LEACHING STUDIES ON SLOPING LAND WITH DEEP TILE DRAINS *

by

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INTRODUCTION

In a previous paper (5) the authors reported on leaching studies in shallow glacial soils with tile drains installed at a depth of 30 inches. Although the surface soil was reclaimed to a depth of 3 feet, the salt concentration of the soil at depths of 3 to 8 feet did not decrease to the same extent. Salts at these depths are a potential source of future salinization under shallow water table conditions. Installation of tile drains deeper than 30 inches is generally recommended (3). The problem with deep tile drains in glacial till is the low hydraulic conductivity of the soil, which causes slow removal of water and salts to these drains.

Leaching of salt-affected soils is generally done in level basins after the land has been levelled and diked. This procedure, however, can be costly or impractical in some cases.

The objective of this study was to determine the feasibility of using deep tile drains in reclaiming glacial till soils to depths of 5 to 7 feet on sloping land with a border-dike system. In addition a study was made of the possibility of reclamation without artificial drainage.

MATERIAL AND METHODS

The study was conducted on 13 acres of Shallow Chin loam northeast of Vauxhall, Alberta. The land had become salt-affected from seepage along the slope of the land and ponding of waste water in the lower part of the field. In the upper part of the field three tile drains were installed across the slope 6 feet deep and 200 feet apart. In half of this drained area a system of both shallow and deep tile drains was used, tile drains being installed 3 feet deep and 33 feet apart (parallel to the deep drains) over half the distance occupied by the deep drains. No drains were installed in the lower part of the field. Four-inch burnt clay tile was covered with 6 inches of pit-run gravel before the trench was backfilled. The slope of the land varied from ½ percent at higher elevations to 1 percent in the lower part of the field. The undrained area was included in the experiment. In 1959 a stand of Reed canarygrass was established with the aid of sprinkler and flood irrigations. A system of border dikes at right angles to the drains was used for subsequent irrigations.

For comparison purposes an undrained area having similar soil and salinity conditions was basin-irrigated. This area was located near a canal where the soil could be exposed to water tables that fluctuated between 1 and 4 feet as a result of seepage and irrigation.

As the land was not uniformly salt-affected, sampling sites had to be restricted to areas where originally the electrical conductivity of the saturation extract (EC_e) was approximately 12 millimhos per centimeter (mmhos/cm). All soil samples were analysed for EC_e, calcium plus magnesium, and sodium according to procedures of Handbook 60 (4). The sodium absorption ratio (SAR) was calculated with the following equation:

$$SAR = Na^+ \sqrt{½ \ (Ca^{++} + Mg^{++})}$$

where the concentrations of Na^+, Ca^{++} and Mg^{++} are expressed in milliequivalents per liter in the saturation extract.

The irrigation water used in the experiment had a salt content of 400 ppm and an SAR of 2.2. This water was applied in increments varying from 0.5 to 6 inches. The net amounts of water applied annually are shown in table I.

TABLE I. TOTAL ANNUAL AMOUNT (INCHES) OF IRRGIATION WATER APPLIED TO VARIOUS AREAS

Year	Sloping land: Shallow and deep tile drains	Sloping land: Undrained, and deep tile drains	Undrained basins
1959	59.0	48.0	28.0
1960	26.0	27.0	7.0
1961	13.4	16.8	11.0
1962	40.2	26.9	12.0
1963	23.6	21.7	12.0
1964	25.0	25.0	25.0

RESULTS

During the first years of this study the salt content of the soil in the drained areas was gradually lowered (figure 1). Some increase in salt content occurred from May 1962 to May 1963 but by the end of 1964 the soil was reclaimed to a depth of 3 feet and had an EC_e of less than 4 mmhos/cm. Although the amount of water applied on the area with both deep and shallow drains differed from that applied to the area with deep drains only, the general pattern of salt removal from soil depths greater than 1 foot was similar for both areas. When the EC_e of the surface 3 feet of soil had reached 4 mmhos/cm or less, the EC_e of the soil below 4 feet was still approximately 5 to 7 mmhos/cm in both artificially drained areas. The same vertical pattern of salt distribution was observed in a previous study by van Schaik and Milne (5) when shallow tile drains were used on flat land.

A decrease in salt content of the soil on sloping land without artificial drainage was apparent during this study but was not as large as in the drained areas. The surface soil of the undrained area where level basins were used showed about the same improvement as that of the undrained area of the sloping land (figure 1). In both instances the EC_e of the soil throughout the profile to 6 feet did not drop below 7.5 mmhos/cm.

DISCUSSION

Reclamation of the soil in this study was accomplished in approximately 4 to 5 years. Although the time involved was rather long, it was advantageous to use sloping land. After level basins are used, the reclaimed land generally requires levelling for farming operations. In this study the sloping land did

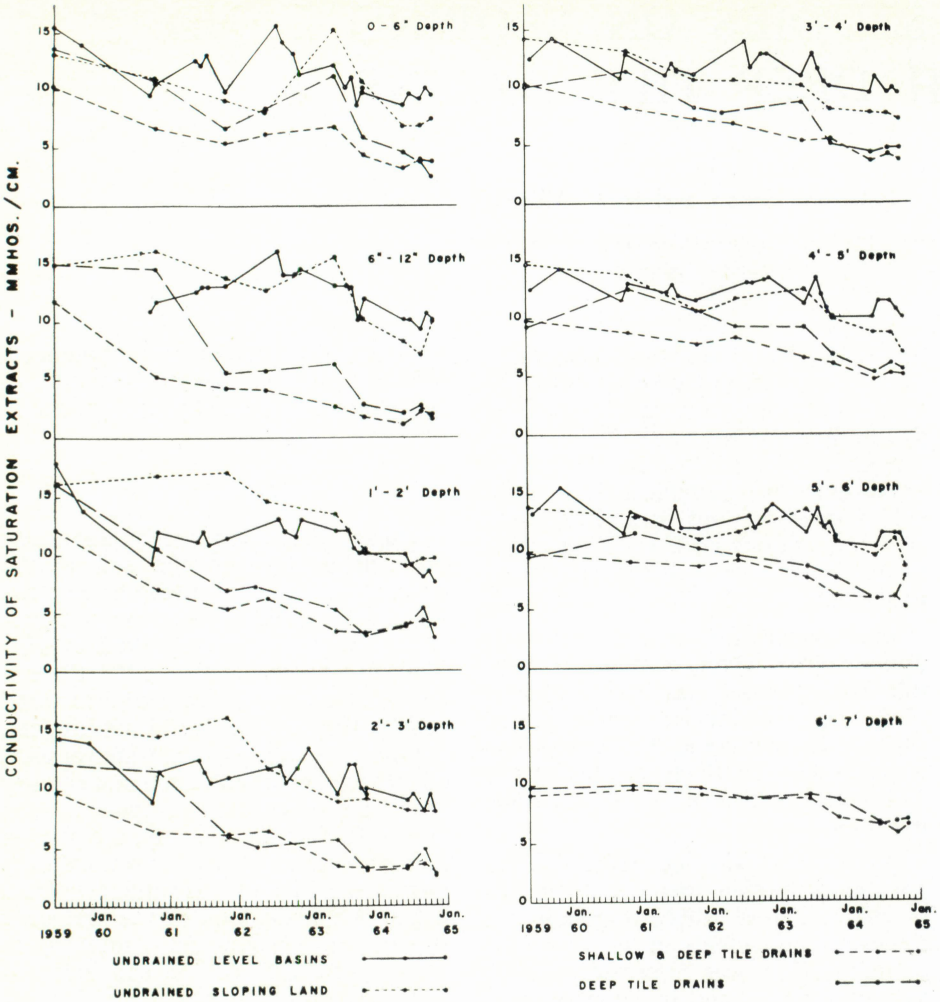

Figure 1. Electrical conductivity of saturation extracts (EC_e) for various depths.

not require additional levelling for the usual border-dike irrigation; another advantage was that after grass was established good yields were obtained during the remainder of the reclamation period.

A minor disadvantage of the practice used in this study is that the amount of water that can be applied in one application without excessive run-off is restricted. Also, generally more water will penetrate into the soil higher up than farther down the slope. It was observed, for instance, that after some irrigations the water table in the drained area was within 1 foot of the surface while the water table in the undrained area farther down the slope was 4 feet from the surface.

A second study was made in the summer of 1962 and 1963 by Laliberte and Rapp (2), who maintained the water table between 0.5 and 3 feet from the surface in the drained and undrained areas. This created a situation comparable to the one described by van Schaik and Milne (6), where the EC_e of the surface soil under grass increased from 4 to 8.8 mmhos/cm in one season. An increase in EC_e in 1962 was also observed in this study, which makes a comparison of the amounts of water applied for reclamation under these high water table conditions meaningless. This salt accumulation shows also that sufficient time should be allowed for the water table to recede to 3 or 4 feet before another irrigation is applied. The decrease in EC_e during 1963 was not expected since the same irrigation practices were followed in 1963 as in 1962. However, consumptive use values* calculated for well-fertilized grass in the Vauxhall area were 36 and 25 inches in 1962 and 1963. The lower consumptive use in 1963 could well have contributed to the decrease in salt content during that year as more water and salts could move away from the root zone.

EC_e values indicate that considerably less salt was removed from the surface 3 feet in the undrained than in the drained area. This was expected as tile drains are generally required for effective reclamation. Laliberte and Rapp (2) concluded that the rate of water-table recession to a depth of 3 feet midway between the tile drains was not appreciably less with tile drains than with no tile drains. However, it may well be that water-table recession was greater below a depth of 3 feet in the drained area. They mentioned that the recession of the water-table depth averaged for all points was greater in the drained area. This would indicate that it was more realistic to consider the average recession of the water table for reclamation purposes than its recession at the midpoint between drains.

The use of deep tile drains or a combination of shallow and deep tile drains does not seem to be more advantageous for reclamation than a system of shallow tile drains only, such as described by van Schaik and Milne (5). Although a direct comparison is not possible, results from both studies showed that considerable amounts of salts were removed below 3 feet but, when the soil of the surface 3 feet was reclaimed, a potential source for future salinization was still present at the 3- to 6-foot depth. The period covered in these studies may be only the initial period of desalinization of the root zone soils as explained by Kovda (1), who considers that gradual desalinization of the groundwater at greater depths may take from 20 to 30 years.

The EC_e in the level basins without drainage varied somewhat during the seasons. The most effective leaching could be expected when water was applied shortly before the supply of irrigation water to the farmers was discontinued in the late fall. The water table normally recedes at that time. These fall irrigations sometimes suggested for seepage areas along canals did not seem to be very beneficial as sufficient salt could not be removed to counteract the increase in salt during the next growing season. The results of this study for both undrained areas are examples of the extent of the salt removal under these circumstances.

A decrease in the SAR is essential for efficient water movement in the soil when the salt content of the soil is reduced by leaching (7). SAR values relative to the EC_e were calculated and

*Krogman, K. K., Research Station, Lethbridge, Alberta. Private communication.

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first three sections was noted in the May 1966 inspection. This increase was due primarily to the formation of longitudinal cracks, which were not present in the remaining four sections.

The water table at this site has been rising each year as a result of seepage from an adjacent unlined canal and deep percolation during the irrigation season. The average depth of the water table during the winter preceding the May 1966 inspection was 8 feet. The water table had risen more rapidly under the first three sections because of the proximity of the unlined canal. Probably the rising water table has increased frost heave and accelerated crack formation.

The expansion joint grooves in the first three sections were smaller than is usually considered adequate. The grooves in these sections were about ¼ inch wide and ⅜ inch deep; in the remaining four sections they were about ½ inch wide and ¾ inch deep. Presumably the smallness of the grooves in the first three sections was partly responsible for the formation of cracks between expansion joints, particularly in the presence of a high water table.

The seepage loss from this ditch was reduced by more than 80 percent from the pre-lining value of 0.34 cubic foot per square foot of wetted perimeter per day (table II). There was a further 10 percent reduction after the expansion joint grooves had been filled with a sealing compound. During the two years after the joints were sealed there was a slight increase in seepage loss. However, the seepage loss reduction was still greater than 70 percent.

After three years of service most of the seepage loss was occurring from the first three and the last sections. The reason for the high loss from the last section is not apparent. However, the relatively high losses from the first three sections were probably due to the greater amount of interjoint cracking in these sections. In general, crack formation between joints was reflected by greater seepage loss. Evidently the restriction of cracking to the expansion joints is a significant factor in seepage control. The relatively low losses from sections four, five, and six indicate that cracking between joints can be controlled by proper groove construction.

Experience gained during the construction of this concrete-lined ditch indicated that its cost on a commercial basis would be about $1.50 to $2.00 per lineal foot.

SUMMARY

Seepage loss from an irrigation ditch was reduced by more than 90 percent by installing an unreinforced concrete lining with a subgrade-guided slipform. After three years of service the seepage reduction was still greater than 70 percent. Most of the increase in seepage is attributed to crack formation between expansion joints. The importance of providing adequate expansion joints is emphasized.

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expressed as EC_e/SAR ratios over the range of EC_e from 1 to 20 mmhos/cm. Ratios obtained throughout this study were combined and grouped according to the EC_e values (table II). Although

TABLE II. EC_e/SAR RATIOS FOR SOILS AT DIFFERENT EC_e VALUES EXPRESSED IN MMHOS/CM

EC_e	EC_e/SAR	S.D.	n
1- 2	0.530	0.298	14
2- 4	1.198	0.534	42
4- 6	1.029	0.354	56
6- 8	0.789	0.105	35
8-10	0.695	0.070	53
10-12	0.706	0.075	25
12-14	0.790	0.178	24
14-16	0.813	0.100	6
16-18	0.755	0.070	5
18-20	0.883	0.089	5

the standard deviation was fairly large for the lower EC_e, ratios did not change very much. No differences in relation to the EC_e during the reclamation period were observed for the various drainage practices. Thus the concentration of Na^+ relative to Ca^{++} and Mg^{++} decreased continuously with decreasing EC_e, indicating that water movement through these soils was probably not restricted. The gypsum present probably had a beneficial effect.

CONCLUSIONS

The study showed that reclamation of salt-affected glacial soils can be attained on sloping land with deep tile drains. However, it is questionable if deep tile drains are more useful than shallow tile drains for salt removal at depths from 3 to 6 feet. Care should be taken that the water table is not within 3 feet of the surface for long periods during the growing season.

Although the areas with a combination of shallow and deep tile drains received more water than the area with deep tile drains only, no significant difference was found in the effectiveness of reclamation of both treatments. The initial salt content of the soil with deep drains only was higher than that of the other treatment but at the end of the study EC_e values were nearly the same for both treatments.

The EC_e of soil leached without artificial drainage did not drop below 7.5 mmhos/cm, indicating that fall leaching of soils in seepage areas is not effective in reclaiming land.

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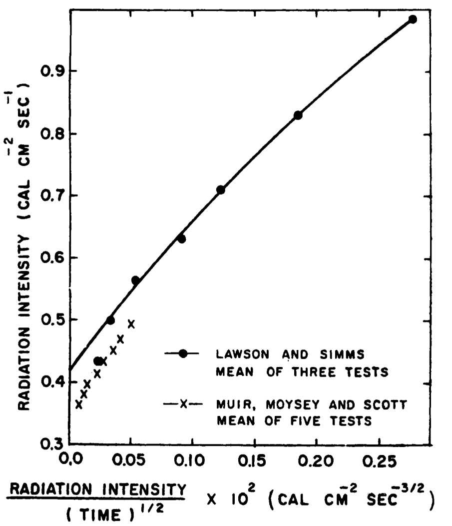

Figure 4. Comparison with Lawson and Simms Data for Pilot Ignition of Cedar.

times ranging from 125 to 1200 seconds. This is illustrated in Figure 4. The longer time interval is representative of the marginal situation where the exposed surface is almost far enough from the burning building to prevent ignition. The longer time interval may have also resulted in a greater self-heating effect. Lawson and Simms did test fibre insulation board at the lower intensities where ignition occurred in about 1000 seconds. They obtained a value of 0.18 cal m^{-2}sec^{-1} for the critical intensity while in the tests reported here, a similar value of 0.16 cal cm^{-2}sec^{-1} was obtained.

The two plywoods tested had similar critical and minimum intensities for pilot ignition. Differences in heat transfer through the samples and in loss of heat from the back of the samples were apparently minor for the two thicknesses tested. The values obtained for plywood were somewhat lower than for fir board and for other species of wood.

Both types of manufactured fibre board had considerably lower minimum and critical intensities than plywood or sawn lumber. This may possibly be due to differences in thermal properties or chemical composition.

Asphalt shingles ignite at somewhat lower intensities than sawn lumber but the asphalt will melt and slide off at as low an intensity as 0.06 cal cm^{-2} sec^{-1} after 15 minutes exposure. In comparison, plywood exposed for 15 minutes to a radiation intensity of 0.16 showed only very slight discoloration.

CONCLUSIONS

In calculating the spacing between buildings necessary to prevent the spread of fire, the following values of radiation intensity at the receiving surface may be permitted:

Unpainted sawn lumber and plywood

0.35 cal cm^{-2}sec^{-1}

Unpainted manufactured hardboard

0.25 cal cm^{-2}sec^{-1}

Asphalt shingles

0.30 cal cm^{-2}sec^{-1}

For particular situations, somewhat larger or smaller values could be used, depending on the margin of safety desired. It is most unlikely that pilot ignition of these materials will occur when exposed to the above radiation intensities for 15 minutes. However, materials exposed to these intensities would be seriously discolored or otherwise damaged.

The pilot ignition properties of painted wood products and of wood protected by non-combustible claddings is currently being investigated.

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