylis glomerata L.	78.5	734	545	90	491
Elymus junceus Fisch.	155.5	386	545	94	512
Festuca rubra L.	44.2	1,356	545	89	485
Koleria cristeta (L.) Pers.	13.9	4,323	545	31	169
Phleum pratense L.	22.1	2,711	545	97	529
Poa pratensis L.	12.5	4,800	545	53	289
Amerlanchier alnifolia Nutt.	19.9	301	55		
Prunus virginiana L.	485.5	12	55		
Rosa woodsii Lindl.	666.7	9	55		
Caragana arborescens Lam.	156.5	38	55	63	35
Medicago sativa L.	27.2*	441	109	86	94
Melilotus alba Desr.	20.9	573	109	96	105
Vicia americana Muhl.	151.2	79	109	18	20
Elaeagnus commutata Bernh.	644.5	9	55	43	24
Epilobium angustifolium L.	0.07	171,428	109	57	62
Cornus stolonifera Michx.	360.0	17	55		
Phacelia sericea (Graham) A. Gray	3.8	3,141	109	32	35
Linaria dalmatica (L.) Mill	2.1	5,581	109	18	20
Lonicera tatarica L.	121.3	49	109	81	88
Aster conspicuus Lindl.	22.9	528	109	12	13

* Seeding rates reduced by one-half for mix 11.

[a] = lbs./acre = grams/110 square meters multiplied by .08.

[b] = seeds per lb. = seeds per gram multiplied by 453.59.

Table 4. Slurry mixtures used with the hydroseedings.

Ingredients	Slurry a	Slurry b	Slurry c
Water (liters/sq. meter)*	3.5	3.5	3.5
Wood Fiber Mulch (grams/sq. meter)**	206 to 245	206 to 245	-
Fertilizer (grams/sq. meter)**			
10-30-10	32.5	32.5	-
Organic	32.5	32.5	-
46-0-0	15.0	15.0	-
Adhesive, Curasol AH (liters/sq. meter)*	0.06	--	-

* gal./acre = liters/sq. meter multiplied by 890.21

** lbs./acre = grams/sq. meter multiplied by 8.92

Table 5. Biomass production as influenced by surface treatment in ten seed mixtures.

A - contour trenched B - packed by crawler tractor. (In grams per square meter).

Surface Treatment	Plant Organ	Seed Mixture									
		1	2	3	4	5	6	7	8	9	10
A	Tops	644	ns	ns	408	424	353	286	104	247	62
	Roots	229			105	404	436	377	104	228	47
	Total	873			513	828	789	663	208	475	109
B	Tops	ns	169	140	219	222	77	174	12	154	24
	Roots		130	153	105	278	78	153	12	169	37
	Total		299	293	324	500	155	326	24	323	61

Table 6. pH distribution according to depth in the five berms of the tailings dyke.

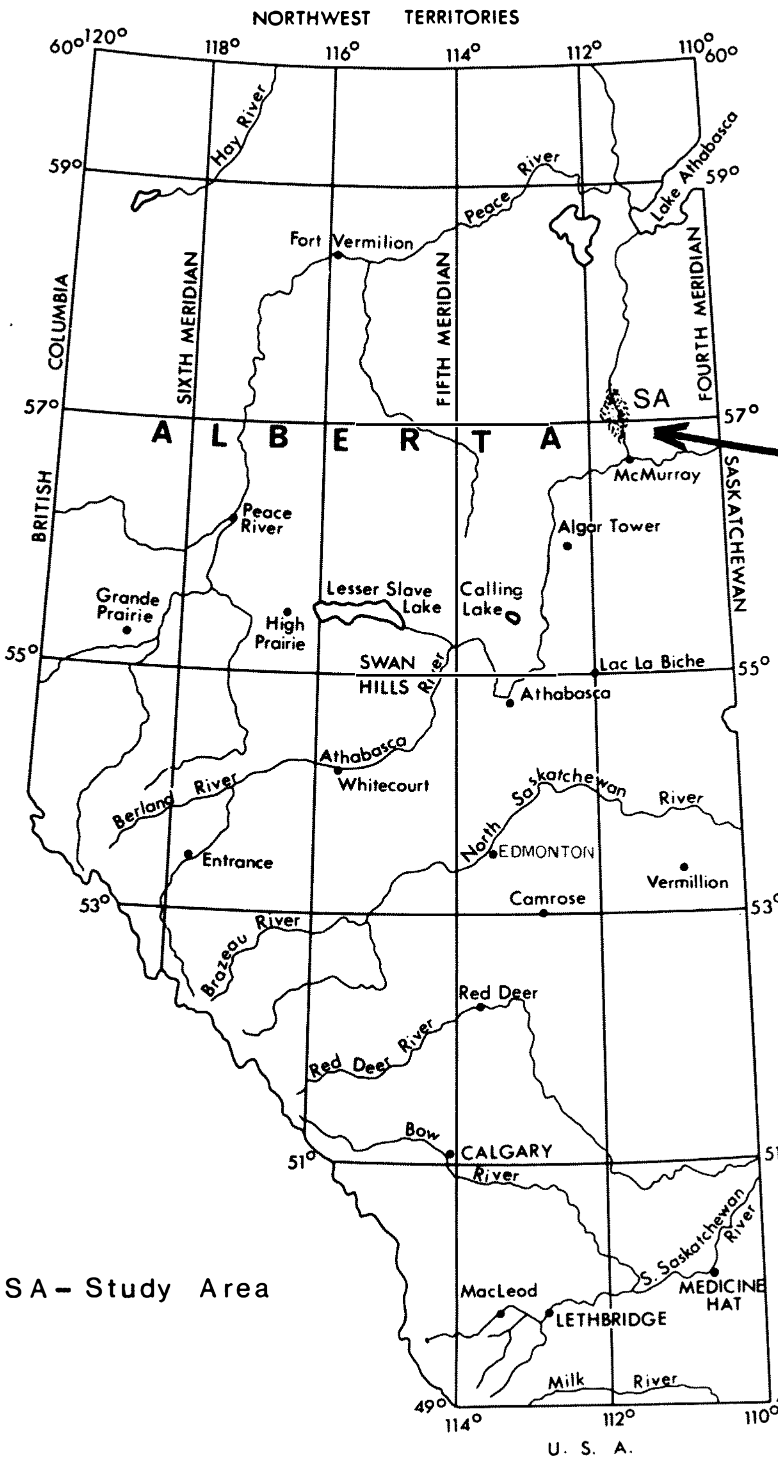
Depths in cm	Berm 1	2	3	4	5	Average pH
0 - 10	6.47	7.90	6.80	7.57	8.40	7.40
10 - 20	6.75	8.15	7.35	8.00	8.37	7.72
20 - 30	7.40	8.15	7.57	8.25	8.60	7.99
30 - 40	7.34	8.15	8.50	7.92	8.70	7.92
Average	6.99	8.09	7.30	7.92	8.52	

Figures are averages of two readings.

Table 7. Salinity distribution according to depth in the five berms of the tailings dyke expressed as electrical conductivity in millimhos/cm

Depths in cm	Berm 1	2	3	4	5	Average
0 - 10	0.36	0.19	0.26	0.38	0.45	0.33
10 - 20	0.50	0.23	0.18	0.39	0.27	0.31
20 - 30	0.58	0.18	0.18	0.31	0.39	0.32
30 - 40	0.53	0.16	0.17	0.31	0.29	0.29
Average	0.49	0.19	0.20	0.35	0.35	

Figures are averages of two readings.



SA – Study Area

FIGURE 1. Location of study area

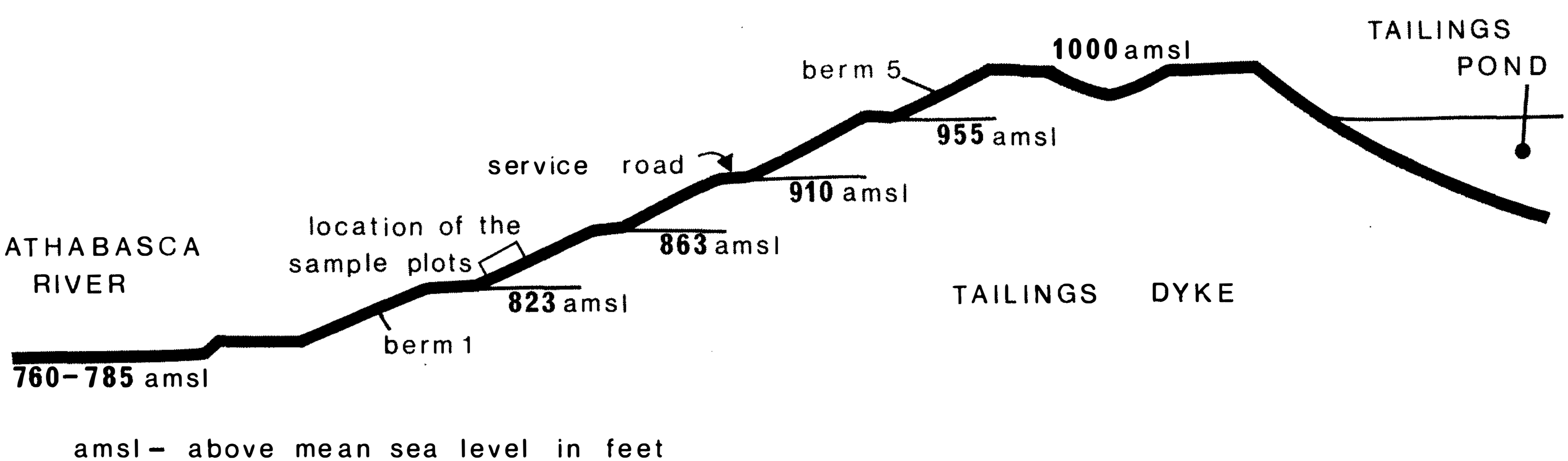
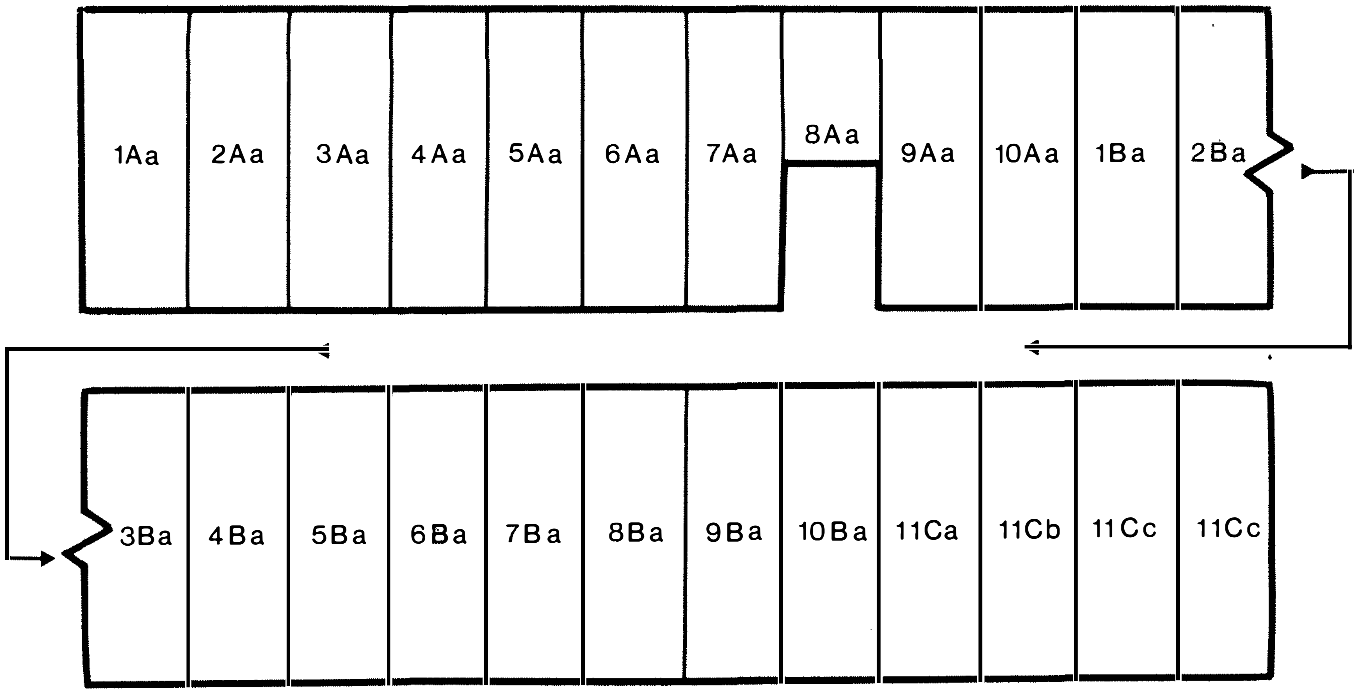


Figure 2. Transect of the tailings dyke showing plot location.



1– 11 seed mixtures

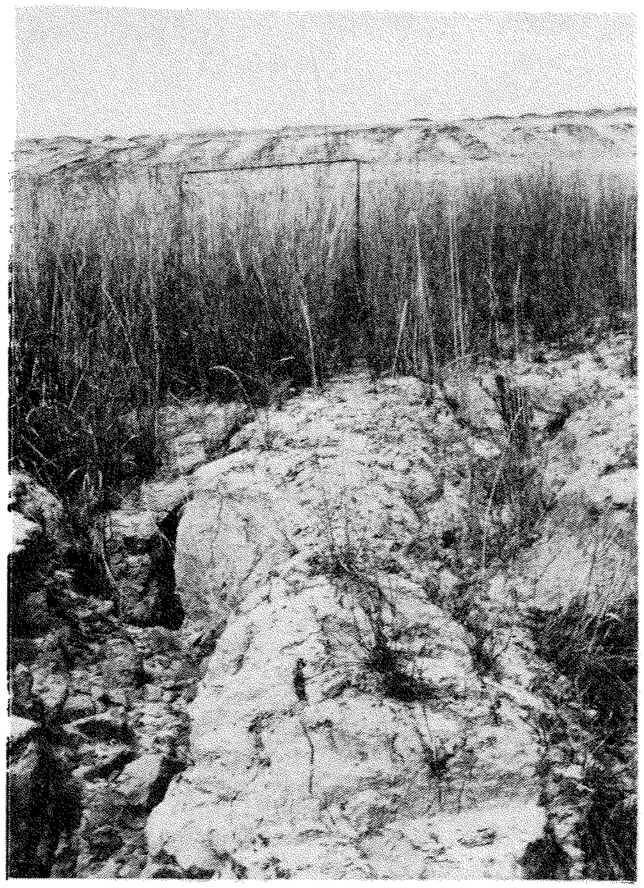
A, B & C surface treatment

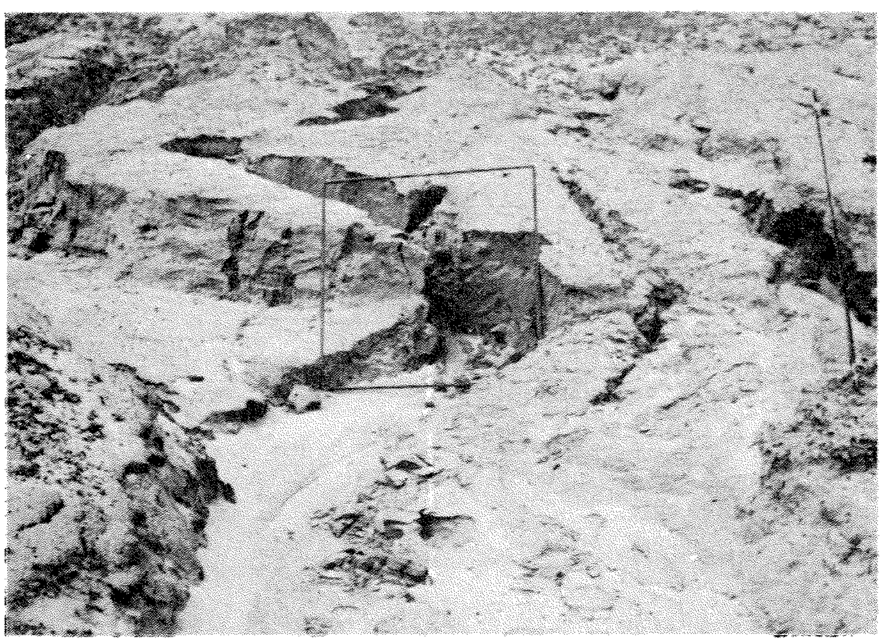
a – c slurry mixtures

Scale: 1" = 40'

Figure 3. Plot layout of seed mixtures and treatments

Figure 4. View of the sample plots on the tailings dyke.





Figures 5 and 6. Erosion damage in sample plots. The side of the square is 1 m.

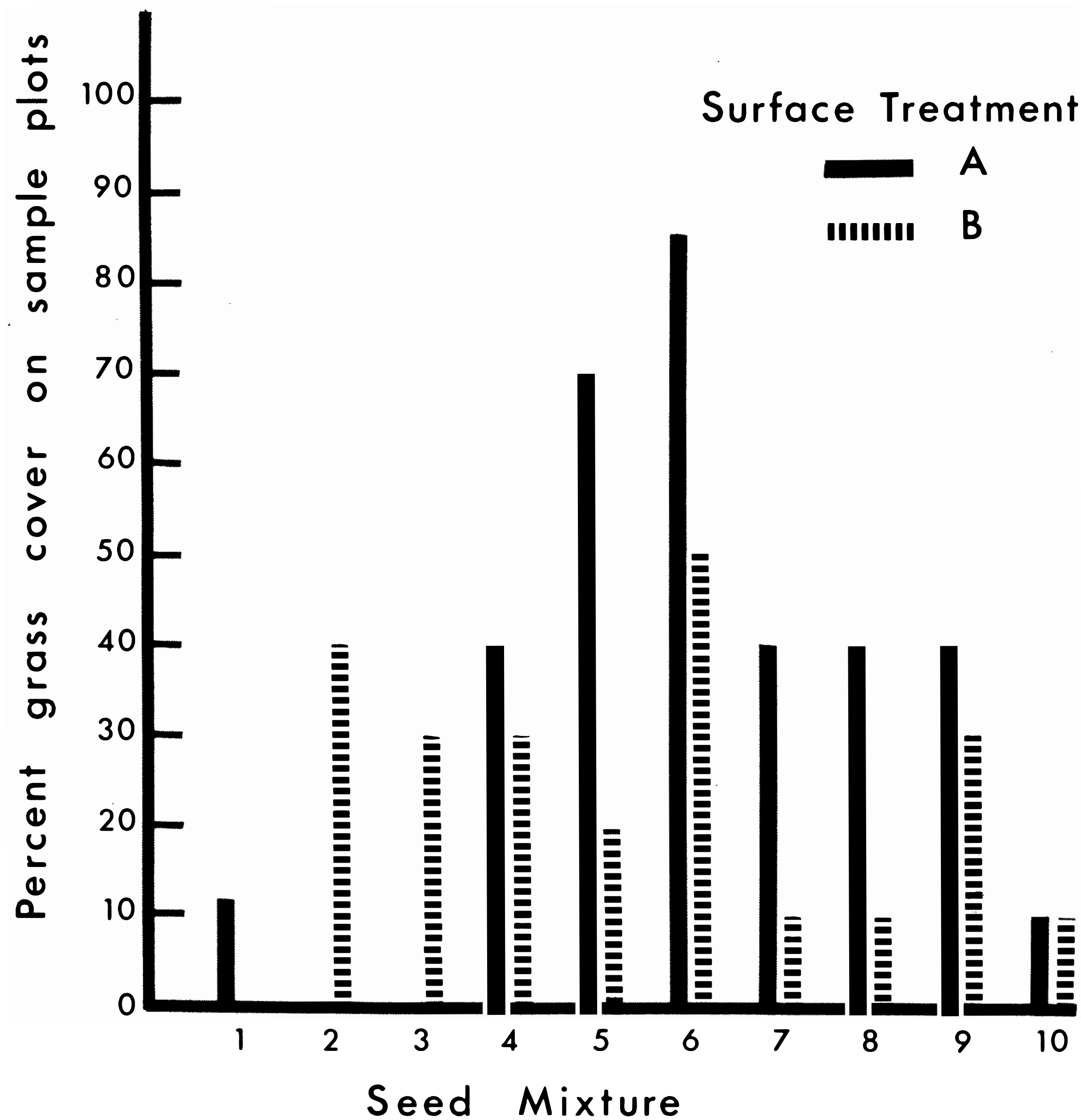


Figure 7. The influence of soil surface treatment on grass cover in different seed mixtures including areas affected by erosion. A - contour-trenched; B - packed by crawler tractor.

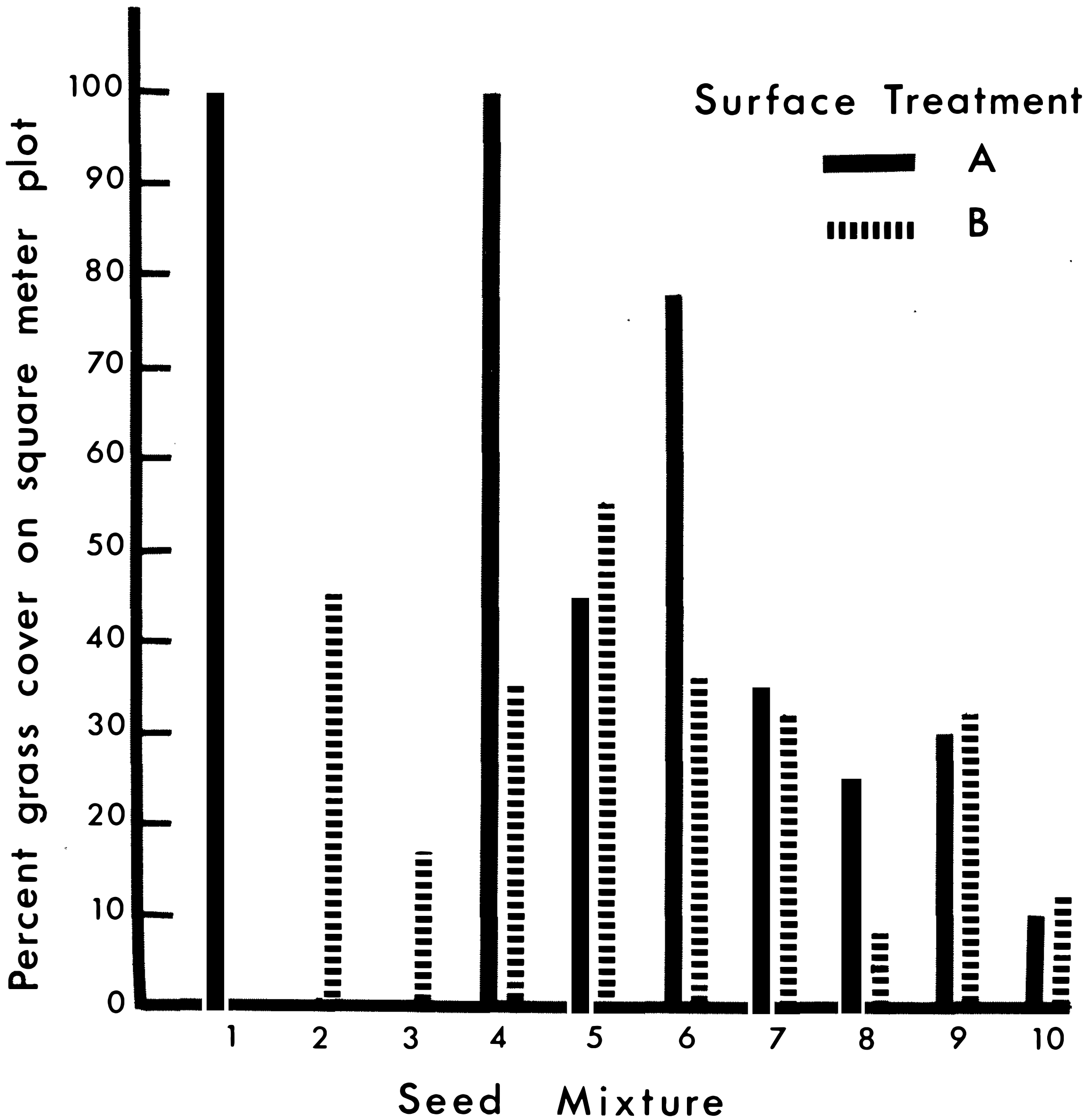


Figure 8. The influence of soil surface treatment on grass cover in areas not affected by erosion.
A - contour-trenched; B - packed by crawler tractor.

Figure 9. Grasses grow in rows along the contour trenches in surface treatment A.

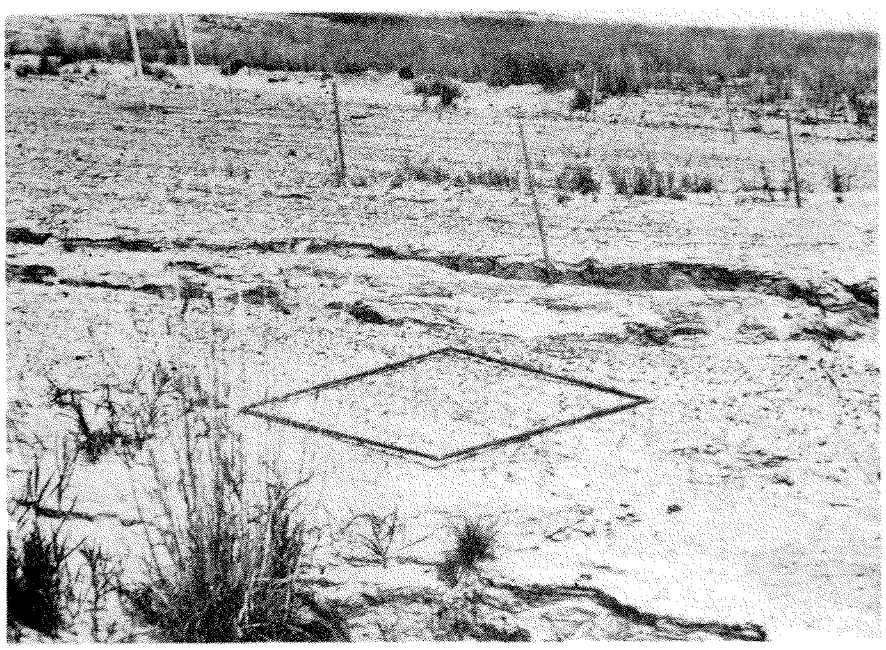


Figure 10. Seeding almost completely failed where surface was not treated after grading (surface treatment C).

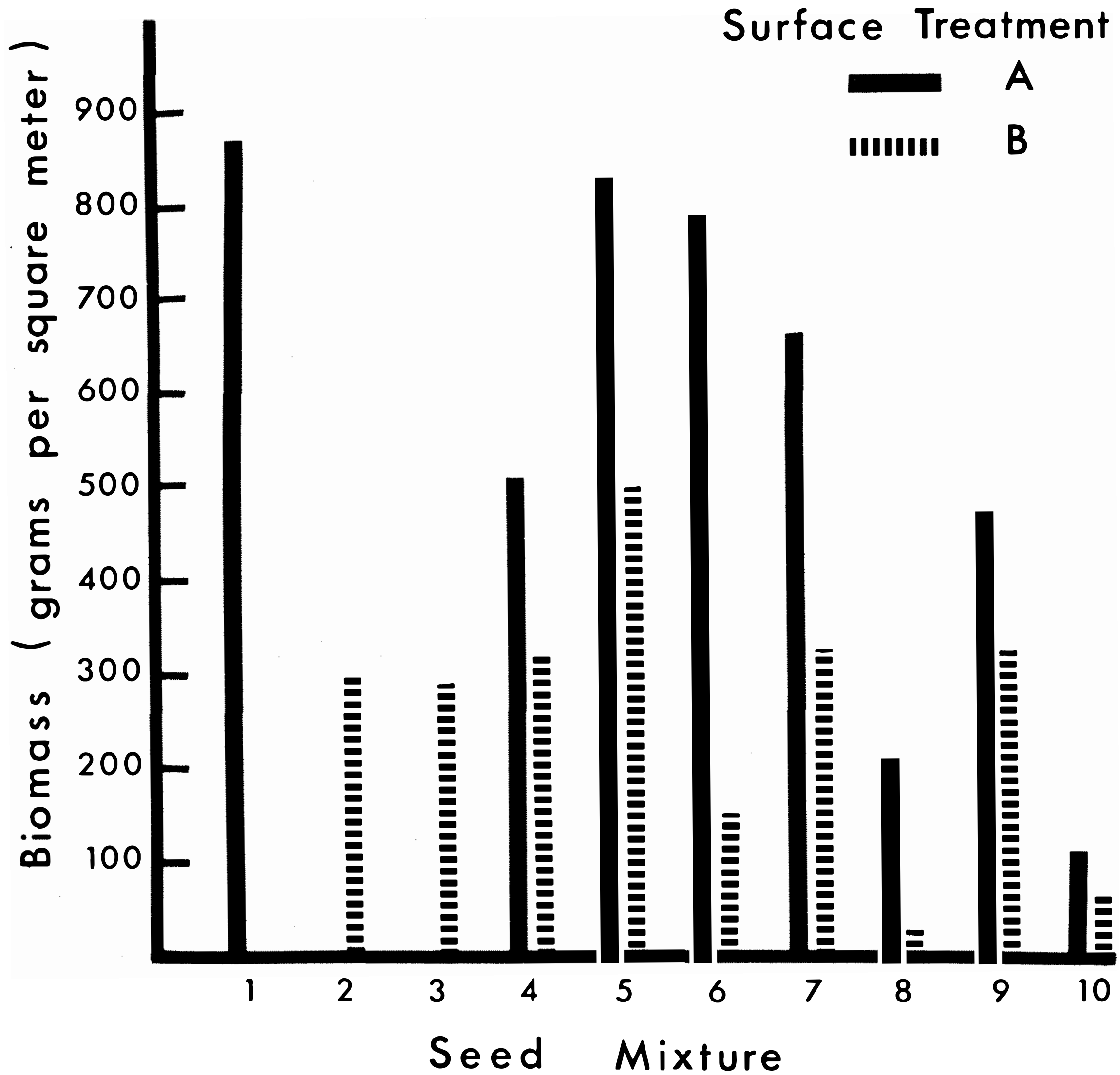


Figure 11. Total biomass production of ten seed mixtures in two surface treatments.
A - contour-trenched; B - packed by crawler tractor.

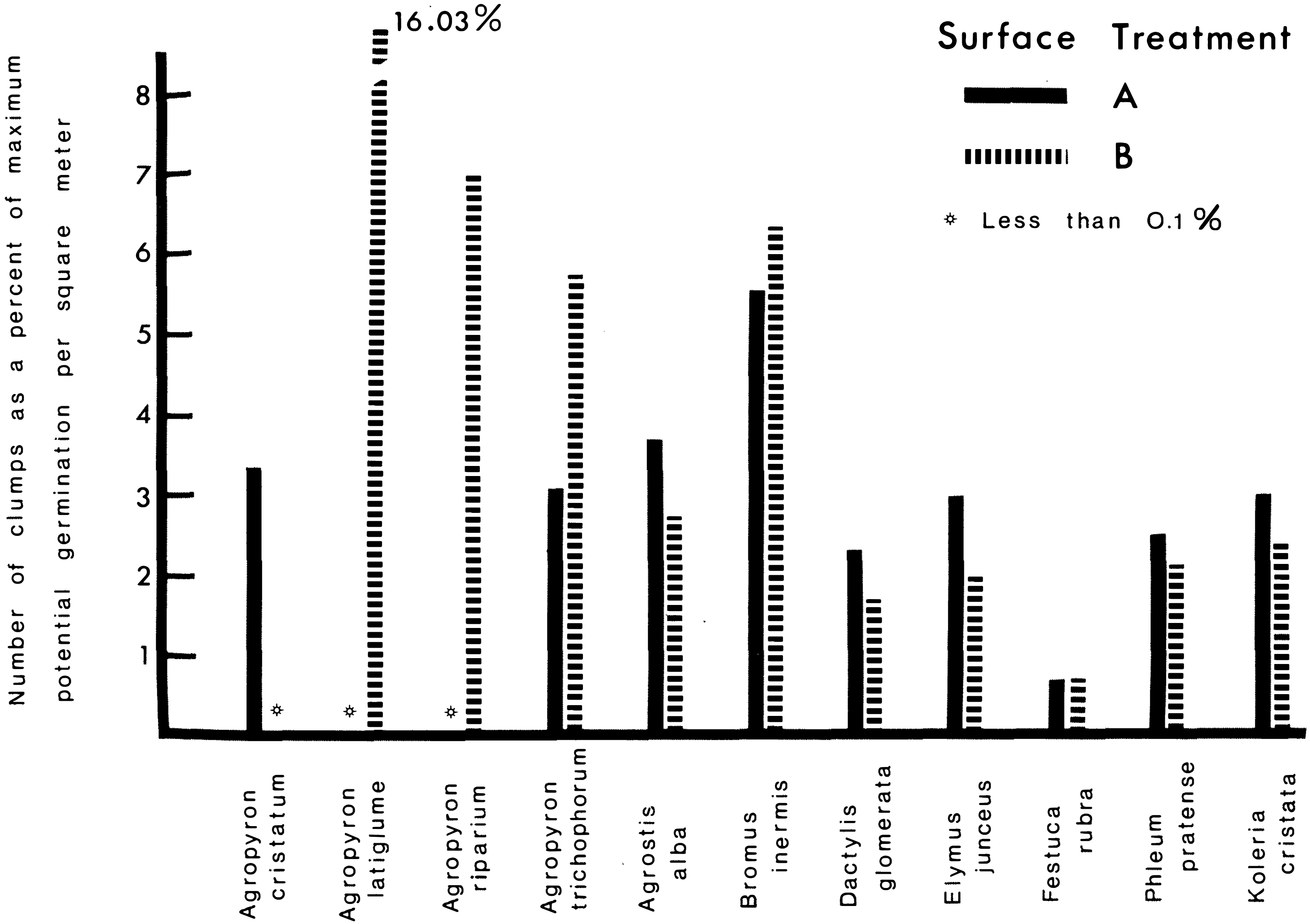


Figure 12. Establishment rates of 11 species in contour-trenched (A) and crawler tractor-packed (B) areas. Seedings marked by asterisk were severely eroded.

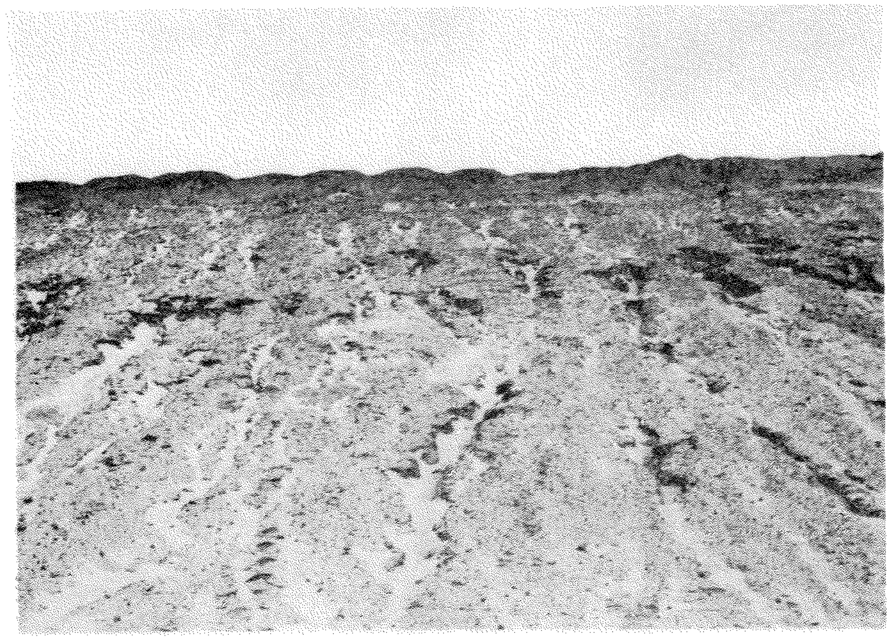


Figure 13. Rill erosion on the tailings dyke.

Figure 14. Rye seeding by G.C.O.S. on tailings mixed with peat and fertilized.

Figures 15 and 16. G.C.O.S. seedings in pure tailings sand.

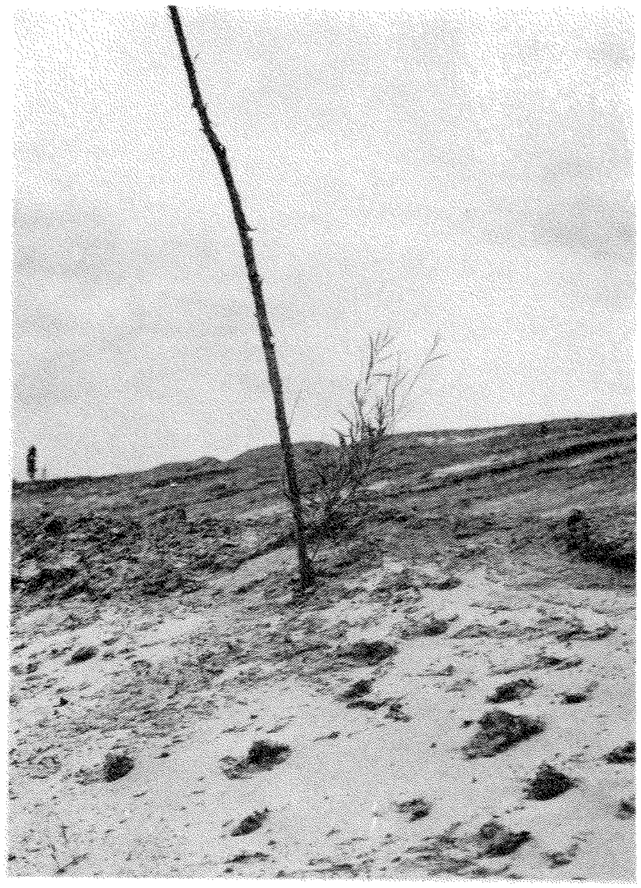


Figure 17. Rooted willow pole on the third berm of the tailings dyke.

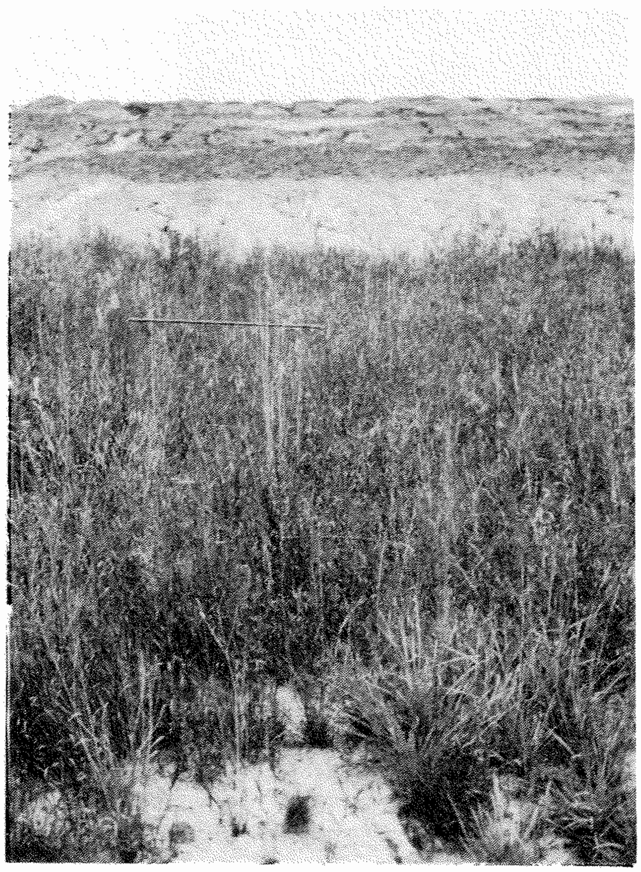


Figure 18. Dense grass cover developed on contour trenched sample plot. The side of the square is 1 m.

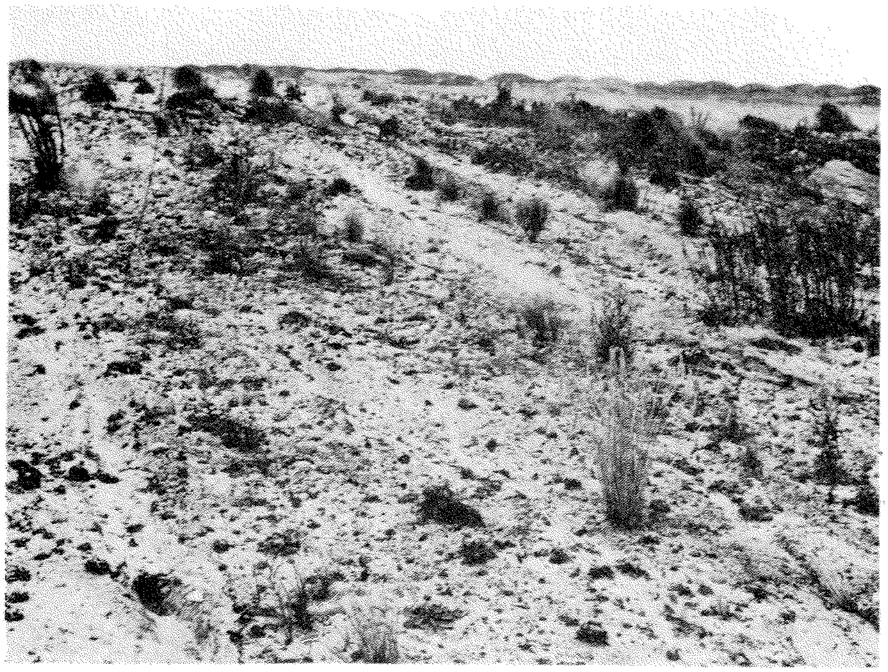


Figure 19. Native vegetation established from surface soil mixed into the tailings.