HIGHVALE SOIL RECONSTRUCTION

RECLAMATION RESEARCH PROGRAM

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ABSTRACT

Experimental plots were established in 1982 at Highvale Mine to test several hypotheses relative to reclamation of sodic minespoil and to provide interpretive data for reclamation planning and post-mining land management.

Data collected during the first monitoring program in 1983 showed that soil moisture, bulk density, chemistry and crop productivity were significantly affected by the various treatment components for both the subsoil depth and slope drainage experiments.

As this is the first year of monitoring on these plots, the conclusions presented should be regarded as interim conclusions only.

INTRODUCTION

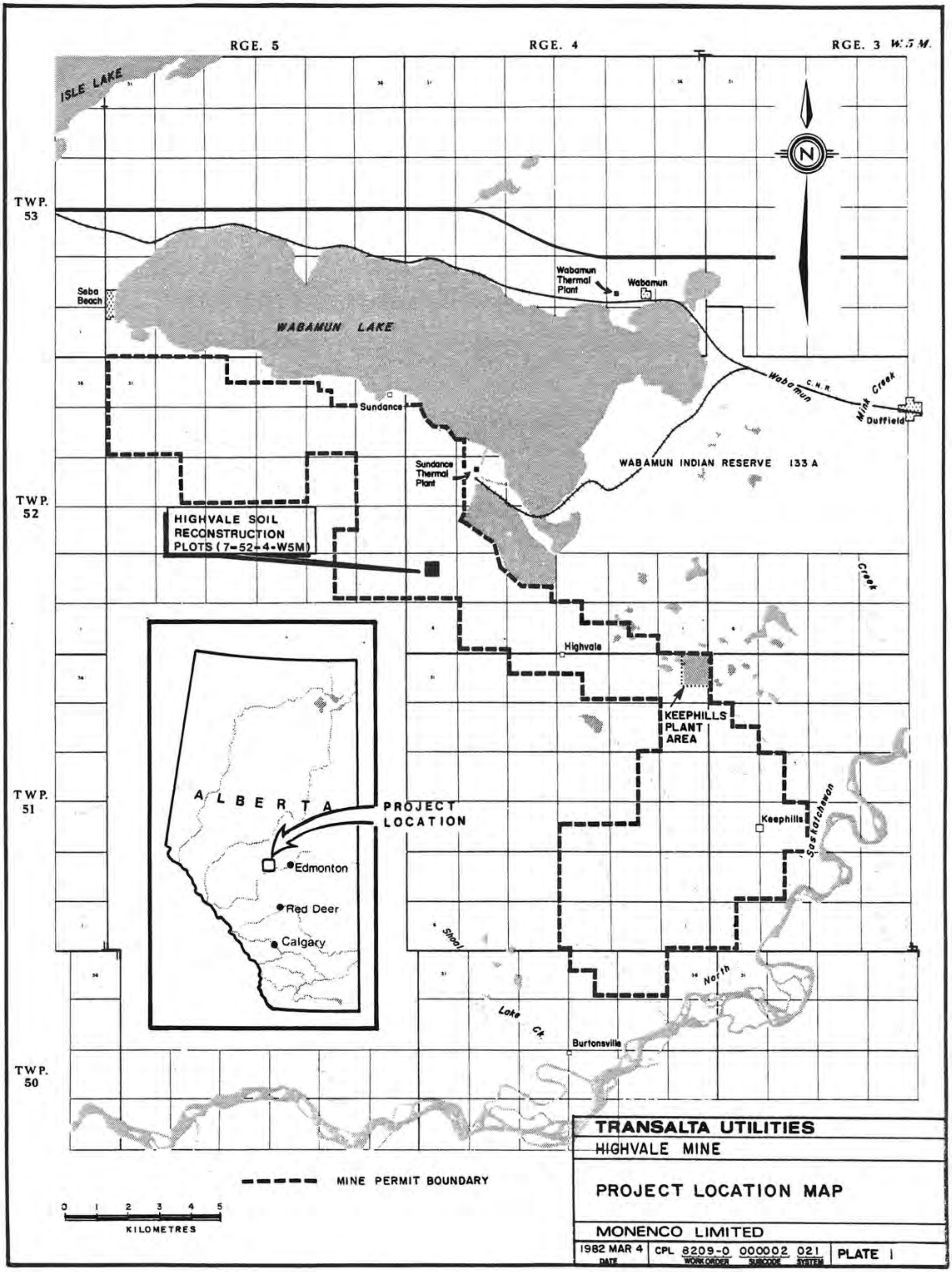
Experimental plots were established in 1982 at Highvale Mine to test several hypotheses relative to reclamation of sodic mine spoil and to provide interpretive data for reclamation planning and post-mining land management. TransAlta Utilities Corporation provided construction funding for the research plots located in Section 7, Township 52, Range 4 west of the 5th Meridian (Plate 1). Monenco Consultants Limited supervised the construction as well as selection, sampling and analyses of topsoil, subsoil and minespoil.

The subsequent monitoring programs including those discussed in this paper are funded from the Alberta Heritage Savings Trust Fund through the Land Conservation and Reclamation Council. Project management is the responsibility of Alberta Environment's Research Management Division.

The primary objectives of the program are:

1. To determine an optimum depth of subsoil replacement over minespoil to ensure adequate vegetative productivity, especially in the Highvale Mine Permit area.

2. To establish productive agricultural soil on reclaimed land. This involves assessing the sustainability of re-established


RGE. 5
RGE. 4
RGE. 3 W.5 M.
ISLE LAKE
TWP. 53
TWP. 52
TWP. 51
TWP. 50
Seba Beach
WABAMUN LAKE
Wabamun Thermal Plant
Wabamun
Sundance
Sundance Thermal Plant
Wabamun C.N.R.
Mink Creek
Duffield
WABAMUN INDIAN RESERVE 133 A
HIGHVALE SOIL RECONSTRUCTION PLOTS (7-52-4-W5M)
Creek
Highvale
KEEPHILLS PLANT AREA
ALBERTA
PROJECT LOCATION
Edmonton
Red Deer
Calgary
Keephills
Saskatchewan
North
Shool
Lake Ck.
Burtonsville
MINE PERMIT BOUNDARY
0 1 2 3 4 5
KILOMETRES
TRANSALTA UTILITIES
HIGHVALE MINE
PROJECT LOCATION MAP
MONENCO LIMITED
1982 MAR 4
DATE
CPL 8209-0 000002 021
WORK ORDER SUBCODE SYSTEM
PLATE 1

productivity; at the Highvale Mine emphasis is placed on minimizing salt migration from mine spoil into the root zone. Salt movement will be monitored.

3. To examine treatments which could minimize soil quantities needed to restore the original productivity of the lands. Slope configurations are evaluated as methods of minimizing the quantities of subsoil material required to maintain adequate plant productivity.

Two separate experimental plots, the Subsoil Depth Experiment, and the Slope Drainage Experiment, were constructed to provide data relative to the objectives discussed above. Each experiment was designed to test certain null hypotheses.

Subsoil Depth Experiment - Null Hypotheses

1. Crop productivity on reclaimed sodic spoil is not a function of subsoil depth (subsoil is defined as non-sodic soil material placed between spoil and replaced topsoil). If rejected, identify optimal subsoil depth.

2. Forage and grain crops will not respond differently to varying subsoil depths. If rejected, identify optimal subsoil depth for each crop.

3. The subsoil/sodic minespoil interface will not interfere with vertical movement of water. If rejected, quantify the effect.

4. Salts will not migrate from sodic minespoil into subsoil. If rejected, quantify the effect.

Slope Drainage Experiment - Null Hypotheses

1. Downslope salt transport is independent of slope and aspect. If rejected, quantify effect of slope and aspect.

2. Crop productivity is not a function of slope position, slope steepness or aspect in the reclaimed landscape. If rejected, quantify effect of slope steepness, slope position and aspect.

PROJECT DESIGN

Experimental designs and the assumptions made for each experiment in the study are described below.

Subsoil Depth Experiment - Treatments and Experimental Design

Treatments

1. Subsoil depths: 0, 0.25, 0.50, 1.00, 1.50 and 3.00 m.

2. Crops: forage/bromegrass and small grain rotation (barley, oats). This crop combination was chosen from those grown successfully in the area.

Experimental Design

The experimental design used for this experiment is a split plot with the six subsoil depths randomized in the main plots and the two crops (a forage and a cereal) randomized in the subplots. The total number of replications is three. The layout of the subsoil depth experiment, showing the randomized treatments, is illustrated in Figure 1.

Slope Drainage Experiment - Treatments and Experimental Design

Treatments

1. Slope Type - North facing at 5° slope;
   - North facing at 10° slope;
   - South facing at 5° slope; and
   - South facing at 10° slope.

2. Position on Slope: Top half of slope;
   Bottom half of slope; and
   Pad at base of slope.

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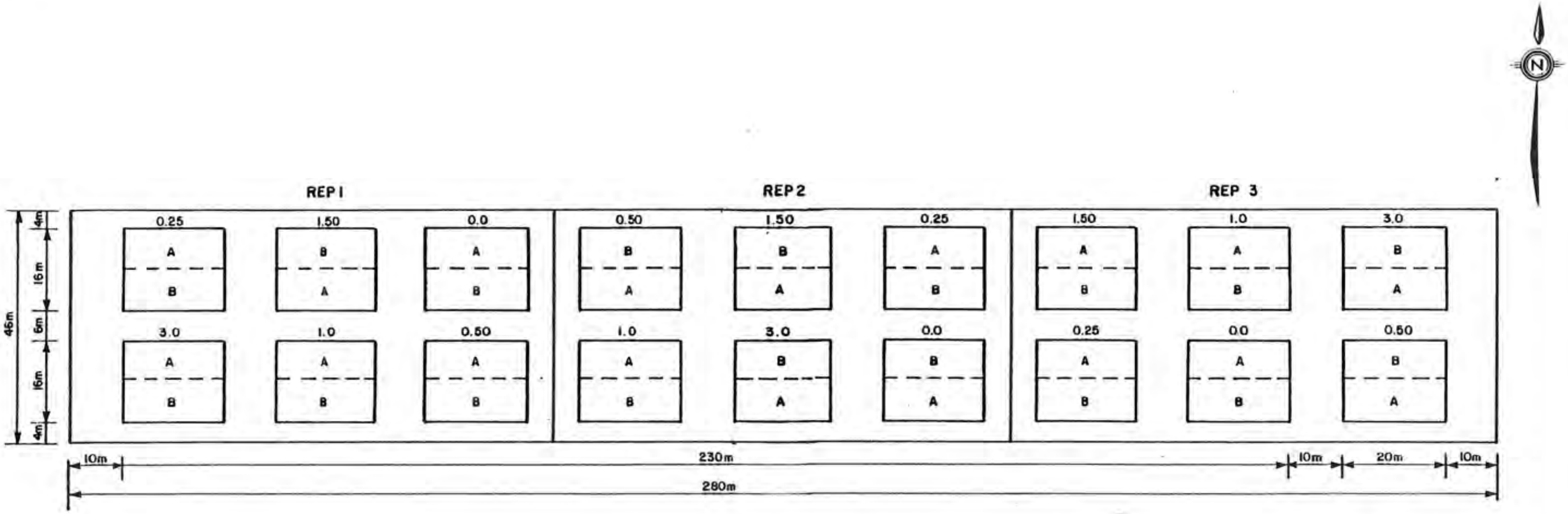

A - ALFALFA (RAMBLER) AND BROMEGRASS (CHARLTON)
B - BARLEY (KLONDIKE)
0.0 NO SUBSOIL
0.25 0.25 m SUBSOIL
0.50 0.50 m SUBSOIL
1.00 1.00 m SUBSOIL
1.50 1.50 m SUBSOIL
3.00 3.00m SUBSOIL

FIGURE 1

ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT

SUBSOIL EXPERIMENT LAYOUT

Experimental Design

Since slope steepness, slope aspect and position are treatments applied in strips rather than randomly, the precision for testing these main effects is sacrificed for increased sensitivity to interaction effects (Cochran and Cox 1957, page 307). Since interaction between slope aspect and slope steepness is internal to the experimental design, these two treatments may be combined to form a "slope type" treatment which can be randomly applied in three complete blocks. Across these whole plots or main treatments, the testing of three different slope positions introduces a "factor" again applied in strips and which can then be analyzed as a "strip-plot" or "split-block" design (Little and Hills 1978, page 115).

The layout of the slope drainage experiment is illustrated in Figure 2.

METHODOLOGY

FIELD PROGRAM

A baseline soil/spoil inventory was conducted in the fall of 1982, and neutron probe access tubes were installed.

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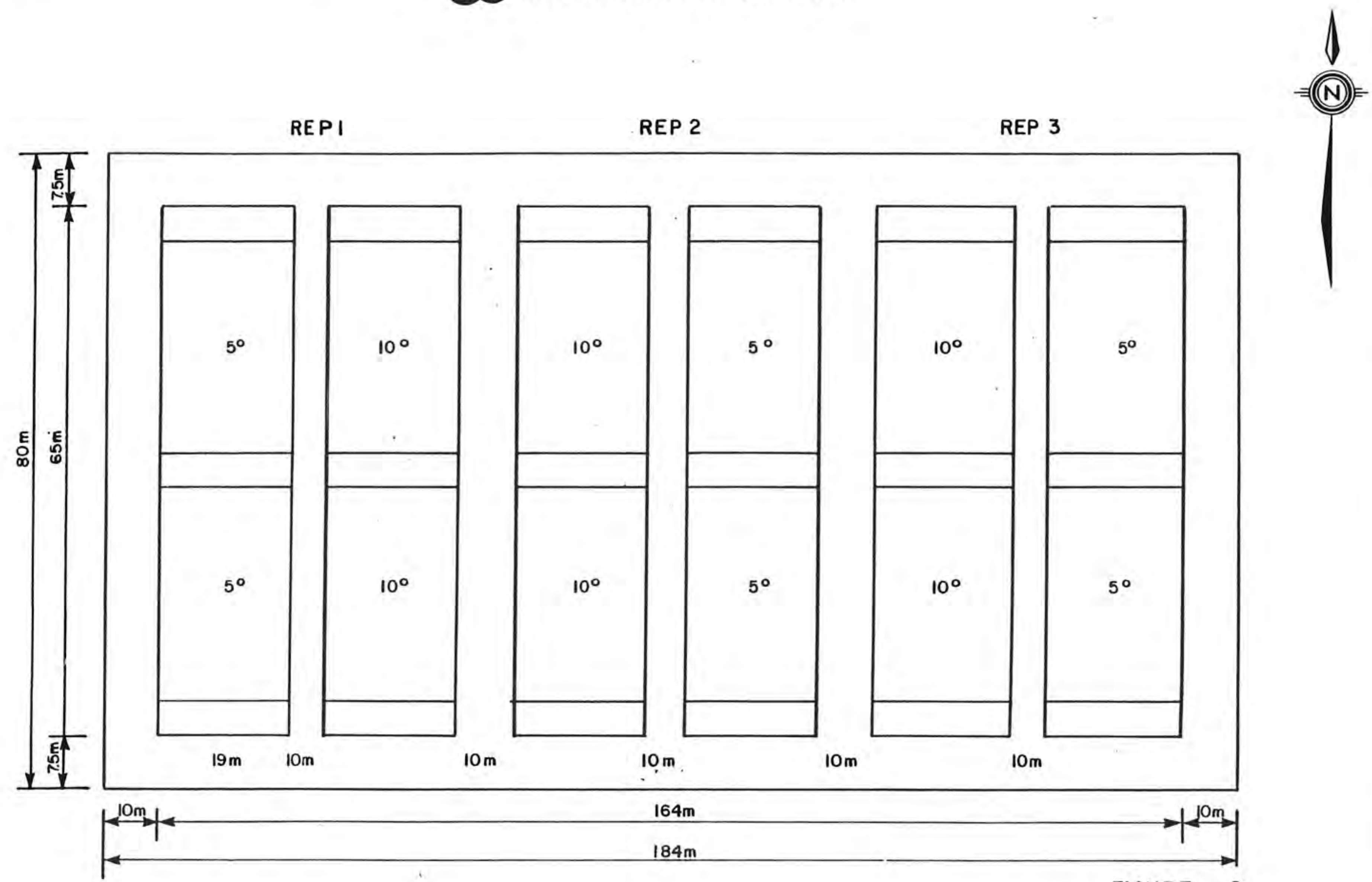


FORAGE CROP

FIGURE 2
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SLOPE EXPERIMENT
LAYOUT
(NOT TO SCALE)

The 1983 field program consisted of soil moisture monitoring, soil density monitoring, gravimetric sampling, soil sampling for fertilizer requirements, weed control, site preparation, selection of seed, seeding, harvesting, crop observation, plot maintenance and soil/spoil sampling.

1. Soil Moisture and Density Monitoring

Neutron probe monitoring was conducted monthly from April through October except in June due to continuous excessive rain. A total of 108 neutron access tube locations were monitored throughout the reconstructed profiles. Neutron probe density measurements were taken concurrent with the April and October soil moisture monitoring program.

The method of neutron probe calibration as discussed by Nakayama and Reginato (1982) was used to calibrate the probe.

2. Soil/Spoil Sampling

Soil samples were collected from the sampling intervals suggested by the PCRRP Steering Committee at two sites randomly selected in each subsoil subplot. Additional samples were taken where anomalies in soil depth occurred. Two locations from each of the slope positions on the slope experiment were also sampled.

A truck mounted B24 auger rig equipped with a 60 cm long by 5 cm diameter split tube sampler with a modified cutting head was used to penetrate the plots. The experiment necessitated sampling immediate above and below topsoil/subsoil and subsoil/spoil contacts.

STATISTICAL ANALYSES

Collected data were entered onto a computer data storage file. Since the subsoil/minespoil interface was variable within treatments, a coding system was used to identify each sample as to its position relative to the measured interface for ease of statistical analyses.

Statistical analyses of the stored data were performed utilizing the PROC MEANS, PROC GLM, PROC ANOVA and PROC CORR procedures of the SAS package (SAS 1979).

Calculated statistics included means, standard deviations, coefficients of variability, analysis of variance, and linear and step-wise regressions.

RESULTS AND DISCUSSION

SUBSOIL EXPERIMENT

Soil Moisture

Table 1 shows the mean values and standard deviations of moisture in the topsoil, subsoil and minespoil of the forage and cereal subplots for each treatment during the period from April through October 1983. The reported July results are a combination of two sets of readings taken in July.

ANOVA and the Waller-Duncan K-ratio t-test performed on the data show the following results:

- mean topsoil moisture was generally significantly lower than mean subsoil and minespoil moisture (at the 95% level, Pr>F = 0.0001).

- mean monthly moisture through the profile is significantly different across the treatments for each month.

- the forage subplots were generally moister than the cereal subplots.

Soil moisture profiles for the 1.0 m treatment are shown in Figure 3. A general increase in moisture at the subsoil/minespoil interface in

TABLE 1

MONTHLY TOPSOIL, SUBSOIL AND MINESPOIL MOISTURE % BY TREATMENT FOR EACH SUBPLOT

*TREATMENT	***MATERIAL (TS, SS, MS)	ALFALFA SUBPLOT												BARLEY SUBPLOT											
		**APRIL u		MAY t		JULY s		AUG x		SEPT w		OCT v		APRIL u		MAY t		JULY s		AUG x		SEPT w		OCT v	
		$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
0.00 m	TS	-	-	-	-	33.25	2.50	19.71	2.96	24.73	2.02	29.77	2.33	26.30	-	-	-	32.15	4.18	16.16	0.81	24.42	1.63	29.31	2.49
e																									
	MS	30.90	2.90	30.97	2.99	31.09	2.89	27.88	2.82	29.95	2.27	31.92	2.99	30.98	3.13	30.43	2.73	31.48	2.52	26.98	2.84	30.32	2.76	32.37	1.90
0.25 m	TS	-	-	-	-	30.90	2.57	21.32	2.24	24.99	1.59	29.45	1.44	-	-	-	-	29.97	3.70	19.64	1.17	24.21	0.65	29.86	1.21
cd	SS	31.72	1.11	32.45	1.59	32.75	0.85	31.75	1.67	29.35	1.88	30.39	1.79	32.35	1.20	33.14	1.67	32.59	1.64	27.65	2.12	26.93	1.81	29.45	2.31
	MS	30.69	1.76	31.95	2.00	32.07	1.67	32.40	1.63	32.11	1.51	32.93	1.55	32.83	2.80	31.31	2.42	32.70	2.19	32.17	1.87	31.16	1.82	31.45	1.56
0.50 m	TS	-	-	-	-	32.24	1.78	21.45	1.71	24.78	1.59	29.75	1.32	-	-	-	-	29.88	2.47	20.39	1.73	24.94	0.98	29.90	1.25
b	SS	32.45	1.56	32.15	1.45	33.35	1.12	32.22	2.65	29.45	2.72	30.30	2.47	31.87	1.33	32.41	1.77	32.75	1.47	31.10	2.20	28.83	2.46	30.22	1.77
	MS	30.35	1.24	34.77	4.39	33.93	4.15	33.04	2.91	33.04	3.65	31.63	1.45	30.09	1.62	30.59	1.54	30.17	1.82	30.75	2.15	30.03	1.90	30.65	1.74
1.00	TS	-	-	-	-	31.63	2.43	20.89	1.76	24.76	1.43	30.37	1.38	-	-	-	-	30.60	2.63	19.99	1.71	24.64	0.72	29.55	2.59
d	SS	31.36	1.34	31.43	2.33	33.04	1.55	30.29	2.50	29.58	2.03	30.94	2.35	30.56	1.39	32.04	1.84	32.08	1.55	30.03	2.79	28.86	2.55	30.00	2.49
	MS	31.34	1.37	32.24	1.81	32.33	2.16	31.39	1.65	31.62	1.69	31.62	1.70	29.14	2.20	31.18	2.92	29.64	2.49	29.58	2.20	29.11	1.91	29.35	1.62
1.50	TS	-	-	-	-	31.84	2.14	22.62	0.64	26.77	1.69	29.36	1.29	-	-	-	-	31.51	3.25	21.61	0.91	25.65	1.37	28.01	1.41
bc	SS	31.03	2.07	31.61	2.40	32.84	2.64	32.17	2.27	31.33	2.67	30.98	2.38	30.58	2.11	31.28	2.00	31.95	2.37	30.64	2.78	29.90	2.87	30.02	2.44
	MS	32.42	2.05	30.98	2.29	31.70	3.26	32.27	2.89	31.57	2.71	31.59	2.84	30.44	2.41	30.90	2.13	29.78	3.67	30.11	2.68	29.95	2.95	29.37	3.37
3.00	TS	-	-	-	-	33.99	3.27	23.15	1.17	26.20	0.72	24.68	0.47	-	-	-	-	32.02	1.97	20.09	0.71	26.58	1.08	24.77	1.07
a	SS	31.69	0.49	31.78	1.09	33.40	1.75	31.20	1.17	31.63	1.46	30.47	1.99	32.02	1.46	32.20	1.38	32.61	1.44	30.94	1.93	31.56	1.79	30.50	2.33
	MS	29.89	1.15	31.62	1.98	29.72	2.39	31.17	1.68	29.44	2.46	27.75	1.31	28.82	0.52	30.63	2.92	30.80	2.30	30.50	1.98	31.29	2.09	29.95	2.68

Letters indicate results of Waller-Duncan K-ratio t-test

* Pr > F = 0.0001 at the 95% level. Treatments having the same letters are not significantly different.

** Pr > F = 0.0001 at the 95% level. Mean monthly moisture values are always significantly different.

*** Pr > F = 0.0001 at the 95% level. Topsoil, subsoil and minespoil are always significantly different.

N.B. The coefficient of variability (CV) was generally $\leq 10\%$ for all statistical tests performed.

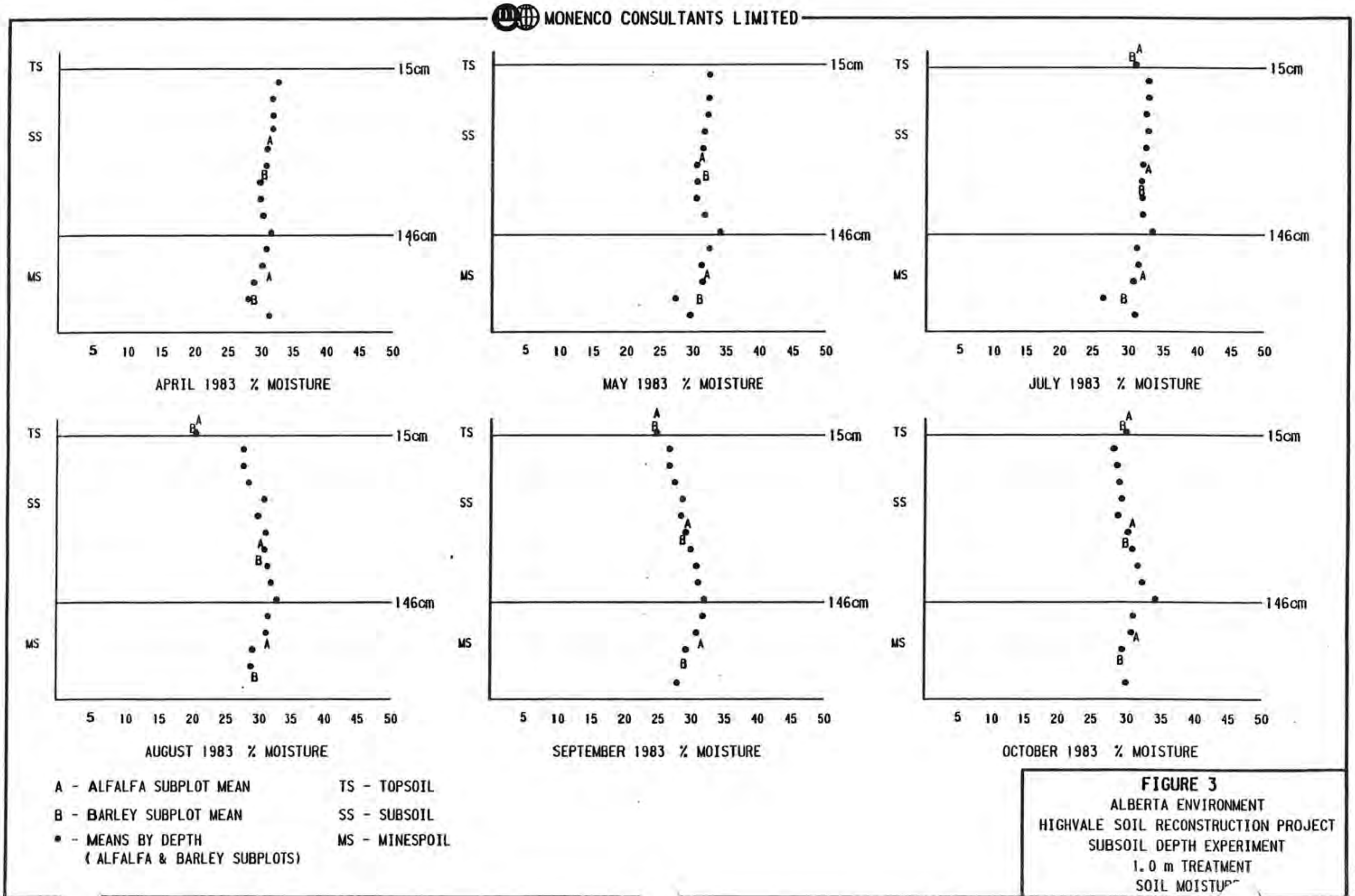


FIGURE 3
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SUBSOIL DEPTH EXPERIMENT
1.0 m TREATMENT
SOIL MOISTUR

all plots may indicate that the interface is affecting the downward vertical movement of moisture. If the trend continues and develops further, a more conclusive statement can be made about the effect of the interface on moisture movement.

Soil Bulk Density

Table 2 shows mean values and standard deviations of bulk density in the topsoil, subsoil and minespoil for the forage and cereal subplots of each treatment.

Analysis of variance and the Waller-Duncan K-ratio t-test performed on the data indicate the following results:

- bulk density increased significantly with depth. Topsoil, subsoil and minespoil bulk densities were significantly different at the 95% level ($Pr > F = 0.0001$).

- Individual bulk density values ranged from a low of 0.90 g/cc to a high of 2.12 g/cc. Mean values for topsoil ranged from 1.20 - 1.5g/cc, for subsoil from 1.59 - 1.83 g/cc and for minespoil from 1.69 to 1.87 g/cc.

A bulk density profile for the 1.0 m treatment is illustrated in Figure 4. The bulk density profile is the result of constructon and one year's settling and can be expected to change with time. Changes

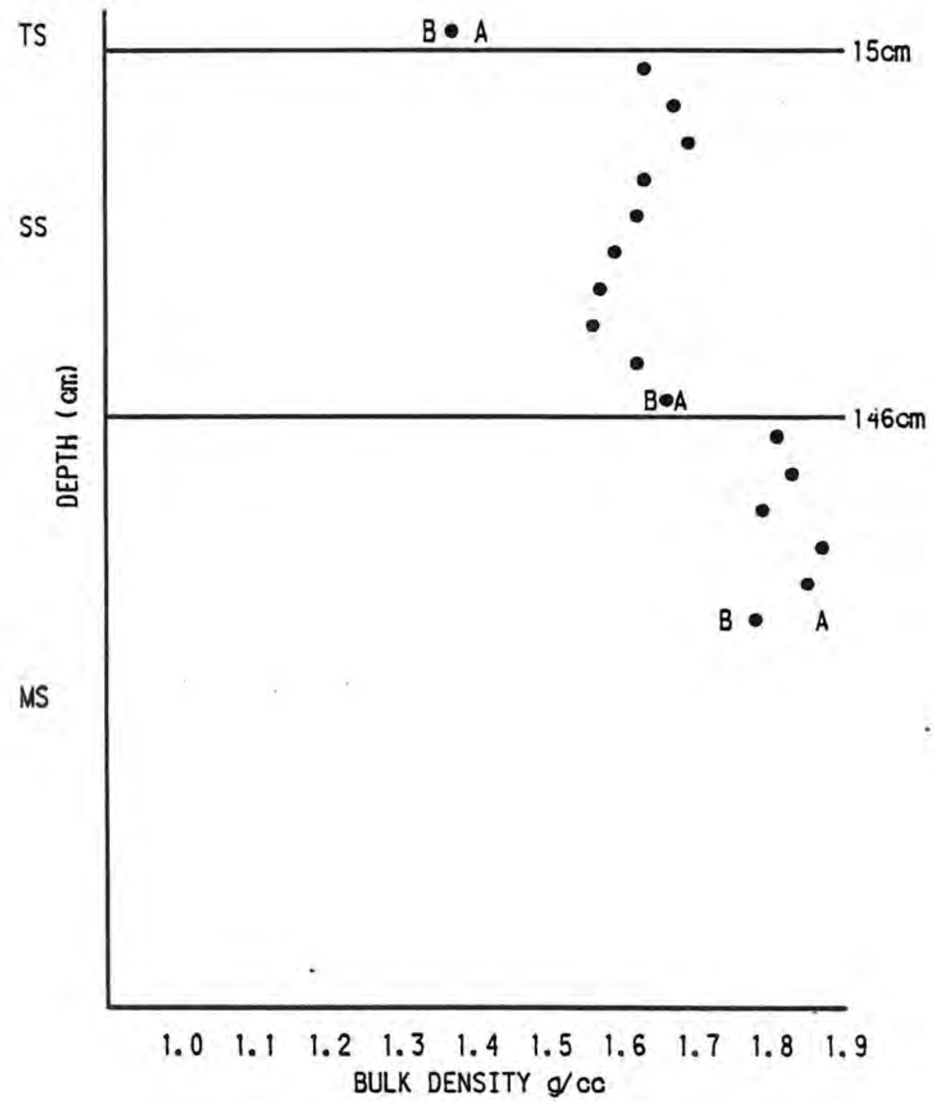
TABLE 2

SOIL BULK DENSITY BY TREATMENT FOR EACH SUBPLOT

TREATMENT*	MATERIAL**	BULK DENSITY g/cc ALFALFA SUBPLOT		BARLEY SUBPLOT	
	(TS, SS, MS)	$\bar{x}$	sd	$\bar{x}$	sd
0.00 m	TS	1.40	0.16	1.36	0.22
a	SS	-	-	-	-
	MS	1.76	0.13	1.71	0.10
0.25 m	TS	1.53	0.21	1.46	0.18
ab	SS	1.76	0.11	1.78	0.17
	MS	1.86	0.13	1.87	0.20
0.50 m	TS	1.30	0.13	1.33	0.12
c	SS	1.73	0.19	1.83	0.08
	MS	1.74	0.20	1.69	0.30
1.00 m	TS	1.41	0.18	1.34	0.25
c	SS	1.68	0.17	1.64	0.13
	MS	1.87	0.09	1.74	0.14
1.50 m	TS	1.49	0.14	1.20	0.15
c	SS	1.78	0.13	1.59	0.23
	MS	1.83	0.12	1.80	0.12
3.00 m	TS	1.31	0.13	1.29	0.26
b	SS	1.65	0.13	1.78	0.16
	MS	1.85	0.18	1.79	0.12

Letters indicate results of Waller-Duncan K-ratio t-test.
* Pr > F = 0.0001 at the 95% level. Treatments having the same letter are not significantly different.
** Pr > F = 0.0001 at the 95% level. Topsoil, subsoil and minespoil are always significantly different.

N.B. The coefficient of variability was generally $\leq$ 10% for all statistical tests performed.



TS - TOPSOIL
SS - SUBSOIL
MS - MINESPOIL
A - ALFALFA SUBPLOT MEAN
B - BARLEY SUBPLOT MEAN
• - TREATMENT MEANS BY DEPTH

FIGURE 4
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SUBSOIL DEPTH EXPERIMENT
1.0 m TREATMENT
SOIL BULK DENSITY

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will be due largely to compaction and subsidence. Some changes due to crop rooting may be expected, especially in the forage subplots. The general trends seem to indicate that compaction may already be occurring beneath the topsoil as the plots settle.

Soil Chemistry

Samples were analysed for pH, EC, soluble cations, soluble sulphate and soluble chloride. Only pH, EC, soluble sodium and SAR measurements were statistically analysed. The other parameters will be statistically analysed after a longer time interval (i.e., 5 years).

Results of soil chemical analysis for pH, EC, soluble sodium and SAR are presented in Table 3, and chemistry profiles for the 1.0 m treatment are shown in Figure 5.

There were no significant differences between replicates or subplots for pH, EC, soluble sodium or SAR at any of the depth intervals. This indicates that each of the topsoil, subsoil and spoil materials used in plot construction were relatively homogeneous across the experimental area and with depth. Significant differences between treatments by depth interval reflect increases of soluble sodium, EC and SAR at the subsoil/spoil depth interval for each treatment. This is further confirmed by results of the Waller-Duncan K-ratio t-test. Both topsoil and subsoil material are significantly different from the spoil material.

TABLE 3

Chemical Analysis of Depth Intervals – Subsoil Depth Experiment

Treatment	Depth	Material	CEREAL								FORAGE							
			pH		EC (mS/cm)		Na(me/l)		SAR		pH		EC (mS/cm)		Na (me/l)		SAR	
(m)			$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	S
0.00	0–15	Topsoil	7.2d*	0.2	3.4a	0.2	3.4d	2.1	2.3d	1.6	7.3c	0.4	0.8c	0.2	3.6c	2.5	2.7d	2.0
	15–40	Spoil	8.5a	0.1	1.6c	0.2	14.7c	2.1	21.0c	2.5	8.5a	0.1	1.76	0.5	16.1b	4.5	23.1a	3.2
	40–55	Spoil	8.5a	0.3	1.6c	0.3	15.1b	3.3	22.2b	2.5	8.3b	0.4	2.5a	2.6	24.7a	26.5	22.1b	9.6
	105–120	Spoil	8.4c	0.2	1.9b	0.5	18.3a	4.5	24.4a	3.3	8.3b	0.3	2.5a	1.7	23.9a	16.9	21.2c	10.4
0.25	0–15	Topsoil	7.2c	0.1	0.5b	0.1	0.4b	0.1	0.2d	0.1	7.3d	0.5	0.8b	0.4	1.9c	3.5	0.7c	0.8
	15–40	Subsoil	7.8b	0.1	0.3c	0.0	0.7c	0.3	0.5c	0.3	7.7c	0.2	0.4d	0.0	0.6d	0.3	0.5d	0.2
	55–70	Subsoil	7.8b	0.1	0.5b	0.2	2.4b	1.3	1.90b	1.0	7.9b	0.1	0.5c	0.2	3.1b	2.0	2.8b	1.9
	105–120	Spoil	8.5a	0.1	1.4a	0.2	13.5a	1.2	23.3a	1.9	8.5a	0.1	1.6a	0.4	15.4a	4.2	24.6a	2.6
0.50	0–15	Topsoil	7.2d	0.1	0.5e	0.1	0.3f	0.1	0.2e	0.1	7.5e	0.2	0.5e	0.1	0.3f	0.1	0.2e	0.1
	15–30	Subsoil	7.9c	0.2	0.3f	0.0	0.5e	0.2	0.4d	0.1	7.8c	0.1	0.4f	0.1	0.5e	0.1	0.3d	0.1
	55–70	Subsoil	8.5b	0.1	1.4b	0.2	13.3c	2.0	25.7b	2.2	8.2b	0.4	1.1c	0.6	10.1c	7.4	16.0b	12.2
	100–130	Subsoil	7.9c	0.2	0.8d	0.1	4.9d	1.4	4.0c	1.3	7.7d	8.1	0.6d	0.9	3.0d	6.5	2.5c	5.7
	130–145	Spoil	8.5b	0.0	2.1a	1.2	20.2a	11.1	25.3a	2.5	8.5a	0.2	1.5b	0.4	14.7b	4.3	24.9a	2.0
	145–165	Spoil	8.7a	0.1	1.2c	0.1	11.7b	1.2	25.2a	2.0	8.5a	0.2	1.8a	0.7	17.6a	7.2	26.5a	2.1
1.00	0–15	Topsoil	7.2e	0.3	0.9b	0.4	1.0d	1.1	0.5d	0.5	7.4f	0.7	0.7c	0.2	0.6f	0.3	0.4e	0.2
	15–30	Subsoil	7.8c	0.2	0.4d	0.0	0.7e	0.2	0.5d	0.1	7.9d	0.1	0.4d	0.0	0.8d	0.2	0.6c	0.2
	50–65	Subsoil	7.7d	0.4	0.4d	0.0	0.6f	0.1	0.5d	0.1	7.9d	0.1	0.4d	0.0	0.7c	0.3	0.5d	0.2
	85–100	Subsoil	7.8c	0.1	0.4d	0.0	0.6f	0.2	0.4e	0.1	7.8e	0.2	0.4d	0.1	0.6f	0.1	0.5s	0.1
	130–150	Subsoil	8.0b	0.2	0.7c	0.2	4.5c	1.5	3.8c	1.4	8.0c	0.4	0.7c	0.4	4.3c	4.9	3.2b	9.9
	150–180	Spoil	8.5a	0.2	1.7a	0.5	16.1b	4.7	24.0b	3.0	8.7b	0.2	1.3a	0.7	13.1b	6.5	24.2a	3.2
	180–215	Spoil	8.5a	0.2	1.6a	1.3	17.1a	9.7	26.0a	3.5	8.8a	0.2	1.1b	0.7	11.2a	6.9	22.3a	7.1
1.50	0–15	Topsoil	7.4e	0.5	0.5d	0.2	0.3f	0.1	0.2f	0.0	7.6f	0.3	0.66	0.1	0.4e	0.1	0.2f	0.1
	15–30	Subsoil	7.9c	0.1	0.4e	0.0	0.5d	0.2	0.4d	0.2	7.9c	0.1	0.4d	0.0	0.5d	0.2	0.4d	0.1
	50–65	Subsoil	7.9c	0.2	0.3f	0.1	0.4e	0.2	0.3e	0.1	7.7e	0.4	0.3e	0.1	0.5d	0.2	0.4d	0.1
	85–100	Subsoil	7.8d	0.2	0.3f	0.0	0.4e	0.1	0.3e	0.0	7.7e	0.3	0.3e	0.1	0.4e	0.1	0.3e	0.0
	120–135	Subsoil	7.8d	0.3	0.3f	0.1	0.5d	0.2	0.4d	0.1	7.8d	0.3	0.3e	0.1	0.4e	0.1	0.3e	0.1
	150–165	Subsoil	7.9c	0.3	0.3f	0.1	0.4e	0.0	0.4d	0.0	7.6f	0.3	0.3e	0.1	0.4e	0.0	0.3e	0.1
	180–200	Subsoil	7.9c	0.2	0.7c	0.3	3.9c	2.8	3.2c	2.0	7.8d	0.5	0.5c	0.3	2.2c	2.1	1.7c	1.6
	200–230	Spoil	8.3b	0.6	2.2b	1.5	20.3b	14.9	22.4b	10.9	8.7b	0.1	1.6b	0.4	14.9b	3.9	29.2b	1.6
	245–260	Spoil	8.5a	0.2	3.3a	1.2	31.9a	11.5	29.1a	3.1	8.6a	0.1	2.1a	1.0	19.0a	8.9	25.3a	1.6
3.00	0–15	Topsoil	7.6g	0.5	1.2c	1.5	6.1c	13.9	5.0b	11.5	7.5g	0.5	0.5b	0.9	0.3f	0.9	0.2e	0.8
	15–30	Subsoil	7.9e	0.1	0.4d	0.1	0.4e	0.1	0.3e	0.1	7.9d	0.1	0.4c	0.0	0.4e	0.1	0.3d	0.1
	50–65	Subsoil	7.9e	0.2	0.4d	0.1	0.4e	0.1	0.3e	0.0	7.8e	0.1	0.4c	0.0	0.4e	0.1	0.3d	0.1
	85–100	Subsoil	7.9e	0.1	0.4d	0.0	0.4e	0.0	0.3e	0.0	7.7f	0.2	0.3d	0.1	0.4e	0.0	0.3d	0.0
	120–135	Subsoil	7.8f	0.1	0.4d	0.1	0.4e	0.1	0.3e	0.1	7.8e	0.0	0.4c	0.1	0.5d	0.2	0.4c	0.1
	155–170	Subsoil	8.0d	0.1	0.4d	0.0	0.5d	0.2	0.4d	0.1	7.8e	0.1	0.4c	0.0	0.4e	0.0	0.3d	0.0
	190–205	Subsoil	7.9e	0.1	0.4d	0.0	0.5d	0.2	0.4d	0.2	7.8e	0.1	0.4c	0.1	0.5d	0.1	0.4c	0.1
	225–240	Subsoil	8.0d	0.1	0.4d	0.0	0.6d	0.2	0.5c	0.2	7.9d	0.1	0.4c	0.0	0.6c	0.2	0.4c	0.2
	285–300	Subsoil	7.9e	0.0	0.4d	0.0	0.4e	0.0	0.3e	0.0	7.9d	0.1	0.4c	0.0	0.4e	0.1	0.3d	0.1
	330–350	Subsoil	8.1c	0.2	1.1c	1.1	7.5c	9.7	6.0b	8.1	8.0c	0.1	0.7b	0.3	3.8b	1.5	2.9b	1.0
	350–365	Spoil	8.5b	0.3	2.0a	1.2	17.8b	10.8	21.9a	10.0	8.5a	0.2	2.3a	2.0	20.5a	17.1	21.0a	3.6
	395–410	Spoil	8.6a	0.3	1.6b	1.1	14.8a	10.1	22.0a	9.1	8.4b	0/3	2.3a	2.5	21.6a	23.9	21.3a	4.1

* Results of Waller-Duncan K-ratio t- test. Numbers for treatment and each soil property by depth increment followed by different letters are significantly different at the 95% level.

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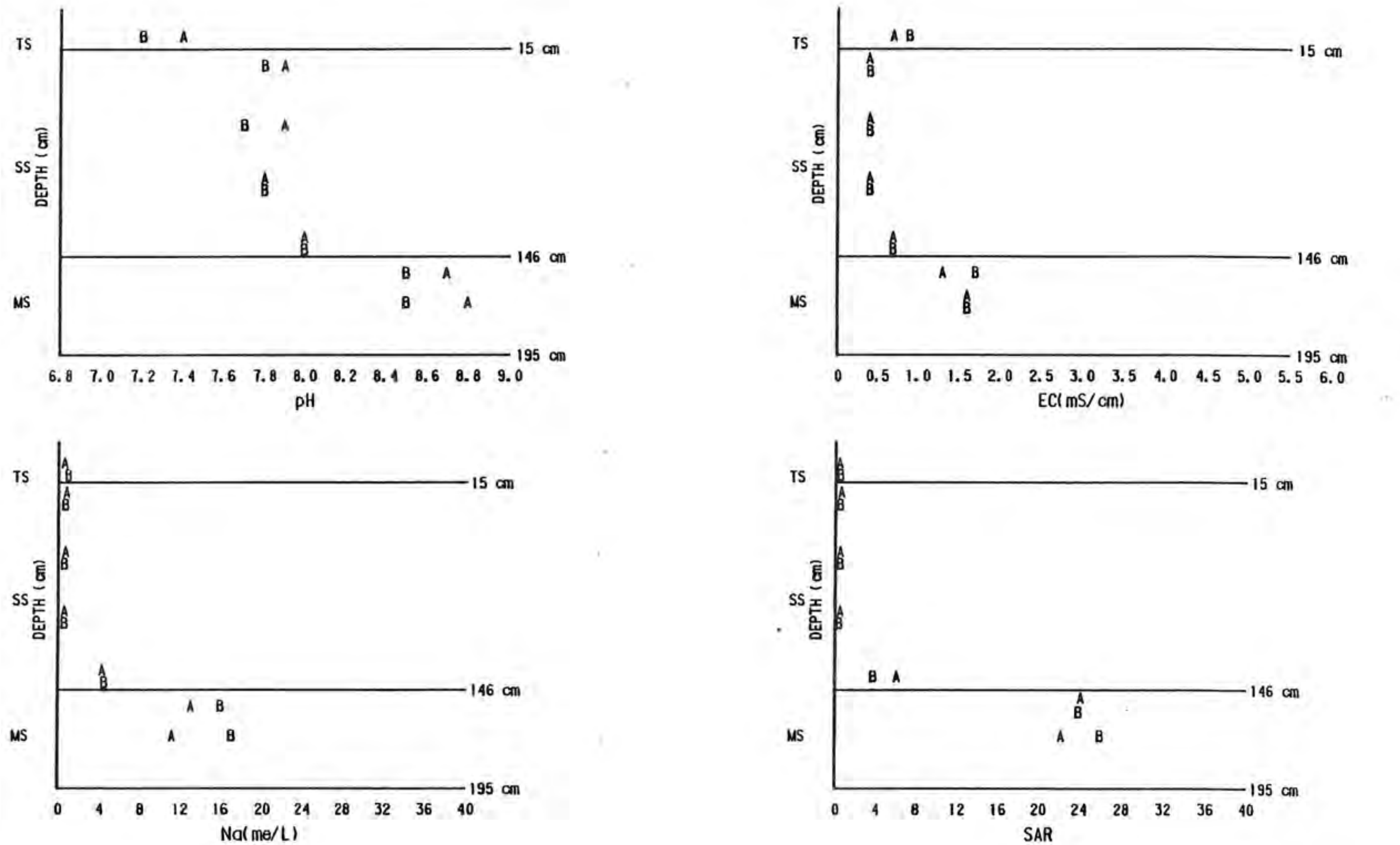

A - FORAGE SUBPLOT
B - CEREAL SUBPLOT

TS - TOPSOIL
SS - SUBSOIL
MS - MINESPOIL

NOTE: SUBPLOT VALUES THAT ARE EQUAL ARE STACKED WITHIN AN INCREMENT.

FIGURE 5
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SUBSOIL DEPTH EXPERIMENT
1.0 m TREATMENT
SOIL CHEMISTRY

ANOVA results indicate that upward movement of salts from the minespoil into the subsoil has occurred since construction, and is occurring more quickly in the shallow treatments. This may be explained by the effect of crop growth on the shallower treatments. The utilization of soil moisture by plants occurs within the upper soil zone and creates a decreasing moisture gradient toward the surface. Soil moisture content decreased throughout the subsoil and topsoil materials as depth decreased. The potential moisture gradient resulted in a net upward movement of water carrying soluble salts from the spoil into the subsoil in the shallow subsoil treatments.

Crop Productivity

Both forage and cereal crop productivity were significantly different by treatment. Figure 6 illustrates crop productivity by treatment. On the forage subplots, highest yield was measured on the 0.50 m treatment. Highest yield for the cereal subplots was associated with the 1.0 m treatment. The 0.0 m treatment had the lowest yields for both crops.

SLOPE DRAINAGE EXPERIMENT

Soil Moisture

Analysis of variance and the Waller-Duncan K-ratio t-test show that the 10°N and 5°N treatments were not significantly different from each

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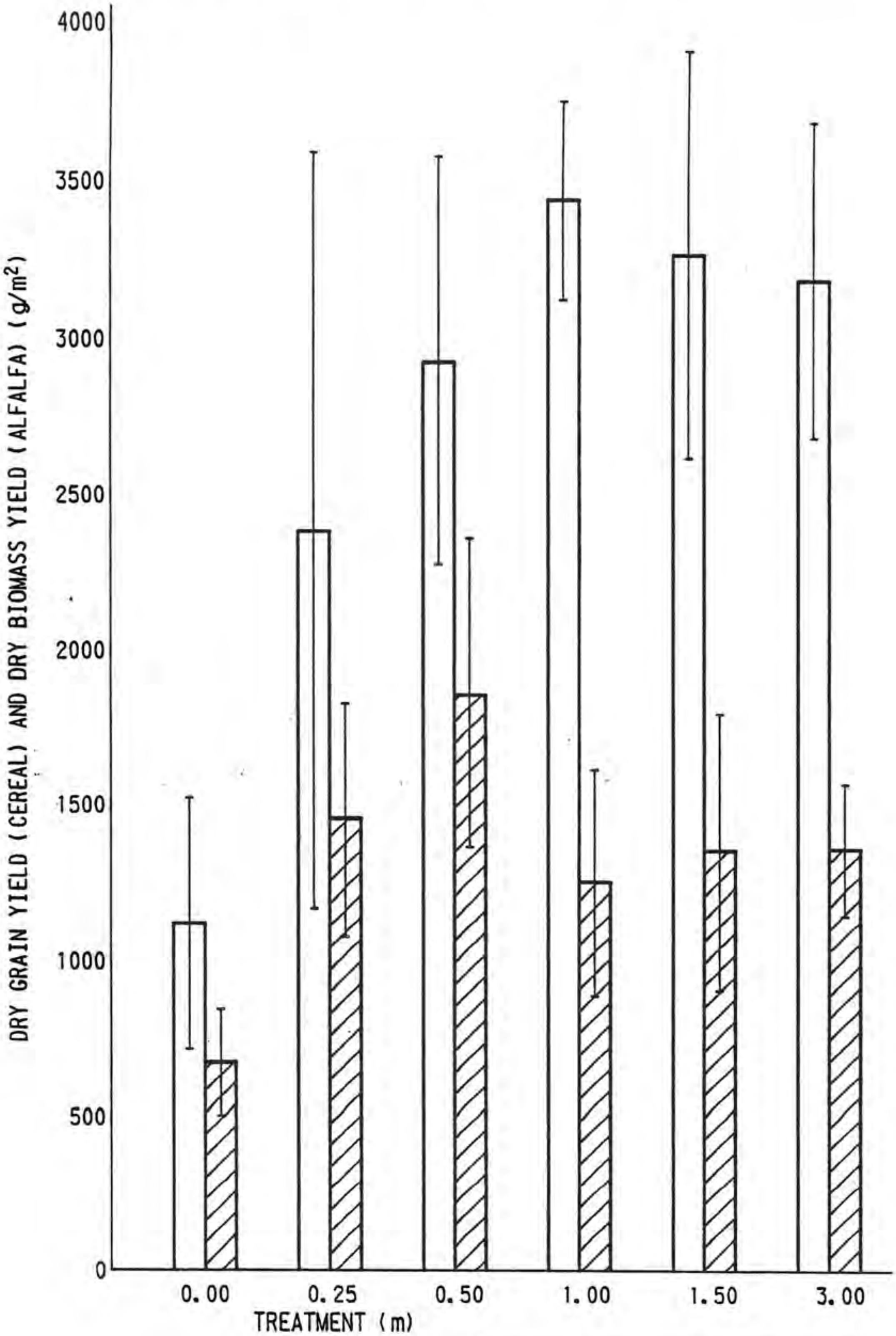

FIGURE 6
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SUBSOIL DEPTH EXPERIMENT
1983 YIELDS
BY TREATMENT (m)

N00489.CHT

other, but were significantly moister than the 10°S and 5°S treatments. Soil moisture increased significantly with depth in the topsoil, subsoil and minespoil. Material*subplot*treatment interactions are also significant at the 95% level ($Pr > F = 0.0004$).

A linear trend analysis was performed on the slope drainage experiment data to determine whether a slope effect (deviation from the linear trend) could be detected. The linear deviation was calculated by summing soil property values of upper and lower slope positions and subtracting twice the middle slope position value. The theoretical value of the calculation would be zero if there was no slope effect. Linear deviation values significantly greater or less than zero therefore represent a slope effect or change in soil property values relative to slope position. The analysis was performed on July, August, and October moisture data. The results indicate a strong trend of increasing moisture down the slope in all of the treatments during these months. The Waller-Duncan K-ratio t-test also showed that upper, middle, and lower slope positions were significantly different ($Pr > F = 0.0001$ at the 95% level).

In general, all the treatments exhibited the same soil moisture profile trends. Moisture was constant down the profile early in the season then drier in the topsoil and subsoil as the summer progressed. The upper slope positions tended to be drier than the lower slope positions. The south-facing plots were also drier overall than the north-facing plots. There were no apparent trends at the subsoil/ minespoil interface.

Soil Bulk Density

Table 4 shows means and standard deviations of bulk density in the topsoil, subsoil and minespoil at lower (Subplot A), middle (Subplot B) and upper (Subplot C) slope positions for each treatment.

Analysis of variance, linear trend analysis, and the Waller-Duncan K-ratio t-test performed on the data also show that mean bulk density on the upper slope is significantly lower than that at middle and lower slope positions ($Pr > F = 0.0048$ at the 95% level). Mean bulk densities at middle and lower slope positions were not significantly different from each other.

Bulk density increased significantly with depth ($Pr > F = 0.0001$ at the 95% level).

Soil Chemistry

Results of chemical analysis for all treatments and positions are presented in Table 5 which shows means and standard deviations of soil chemical data by aspect, slope, position and depth increment. Chemical profiles for the 5°N treatment are shown in Figure 7. Results of a paired comparison t-test are also given for each depth increment within the treatment effects. The pH, EC, soluble sodium and SAR were generally significantly different between depths, and tended to increase with the depth and were significantly higher immediately above

TABLE 4

SOIL BULK DENSITY (g/cc) BY TREATMENT FOR EACH SLOPE POSITION

TREATMENT**	MATERIAL***	LOWER*		MIDDLE		UPPER	
		a		a		b	
		$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
10°Nx	TS	1.44	0.17	1.47	0.19	1.52	0.26
	SS	1.82	0.08	1.70	0.08	1.72	0.17
	MS	1.92	0.05	1.82	0.12	1.75	0.08
10°Sy	TS	1.55	0.24	1.47	0.26	1.34	0.22
	SS	1.66	0.18	1.71	0.11	1.56	0.20
	MS	1.81	0.11	1.79	0.08	1.63	0.13
5°Nx	TS	1.32	0.23	1.49	0.29	1.42	0.26
	SS	1.79	0.10	1.69	-	1.70	0.03
	MS	1.86	0.12	1.91	0.04	1.84	0.06
5°Sy	TS	1.31	0.17	1.37	0.26	1.35	0.31
	SS	1.59	0.12	1.56	0.07	1.78	0.08
	MS	1.81	0.06	1.78	0.18	1.83	0.07

Letters indicate results of Waller-Duncan K-ratio t-test

* Pr > F = 0.0048 at the 95% level. Slope positions having the same letter are not significantly different.

** Pr > F = 0.0031 at the 95% level. Treatments having the same letter are not significantly different.

*** Pr > F = 0.0001 at the 95% level. Topsoil, subsoil and minespoil are always significantly different.

N.B. The coefficient of variability was generally $\leq$ 10% for all statistical tests performed.

TABLE 5
CHEMICAL ANALYSIS OF DEPTH INTERVALS - SLOPE DRAINAGE EXPERIMENT - 1983

TREATMENT	DEPTH	MATERIAL	LOWER SLOPE								MIDDLE SLOPE								UPPER SLOPE							
			pH		EC (mS/cm)		Na (me/l)		SAR		pH		EC (mS/cm)		Na (me/l)		SAR		pH		EC (mS/cm)		Na (me/l)		SAR	
			x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd	x̄	sd
10°N	0-15	Topsoil	7.3d*	0.2	0.5d	0.2	0.4e	0.1	0.3e	0.0	7.4d	0.3	0.5c	0.1	0.5c	0.2	0.3c	0.1	7.2c	0.3	0.7e	0.2	0.4e	0.1	0.2e	0.1
	15-40	Subsoil	7.7c	0.2	0.4e	0.0	0.5d	0.1	0.4d	0.1	7.7c	0.1	0.5c	0.1	0.4c	0.1	0.3c	0.1	7.7d	0.2	0.4d	0.1	0.6d	0.4	0.5d	0.3
	50-65	Subsoil	7.8b	0.1	0.6c	0.1	2.4c	1.0	1.9c	0.8	7.7c	0.2	0.9b	0.3	3.1b	1.9	1.8b	1.0	7.9c	0.3	1.1c	1.2	6.8c	1.06	4.7c	7.1
	65-80	Spoil	8.3a	0.1	1.9b	0.2	16.1b	1.7	14.5b	1.1	8.2b	0.0	3.2a	1.5	25.2a	10.6	15.2a	3.4	8.2b	0.2	2.4b	0.5	20.2b	4.6	15.6b	2.8
	130-145	Spoil	8.3a	0.1	2.5a	1.6	21.1a	11.4	18.6a	7.0	8.3a	0.2	3.1a	1.5	24.1a	9.3	17.9a	7.9	8.3a	0.2	3.5a	1.7	27.4a	9.1	16.4a	1.5
10°S	0-15	Topsoil	7.4e	0.3	0.7e	0.2	0.4c	0.1	02.2e	0.0	7.4d	0.3	0.7c	0.2	0.4d	0.2	0.2d	0.1	7.3d	0.4	0.6c	0.2	0.4d	0.2	0.2d	0.1
	15-40	Subsoil	7.8d	0.1	0.4d	0.0	0.4c	0.1	0.3d	0.1	7.9c	0.1	0.4d	0.1	0.8c	0.8	0.6c	0.6	7.7c	0.2	0.4d	0.0	0.6c	0.3	0.5c	0.2
	50-65	Subsoil	7.9c	0.1	0.6c	0.1	2.5b	0.5	1.9c	0.4	7.8b	0.1	0.5b	0.1	1.2b	0.8	0.9b	0.6	7.9b	0.5	0.9b	1.0	6.1b	8.8	5.3b	8.0
	65-80	Spoil	8.4a	0.1	2.7b	0.2	23.1a	1.4	19.7b	0.9	8.3a	0.2	2.8a	0.2	22.8a	0.9	18.6a	1.4	8.3a	0.1	3.0a	1.0	24.8a	7.5	18.7a	4.0
	130-145	Spoil	8.3b	0.1	3.2a	0.6	27.9a	4.6	22.8a	2.1	8.3a	0.2	2.8a	0.4	23.2a	2.6	17.9a	4.5	8.3a	0.3	3.1a	0.9	26.0a	7.5	18.1a	3.9
5°N	0-15	Topsoil	7.1d	0.2	0.7c	0.0	1.0e	0.8	0.6d	0.5	7.1d	0.2	0.7b	0.1	0.3d	0.1	0.2e	0.0	7.2d	0.4	0.7c	0.1	0.4d	0.2	0.2d	0.1
	15-40	Subsoil	7.7c	0.2	0.6b	0.4	0.7d	0.3	0.5d	0.2	7.6c	0.2	0.4c	0.7	0.4c	0.1	0.3d	0.1	76 c	0.2	0.4d	0.1	0.5d	0.3	0.4c	0.2
	50-65	Subsoil	7.7c	0.1	0.7c	0.1	2.8c	0.7	2.0c	0.5	7.6c	0.2	0.6b	0.2	2.2b	1.8	1.5c	1.2	7.6c	0.1	0.7c	0.3	2.6c	1.8	1.7b	1.0
	65-80	Spoil	8.2b	0.1	1.9b	0.1	16.0b	2.4	14.2b	1.3	8.1b	0.3	2.1a	0.8	17.3a	8.2	13.4a	6.5	8.2b	0.2	2.8b	0.6	24.3b	5.6	18.7a	3.7
	130-145	Spoil	8.3a	0.1	2.3a	0.4	20.1a	5.6	17.4a	3.6	8.3a	0.1	2.0a	0.8	17.7a	6.1	18.3a	6.1	8.3a	0.1	2.4a	0.8	20.1a	6.3	17.9a	5.5
5°S	0-15	Topsoil	7.3d	0.3	0.6c	0.1	0.3e	0.1	0.2e	0.1	7.4e	0.6	0.9d	0.9	4.4c	10.0	3.9 c	9.1	7.4d	0.3	0.6d	0.1	0.4d	0.2	0.3d	0.1
	15-40	Subsoil	7.8c	0.1	0.4a	0.0	0.5d	0.1	0.4d	0.1	7.6d	0.1	0.4e	0.1	0.4e	0.1	0.3 e	0.1	7.9c	0.1	0.4e	0.1	0.4d	0.0	0.3d	0.0
	50-65	Subsoil	7.7b	0.2	0.6c	0.2	2.6c	1.5	2.0c	1.1	7.8c	0.2	0.7c	0.2	2.7d	1.0	2.0 d	0.6	7.9c	0.2	0.8c	0.3	3.6c	2.3	2.6c	1.6
	65-80	Spoil	8.3a	0.1	2.8b	0.5	23.1b	3.5	19.7b	4.0	8.4b	0.2	3.1b	0.3	25.7b	2.6	19.4 b	4.1	8.2b	0.2	2.6b	1.0	20.9b	8.7	17.1b	7.1
	130-145	Spoil	8.1a	0.5	2.1a	0.8	17.4a	8.6	15.8a	8.1	8.0a	0.3	2.6a	0.8	20.8a	7.2	15.4 a	4.5	7.0a	3.4	3.0a	0.5	26.1a	4.6	22.4a	4.6

*Results of Waller-Duncan K-ratio t-test across depth interval. Numbers for depth intervals followed by different letters are significantly different at the 95% level.

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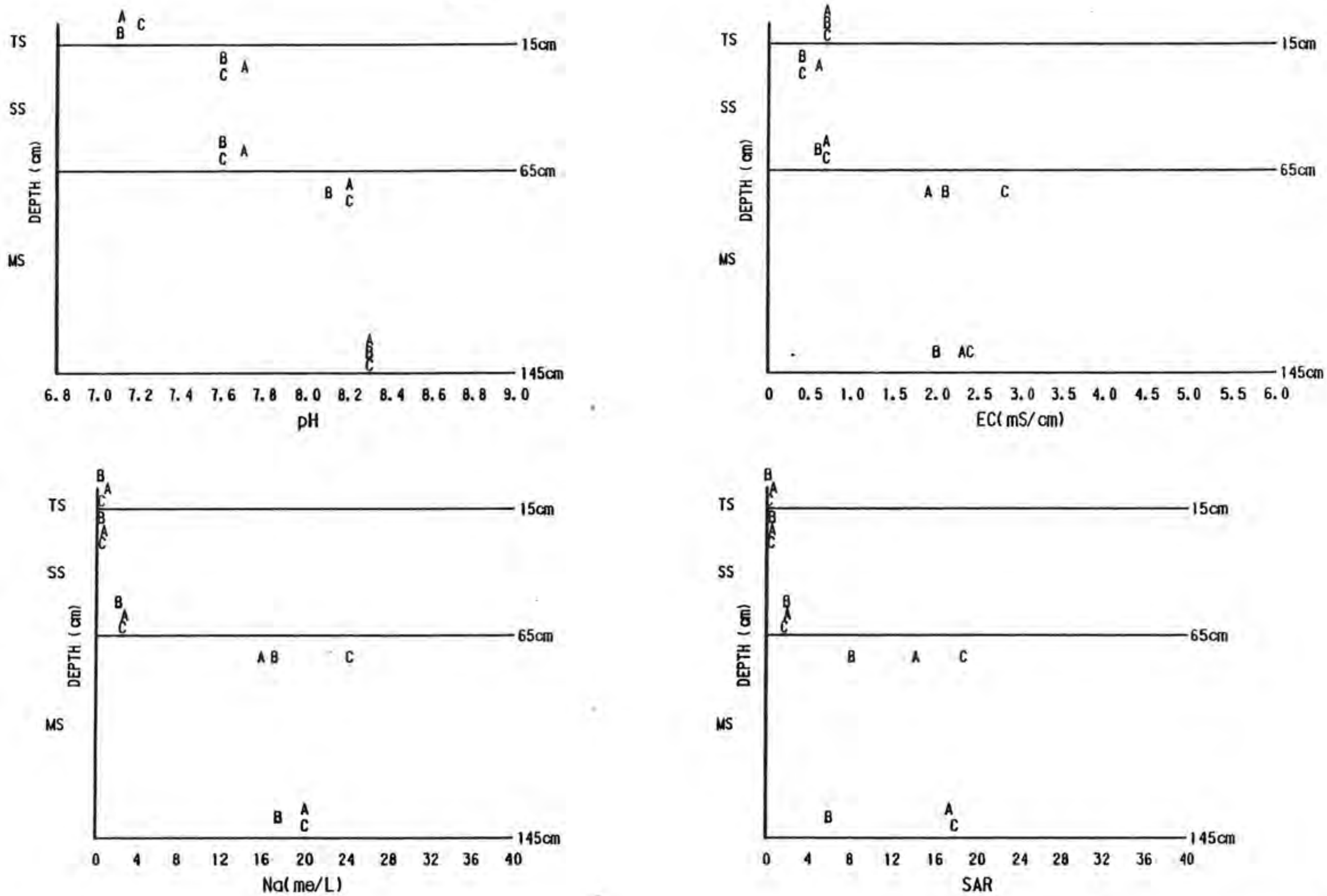

A* - LOWER SLOPE
B - MIDDLE SLOPE
C - UPPER SLOPE

TS - TOPSOIL
SS - SUBSOIL
MS - MINESPOIL

NOTE: SUBPLOT VALUES THAT ARE EQUAL ARE STACKED WITHIN AN INCREMENT.

FIGURE 7
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SLOPE DRAINAGE EXPERIMENT
5°N TREATMENT
SOIL CHEMISTRY

M00470.CHT

the spoil interface (50 to 65 cm) than at 15 to 40 cm. ANOVA results showed that subsoil/spoil interface values were generally significantly higher in 1983. This indicates that upward movement of sodium has occurred since 1982 across all treatments and slope positions.

The magnitude of increase in soluble sodium, EC and SAR at the subsoil/spoil interface was greatest in the upper slope position and for the 10° slope treatments. The upper slope positions were significantly higher in EC, soluble sodium and SAR than lower slope positions.

There were no significant differences in soil properties between treatments or aspects and slope analyzed separately.

Figure 8 is a schematic representation of the results of the linear trend analysis showing sodium and water movement. Deviations from the linear trend are governed by the same general dynamics for both aspects of the 10° slope treatments. The 5° slope treatment linear trends are also similar for both aspects but they are different than the 10° slope treatments.

Significant linear deviations at the subsoil/spoil interface occurred for both aspects of the 10° slope treatments. Soluble sodium and SAR increased significantly from the spoil into the subsoil material (50 to 65 cm and 15 to 40 cm) in the upper slope position. These upper slope plots tended to be relatively drier at the soil surface than lower slope and 5° plots, indicating that soluble sodium is migrating

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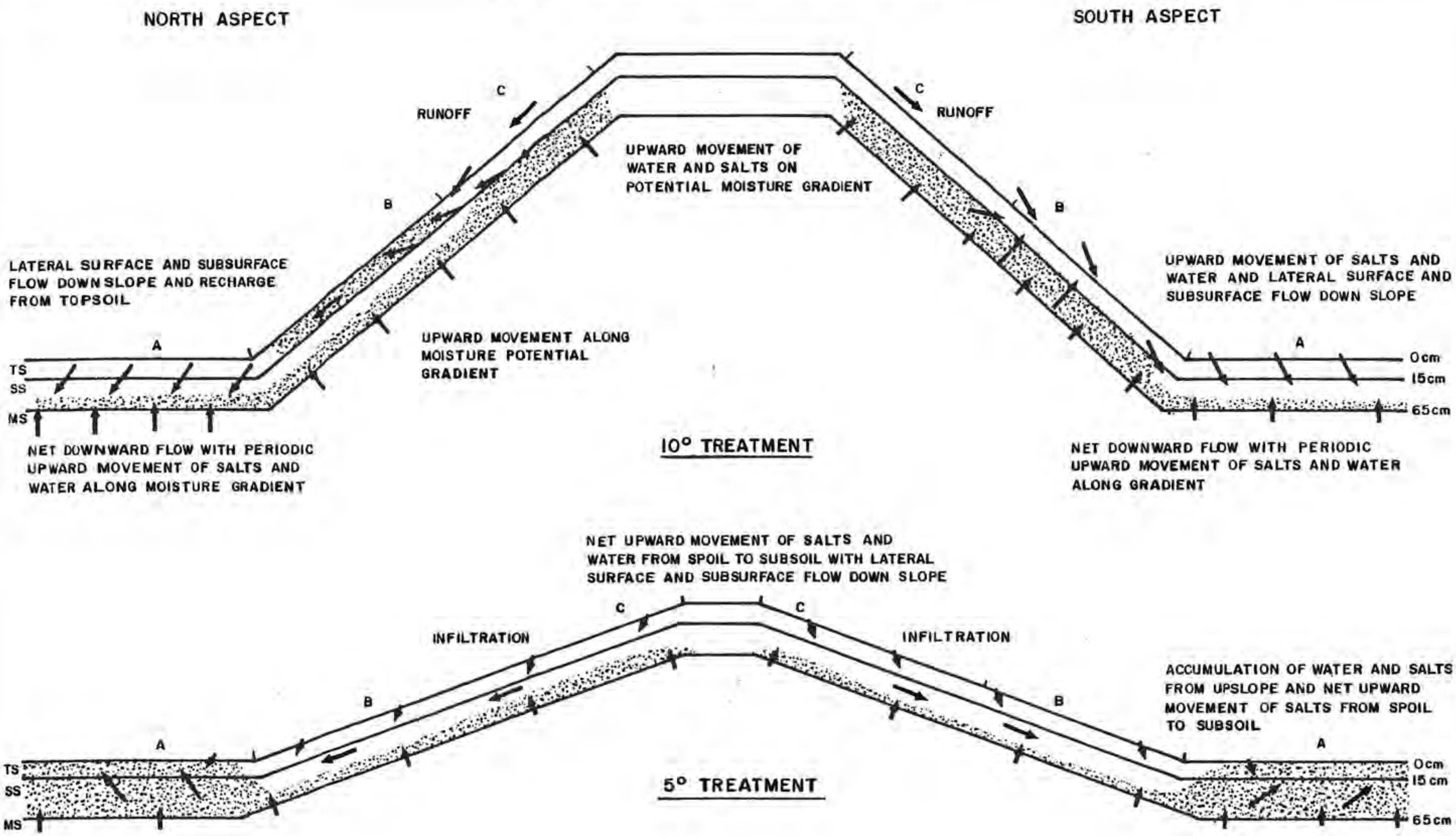


LEGEND

- A LOWER POSITION
- B MIDDLE POSITION
- C UPPER POSITION
- → DIRECTION OF WATER MOVEMENT
- ∴ SOLUBLE SODIUM ACCUMULATION
- TS TOPSOIL
- SS SUBSOIL
- MS MINESPOIL

SCALE 4 x VERTICAL EXAGGERATION

FIGURE 8
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SLOPE DRAINAGE EXPERIMENT
SCHEMATIC DIAGRAM OF SODIUM AND WATER MOVEMENT

upward from the spoil, either with capillary or diffusive movement of soil water in response to a potential moisture gradient at the soil surface. Review of the productivity data shows that yields were significantly higher on upper slope than lower slope positions. Thus, high evapotranspiration rates due to crop growth would enhance development of a potential gradient near the surface. It is unlikely that net downward movement of soil water occurs even periodically at the crest positions of the 10° slopes, due to high runoff and low infiltration rates.

Although the largest increases of soluble sodium and SAR from spoil into the subsoil have occurred in upper and mid-slope (10°N) positions, the net movement of soil moisture and sodium has been upward from spoil into subsoil at each position for the 10° plots. Soluble sodium, SAR and EC are all significantly higher at the interface than in the shallower subsoil intervals, and significant increases have occurred at the interfaces since 1982.

On the 10°S treatment, linear trend results for the 15-40 cm subsoil interval and for topsoil indicate significant increases of EC, soluble sodium and SAR at the midslope position. Increases in soluble sodium and SAR were also significant in topsoil at the midslope position of the 10°N treatment. This indicates a stronger net upward trend (from spoil to subsoil) on the south aspect than the north aspect slopes, which is expected since the moisture data showed that south aspect slopes were relatively dry compared to north aspect slopes.

The increased soluble sodium and SAR in the topsoil at the midslope position of the 10°N treatment probably represents accumulation and discharge of laterally moving subsurface water from upslope. Although some upward movement of salts from spoil to subsoil occurred at the interface, it did not extend into the upper subsoil, and additions of soluble salts to the topsoil in the middle position had to come by lateral movement from above. This suggests that soil water may be moving downslope along the topsoil/subsoil interface as well as the subsoil/spoil interface. The difference in bulk density between the topsoil (relatively low) and the subsoil (relatively high) may be sufficient to result in movement along the interface.

On the drier 10°S treatment, both upward migration of salts from the spoil along a potential moisture gradient and some lateral subsurface movement are probably occurring at the mid-slope position in the 15-40 cm subsoil interval.

It is interesting to note the differences between the north and south aspects on the 10° slope treatments. The higher evapotranspiration rate on the south aspect slopes results in more upward movement and less lateral movement than on north slopes where crop productivity was less and soil moisture greater throughout the profile. Thus, on south-facing slopes, sodium has increased at the interface, throughout the subsoil and somewhat in topsoil materials, while on north-facing slopes accumulation of soluble sodium is associated with only the interface and topsoil intervals.

The 5° slopes show less upward movement of sodium from the spoil into the upper zone (15-40 cm) of the subsoil and a greater accumulation of sodium in the lower slope position. Comparison of the interface subsoil sample (50-65 cm) and the 15-40 cm subsoil sample for each position by ANOVA also show that the soluble sodium has increased at the interface. The linear trend analysis did not show a significant slope effect related to upward movement of soluble sodium from the spoil at the interface because it occurred to the same extent at every slope position.

The upper slope positions of both north and south aspects of the 5° slope treatments are moister than their 10° slope counterparts. This results in a reduced potential moisture gradient toward the soil surface and less upward movement of sodium. It is also likely that the infiltration rate is higher on these more subtle slopes resulting in a greater potential for subsurface lateral flow at the spoil interface. The linear trends indicating accumulation of soluble sodium and higher SARs in the 15-40 cm subsoil interval and topsoil/spoil interface show that most of the increase is due to lateral (downslope) subsurface flow and not to upward movement.

Crop Productivity

Table 6 shows the means and standard deviations calculated for forage productivity by position, slope, aspect and combinations of those treatment factors. The table also shows the results of analysis of

TABLE 6

Productivity by Position, Aspect and Slope - Slope Drainage Experiment

TREATMENTS (Subsoil Depth) (cm)			PRODUCTIVITY - DRY BIOMASS (g/m²) $\bar{x}$	sd	Pr > F (MODEL)*
POSITION					0.0001
Lower			734c**	305	
Middle			1440b	409	
Upper			1783a	408	
ASPECT					0.01
North			1158b	464	
South			1494a	619	
SLOPE					NS
10°			1209b	559	
5°			1442a	562	
ASPECT	POSITION				0.0001
North	Lower		669f	305	
	Middle		1214d	306	
	Upper		1589c	179	
South	Lower		838e	294	
	Middle		1667b	380	
	Upper		1976a	480	
ASPECT	SLOPE	(TREATMENT)			0.01
North	10°		1045d	219	
	5°		1270c	226	
South	10°		1374b	321	
	5°		1613a	367	
SLOPE	POSITION				0.0001
10°	Lower		675f	181	
	Middle		1245e	243	
	Upper		1709d	425	
5°	Lower		832c	362	
	Middle		1636b	337	
	Upper		1857a	253	
ASPECT	SLOPE	POSITION			0.0001
North	10°	Lower	655f	273	
		Middle	990e	191	
		Upper	1490d	194	
	5°	Lower	683f	360	
		Middle	1438c	221	
		Upper	1688b	97	
South	10°	Lower	695f	94	
		Middle	1500d	214	
		Upper	1927a	655	
	5°	Lower	982e	363	
		Middle	1833a	453	
		Upper	2025a	285	

*Results of ANOVA - Probability > F of model at 95% level.

**Results of Waller-Duncan K-ratio t-test - Numbers followed by different letters are significantly different at the 95% level.

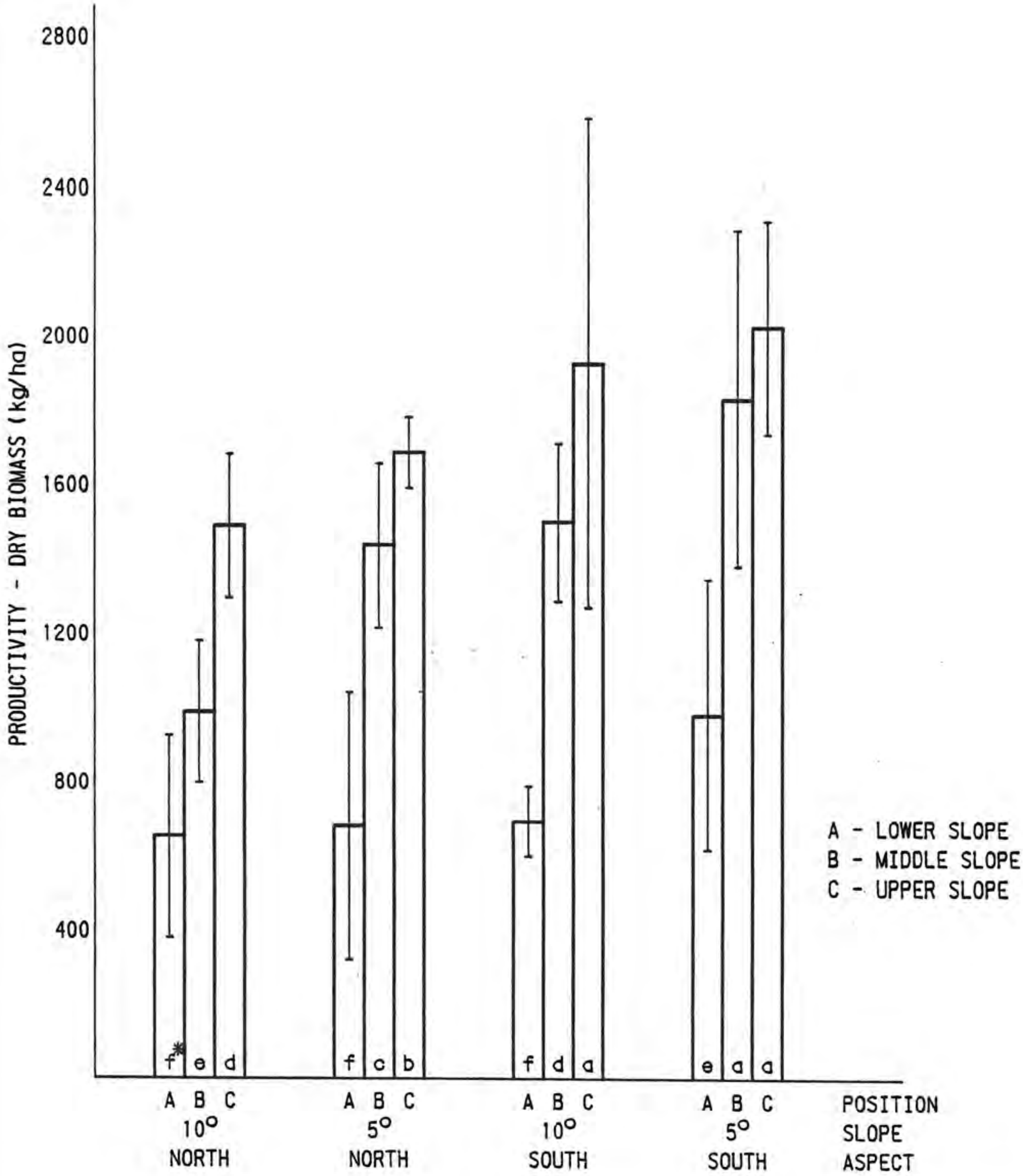
variance (PR> F) and the Waller-Duncan K-ratio t-test, both at 95% confidence. Results are also presented graphically for analysis by aspect, slope and position (Figure 9).

Significant differences in forage productivity were measured for all treatments and combinations except slope across all plots (PR > F = 0.0834). However, t-test results did show a significant difference across slope at the 95% level. Figure 9 shows the results of the paired comparison t-test by treatment (aspect and slope) and position. Lowest yields were measured on 10°S, 10°N and 5°N treatments all in the lower position. This indicates that lower position, regardless of degree of slope, is the worst case situation within the north aspect plots and that within the south aspect, both 10° slope and lower position result in reduced yields. Highest yields were measured within the south aspect plots. These results show that the strongest plant growth response is to upper slope positions in the south aspect.

CONCLUSIONS

Data from the first year's monitoring program indicates the following interim conclusions in the regard to the Subsoil Depth Experiment:

1. The null hypothesis that the subsoil/minespoil interface will not interfere with vertical water movement should be rejected.



*RESULTS OF T-TEST (PAIRED COMPARISON). BARS LABELLED WITH DIFFERENT LETTERS ARE SIGNIFICANTLY DIFFERENT AT THE 95% LEVEL.

FIGURE 9
ALBERTA ENVIRONMENT
HIGHVALE SOIL RECONSTRUCTION PROJECT
SLOPE DRAINAGE EXPERIMENT
1983 YIELDS
BY POSITION, SLOPE AND ASPECT

HG0489.CHT

2. The null hypothesis that no sodium migration will occur should be rejected.

3. The null hypothesis regarding the lack of response of crop productivity to depth treatment and the similarity of the cereal and forage crop response should both be rejected. Maximum cereal yield occurred on the the 1.0 m treatment and maximum forage yield on the 0.5 m treatment, indicating that these are the optimal depths of subsoil for growth of these crops.

With regard to the Slope Drainage Experiment; the following interim conclusions can be made:

1. The null hypothesis regarding no slope effect on salt transport can be rejected.

2. The null hypothesis that crop productivity is not a function of slope treatments should be rejected.

3. Maximum yields were associated with upper slope positions and south aspects on the 5° slope plots.

It must be stressed that these conclusions are tentative, based only on one year's data, and may change as time goes on. Final conclusions and quantification of treatment effects will be reached after 5 years data has been collected and analysed.

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1. Mr. L.A. Panek - responsible for project management and administration.

2. Mr. T.A. Oddie - responsible for all "field" related agricultural activities.

3. Ms. M.M. Boehm - responsible for complete data base construction and statistical analyses.

4. Ms. V.E. Klaassen - responsible for moisture and bulk density analyses, data base construction and statistical analyses.

5. Dr. J.R. Dean - responsible for the laboratory analytical component.

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NINTH ANNUAL MEETING CANADIAN LAND RECLAMATION ASSOCIATION

RECLAMATION IN MOUNTAINS, FOOTHILLS AND PLAINS: **DOING IT RIGHT!**

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