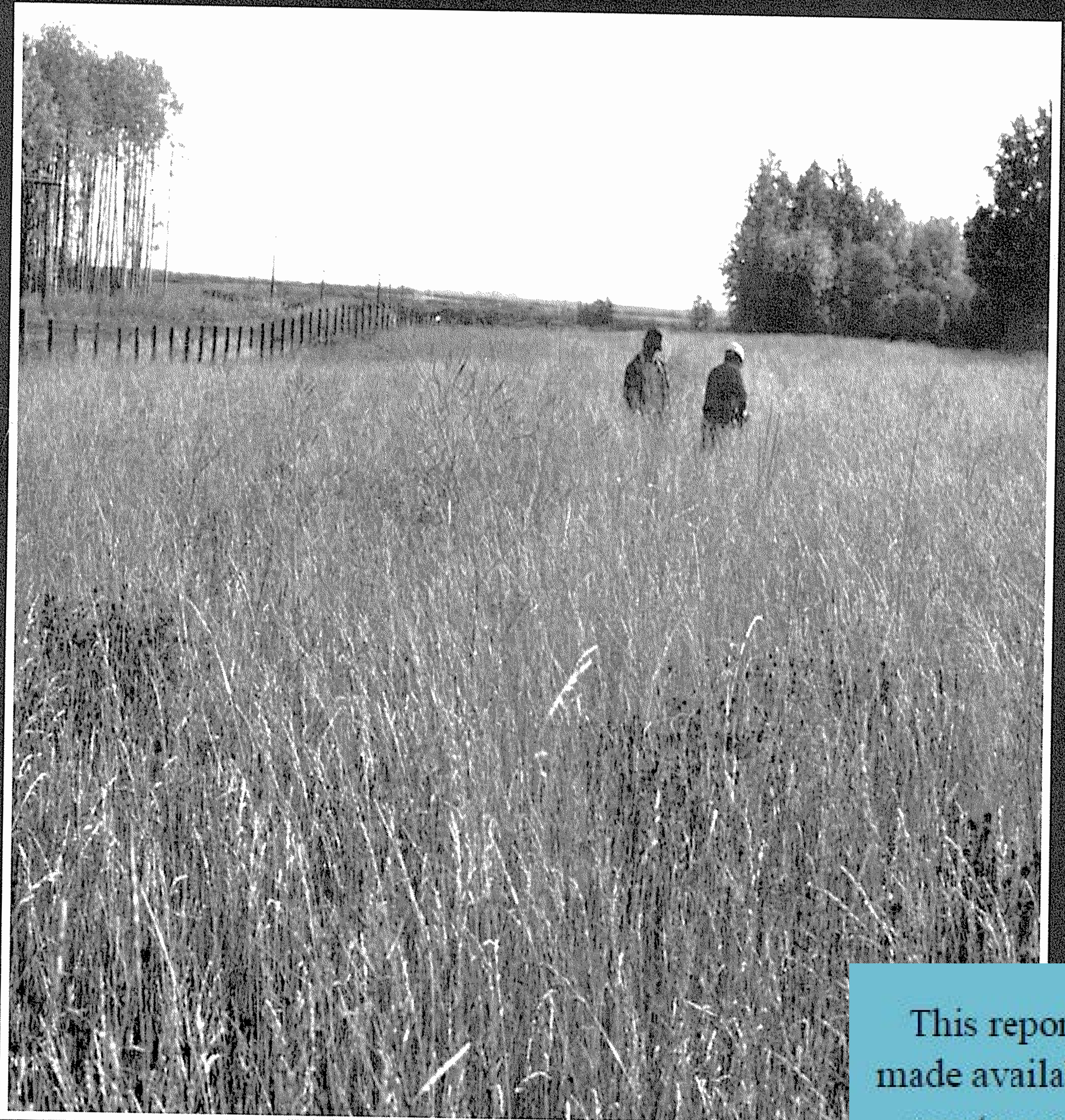
Topsoil Handling During Pipeline Construction in Potentially Arable Forested Luvisols of Northwest Alberta



NOVA Gas Transmission

TOPSOIL HANDLING DURING PIPELINE CONSTRUCTION IN POTENTIALLY ARABLE FORESTED LUVISOLS OF NORTHWEST ALBERTA

by

A. W. Fedkenheuer, R. G. Faye, N. M. Finlayson,
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FOREWORD

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This study was commissioned to assess the effects of topsoil stripping depths on potentially arable forested Luvisolic soils. Field data collection and a draft report were prepared by Nancy M. Finlayson and Sheila M. Luther, both of Land Resources Network Ltd. (a private consulting company).

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ABSTRACT

The objective of this study was to evaluate several pipeline topsoil stripping depths to determine whether they result in land capability equivalent to that of adjacent forested lands broken for cultivation. Topsoil stripping depths were 0 cm, 15 cm and 30 cm. Soils chosen for the study were Orthic and Gleyed Gray Luvisols located south and west of Beaverlodge in northwestern Alberta. The study site was covered with a mature aspen/poplar forest prior to construction. Percent soil organic matter, pH, electrical conductivity, and sodium adsorption ratio, soil strength and particle size distribution on the pipeline trench were compared with pre-disturbance soils and with adjacent controls (which were cleared of forest and subsequently broken for agriculture using breaking practices typical for this area). Forage biomass, percent cover and species composition comparisons between controls and the trench were made.

Five years after construction, no differences between the trench and control areas in any of the vegetation parameters were found on any of the three stripping treatments. Any differences in soil quality were found not to affect vegetation productivity. Control data tended to be more variable than data for the trench. Topsoil from all three stripping treatments was rated ‘good’ in terms of organic matter 5 years after construction. No stripping (0 cm) of topsoil resulted in lower soil quality compared to the control in some instances, but the agricultural capability ratings for all treatments and their controls were equivalent.

ACKNOWLEDGEMENTS

The authors acknowledge the financial assistance of the Key Technology Area of NOVA Gas Transmission Ltd. for this project. Acknowledgements also go to Toby Entz for clarification of the statistical analyses required for the project. Vegetation sampling and data analysis throughout the project was carried out by Barry Irving. Thanks to Ms. S. Landsburg now of Frickie Creek Consulting for early guidance to the project. Thanks also to Ms. Sylvia Repnow for her work with the various technical aspects of publishing this report.

1. INTRODUCTION

The transportation of oil and natural gas through pipelines is a widely accepted practice in Alberta, where the energy industry is a major part of the economy. By the end of 1989, there were 201,000 km of pipeline in Alberta under the Energy Resources Conservation Board (ERCB) jurisdiction (Fedkenheuer, 1990). The impacts of pipeline construction on the quality of agricultural and potentially arable soils is of major importance in the province. Pipeline installation necessarily disrupts the soil profile, and research on soil handling procedures and changes in disturbed soil properties over time can provide the information necessary to implement appropriate construction and reclamation procedures.

It has become standard practice in Western Canada to conserve topsoil during pipeline trench construction by stripping and handling it as a separate lift; the topsoil is later replaced over the disturbed subsoil (Mutrie and Wishart, 1989). Topsoil is the organic rich, surficial soil horizon generally managed for agricultural production. In Western Canada the topsoil commonly varies from 5 to 30 cm in depth. Without topsoil conservation, a reduction in soil quality and crop yield may occur due to a decrease in the amount of available nutrients and organic matter in the root zone, and a decrease in the quality of soil tilth. When topsoil and subsoil mixing occurs there may be increased stoniness and compaction in the root zone if there are undesirable subsoil materials.

There is little literature available on topsoil handling for pipeline construction in potentially arable forested Luvisols. The thin humus-enriched surface horizons (Ah) in Luvisols makes topsoil handling more difficult than in soils with well-developed surface horizons. Topsoil is often arbitrarily defined as the plough depth of 15 cm. In forested Luvisols this often includes the LFH, Ah and part of the Ae horizon (Agriculture Canada Expert Committee on Soil Survey, 1987). The merits of topsoil stripping have been questioned in these soils because of the marginal quality of the topsoil, which has relatively low organic matter content, low water-holding capacity and few nutrients, especially in the leached Ae horizon. Some have suggested that if topsoil is thin and the B horizon material is adequate, it may be useful to include some B material with the topsoil to ensure sufficient rooting depth (Bratton, 1989). Traditional soil breaking for cultivation involves ploughing to a depth of 30 cm with no topsoil conservation. With no topsoil salvage during pipeline installation, subsoil, often having a higher clay content, would be mixed with the topsoil during construction, potentially improving soil texture, water-holding capacity and nutrient levels.

This 5-year project was aimed at assessing the effects of topsoil stripping depths on potentially arable forested Luvisolic soils on a pipeline constructed under summer pipeline construction conditions. It was initiated in response to concerns expressed by the Public Lands Division of Forestry, Lands and Wildlife, Alberta, that the potential agricultural capability of these areas would be degraded during pipeline construction and reclamation if topsoil was not salvaged separate from subsoil. The issue was to determine the appropriate depth of topsoil stripping: how much, if any, of the Ae horizon should be stripped; whether or not the inclusion of some Bt material results in a decrease in capability; how different depths of stripping affect soil quality and productivity; and the quality and productivity of stripped soils compared to soils cleared and broken for farming.

This report describes the field experiment designed to provide information on the effects of three topsoil stripping treatments on the soil quality for arable agriculture for a pipeline constructed in forested Gray Luvisolic soils. It outlines the experimental design and methods, presents results of five years of soils and vegetation monitoring, and draws comparisons between the results of sampling the pipeline trench, and off-right-of-way (RoW) control soil and vegetation parameters from 1989 to 1994. Agricultural capability was rated according to criteria presented by (Leskiw, 1993).

1.1. OBJECTIVE

The objective of this project was to determine which pipeline topsoil stripping depths result in soil conditions comparable to those of forested lands broken for cultivation using breaking procedures typical in the study area. The study assessed whether any difference in soil quality or forage productivity existed in potentially arable Orthic and Gleyed Gray Luvisolic soils between the trench zone of the pipeline RoW, which was constructed with three topsoil stripping depths, and an adjacent control treed area cleared and broken for agriculture.

1.2. STUDY HYPOTHESES

The following discussion includes the expected effects of pipeline construction on Luvisolic soils compared with control soils broken for cultivation.

0 cm Treatment. In this topsoil stripping treatment the "grubbing" procedure (defined in section 2.3 of this report) was not carried out. Consequently, it can be expected that the entire soil profile will be mixed and dominant characteristics of the thickest soil horizons, particularly the parent material, should be most evident (Zellmer et al., 1985). Because parent material pH is likely to be neutral to basic due to the presence of carbonates, this characteristic should be spread throughout the profile, and pH to the depth of the parent material is expected to be higher than the control. There should no longer be a clay-enriched B horizon but rather a uniformly textured profile reflecting the dominant textural class before trenching occurred. Surface clay content may be enriched compared to control or pre-disturbance levels, whereas clay content at the level of the B horizon may be lower due to the mixing of coarser surface A and possibly C horizons with finer-textured B horizons. Natural compaction may decrease because of the breakup of the Bt horizon. The organic matter of the original surface mineral horizons is expected to be distributed throughout the disturbed trench profile. The electrical conductivity (EC) and sodium adsorption ratio (SAR) of the parent material should dominate at the surface. Crop yields should not vary greatly from the control provided soils were non-saline and non-sodic before construction.

15 cm Treatment. In post-construction soils the upper 15 cm of a 15 cm stripping treatment is expected to most resemble that of the pre-disturbance soil, with some benefits from mixing of organic matter throughout the upper 15 cm, thus breaking up and improving the upper portion of the leached and platy Ae horizon. The pH usually increases with disturbance of surface soils. EC and SAR of the upper 15 cm should not increase. There may be some increase in pH compared with the control, as reported in some pipeline studies (Landsburg, 1989). Yield should be equivalent to the control. The profile below 15 cm should display the inherent qualities of all of the horizons mixed together, such as a neutral to basic pH, typical of Luvisolic C horizons, and a change in texture, depending on how clay is distributed throughout the profile below the Ae horizon. The Bt horizon is expected to be broken. A lower penetration resistance may result compared to the cultivated control at depths below the 30 cm depth of the breaking plough. In soils developed on parent material without high salinity or sodicity, subsoil mixing effects during trenching should have minimal effects on soil productivity. This treatment is similar to the "grubbing" procedure normally carried out before trench construction through forested soils.

30 cm Treatment. The results of the 30 cm stripping treatment are expected to most resemble the normal ploughing process used to break soils for agricultural use in the study location. The difference between ploughing and trenching is that during ploughing the upper 30 cm is partially inverted, thus mixing the Ah, Ahe, and Ae and exposing part of the Bt at the surface. During trenching these horizons are more uniformly mixed together. Because of this difference, the 30 cm stripping treatment may be expected to retain more organic matter in the upper 15 cm compared with the cultivated soil. Also, pH may be higher at the surface; this is a well-documented effect of trenching on Luvisols regardless of stripping depth. Yield and penetration resistance should be similar to control soils. In the lower B horizon some effects of mixing the B horizon with the parent material may be observed. Changes in pH, penetration resistance, clay content, EC, SAR and soluble salts may occur, but the importance of these effects for soil quality is expected to be minimal in the absence of sodicity or salinity.

2. LITERATURE REVIEW

2.1. LUVISOLIC SOILS

Luvisolic soils develop under deciduous, coniferous, mixed forest and forest-grassland transitions in a wide range of climates across large parts of the northern hemisphere. They occur in the cooler boreal, cryoboreal and subarctic regions of Canada (Clayton, et al., 1977), and are the main soil of forested areas in the interior plains of Western Canada. They do not have a Solonetzic or Podzolic B horizon, Chernozemic Ah or organic horizons, nor are they dominated by gleying or permafrost (Agriculture Canada Expert Committee on Soil Survey, 1987). Most Luvisols in central Alberta have formed in glacial till with loam to clay loam texture.

Only 15 percent of the total area cultivated in Alberta is on Luvisolic soils (Bentley et al., 1971); however, expansion of arable agriculture has occurred and will continue to occur in areas dominated by these soils. Nearly one third of the 20 million hectares of Luvisols is considered arable (Holmes, et al., 1976). Knowledge of suitable management practices for these soils is important for achieving maintenance of equivalent land capability and satisfactory productivity.

The soil horizons that typically occur in a Luvisol are an LFH horizon, below which is a shallow Ah and/or Ahe horizon, an Ae horizon, a Bt horizon, in some cases a BC horizon, and at depth a Ck horizon with free carbonates. On the surface of a forested Luvisol there are typically three organic horizons in various stages of decomposition. The L horizon is composed mainly of fallen leaves and needles that are slightly decomposed and still recognizable as to origin. A loose to matted, partially decomposed F horizon, in which the origin of material is difficult to ascertain, is underlain by the highly decomposed H horizon. This last layer is fibrous to matted in nature and is unidentifiable as to origin. This organic LFH layer may vary from 2.5 to 12.5 cm in total thickness (Bentley, et al. 1971).

Under the organic LFH horizon is a layer of humus and mineral matter, the Ah horizon. In Gray Luvisols this layer is always less than 5 cm thick, and usually is less than 2.5 cm thick (Bentley, et al. 1971), while in Dark Gray Luvisols the Ah or Ahe horizons are more than 5 cm thick and have eluvial features such as gray streaking or platy structure (Agriculture Canada Expert Committee on Soil Survey, 1987).

The underlying Ae horizon can be from 10 to 30 cm thick. This layer presents management problems because it is often powdery when dry and when wet, becomes pasty and subsequently dries to a hard consistency. Generally, the Ae horizon has a low moisture content relative to other horizons and has a platy structure with reduced clay content, little build-up of organic material and an acid reaction. The primary soil-forming process in Luvisols is eluviation, or the movement of clay from the Ae horizon into the illuvial Bt horizon.

The Bt horizon results from an accumulation of clay, iron, aluminum and organic carbon. With a weak to strong blocky structure, it is often acidic in reaction and has reduced permeability when dry. Soil texture in Bt horizons tends to be higher in clay than the horizons above and below it, and root penetration can be impeded. The C horizon is, on average, 1.2 m or more below the surface (Bentley, et al. 1971). Carbonates, inherited from calcareous parent material (Ck), are usually concentrated in this horizon. The Ck horizon has a neutral to basic pH.

2.2. EFFECTS OF CULTIVATION ON LUVISOLIC SOILS

During the initial "breaking" of forested soils to bring them under cultivation, mixing of the LFH, Ah and part of the Ae horizon occurs. Sometimes part of the Bt horizon is also incorporated in the "breaking" process. Research at Beaverlodge indicates that soil breaking is best performed early in the season, with a cultivation depth no more than 10 to 15 cm (Bentley, et al. 1971). In conversation with B. Smith, District Agriculturist, and K. Hudson, Agriculture Fieldman, both of Grande Prairie, Alberta, it appears that in practice, breaking is most often done deep enough to mix some of the heavier textured Bt horizon material into the A horizon. Most farmers feel that increasing the clay content of the topsoil slightly in this way improves soil trafficability, workability and tilth.

The cultivated horizon (Ap) presents a number of management problems, including a tendency to crust and a susceptibility to pulverization due to the predominance of Ae material. This horizon is also sensitive to clod formation and compaction, with low water holding capacity, limited fertility and poor pH buffering capacity (Robertson and McGill, 1983.) As a result, there is reduced aeration and water infiltration and retention, which may lead to poor plant germination, emergence and development, as well as increased erosion and rapid soil acidification. The surface horizons may be subject to poor drainage due to the underlying clay rich B horizon, which may impede water transmission and thus restrict crop root growth.

The agricultural potential of Luvisols in Alberta is limited by climatic restrictions, with 90 frost-free days in the Beaverlodge area and only 80 frost-free days in the Peace River region (Odynsky, et al., 1952). Although there is a tendency for excessive moisture at inopportune times, precipitation is more reliable than in the grassland areas. Use of recommended cropping and soil management practices can result in improved soil conditions for agriculture (Bentley, et al. 1971).

2.3. PIPELINE CONSTRUCTION

The phases of installation for pipelines are well documented by (Alberta Environment, 1985; Hardy and Associates [1978] Ltd., 1983; Mutrie and Wishart, 1989; Cannon and Landsburg, 1990). Typical pipeline installation in forested areas consists of a series of sequential activities (Mutrie and Wishart, 1989). A RoW with a width of 15 to 25 m is surveyed and staked out, cleared and graded and topsoil is stripped and stockpiled using conventional equipment such as bulldozers or graders. The width and depth of topsoil stripping depends on the specific method implemented. In forested areas, once the RoW is cleared of brush, the loose surface layer of organic material is bladed off to the edges of the RoW, a process called "grubbing". Workers string, bend, weld and coat the welds on the pipe before the ditch is excavated to a depth of 1.2 to 2.0 m, normally by a bucket and wheel ditcher. Spoil (subsoil) from the ditch is piled adjacent to the ditch. The pipe is lowered into the ditch and backfilled with the spoil, which is then compacted. The RoW is ripped to relieve compaction if present. Topsoil is then spread back over the area that was stripped. Rocks and other debris are removed before cultivating the RoW, which is then farmed according to the landowner's specifications.

Selection of a soil conservation method is governed by field conditions, land use, and the timing of construction in the summer or winter. Ditchline and spoilside stripping is one of the more common procedures for soil conservation on cultivated or potentially cultivatable forested land during the summer months. In this method, the subsoil pile is placed on subsoil, resulting in less mixing. Mixing is reduced by keeping topsoil and spoil piles at least one meter apart.

2.4. IMPACTS OF PIPELINE CONSTRUCTION

The magnitude of the environmental impacts caused by pipeline installation is largely governed by the quality and type of soil, present land use and sensitivity of the environment. Possible effects include compaction, topsoil loss, dilution or loss of organic matter and nutrients from the root zone, soil erosion, soil chemistry changes, altered internal drainage, changes in productivity and increased stoniness and weediness (de Jong and Button, 1973; Shields, 1979; Culley, et al., 1982; Hardy and Associates [1978] Ltd., 1983). Many of these problems are due to soil mixing and compaction that may occur when topsoil conservation procedures are improperly implemented.

The chemical and physical characteristics of the soils of the pipeline RoW usually reflect the inherent properties of soil materials from the horizons that were mixed together (Zellmer, et al., 1985). Mixing effects occur when soils from different parts of the profile are combined. Changes can occur resulting from the redistribution of organic matter, texture, pH, salt content and structure, among other things. For instance, the topsoil may suffer loss or dilution of organic matter and nutrients, increased concentrations of harmful salts and increased stoniness (Mutrie and Wishart, 1989).

Soil chemistry and textural changes may occur as a result of mixing subsoil or parent material with topsoil (Alberta Environment, 1985). Changes in texture may cause problems in seedbed preparation, harming seed establishment and root development. Mixing of clay rich subsoils with loamy topsoil may degrade soil structure in addition to altering texture, making the topsoil more difficult to work because of the presence of hard lumps or clods. Increased stoniness by bringing rocks in the lower trench up to the surface may also occur (Mutrie and Wishart, 1989).

There are some beneficial effects from mixing. For example, finer textured subsoil material, if mixed with coarse surface material may improve water and nutrient holding capacity (increased cation exchange capacity), as well as drainage.

Compaction, loss of soil structure and changes in temperature regime are possible results of pipeline installation. Compaction occurs through the passage of equipment over the

RoW, mixing of a denser subsoil with the surface soil, and handling of soil when excessively wet (Swan et al. 1987); it is generally accompanied by a loss of soil structure. Soils are most likely to suffer compaction when there is an intermediate to high level of soil moisture, a clay rich texture, a low organic matter content and a high degree of compactive effort (Lull, 1959; Swan, et al., 1987).

Some problems related to soil compaction include reduced root penetration, difficult cultivation, poor seedbed tilth, reduced water infiltration, reduced water storage capability, increased surface water runoff and decreased soil porosity. There can be associated reductions in aeration and diffusion rates, combined with decreased water loss by evaporation (Swan, et al., 1987; Lull, 1959). There may also be a decrease in root growth and in the soil volume used by roots for nutrient and water uptake. Losses of nitrogen occur through denitrification due to lowered aeration. Compaction may improve the seed-to-soil contact, which promotes faster germination and prevents drying out around the seed.

With surface compaction and decreased infiltration, there is potential for increased soil losses due to runoff (Shields, 1979). Erosion potential also increases through pulverization and loss of the original soil structure and cover. Linear construction may promote rill erosion. These problems can be prevented through the use of a number of erosion control methods and prompt revegetation of the RoW.

Cultivation can be used to improve compacted topsoils, but subsoil compaction is more difficult to ameliorate. Natural freeze-thaw cycles slowly loosen compacted soils (Swan, et al., 1987), but severe subsoil compaction may require deep tillage if topsoil has already been replaced.

In forested Luvisols an increase in soil pH appears to be common. Cloutier (1988) reported that pH increased in the trench of a pipeline constructed through Luvisolic soils by as much as 2.7 units in the upper 30 cm to a pH range from 6 to 7, thus improving nutrient availability. In the study, all three trench stripping depths of 0, 15 and 30 cm resulted in an increase in pH. Cloutier (1988) also noted an increase in organic carbon at the 0-15 cm depth of up to 13.6 percent on forested Luvisols. This was partly attributed to the formation of a sod layer under forage. Landsburg (1989) attributed pH increases on trench Ap horizons to mixing of topsoil and calcareous subsoil over the trench.

Mine reclamation work on Luvisolic soils by (Hardy and Associates [1978] Ltd., 1981) (cited by Hardy and Associates [1978] Ltd., 1983) indicated that if topsoil was not stripped and replaced, pH was higher (7.4), organic matter levels were lower (1.4 percent) and potassium levels increased compared to topsoil. Addition of from 30 to 70 cm of topsoil resulted in a moderately acidic pH (5.5-5.9) and organic matter levels of from 2.0 to 2.5 percent. Nitrate nitrogen tended to be low in both topsoil and subsoil, although phosphorus and potassium were adequate for plant growth in both soils.

Both stoniness and weediness may increase from pipeline installation, depending on construction methods and conditions at the time of construction. Stoniness rose by 35 percent on some trenched Luvisolic soils in the study with most having some mixing of topsoil and subsoil (Hardy and Associates [1978] Ltd., 1983). Weediness was also increased on the trench in some cases. This was attributed to the competitive advantage of weedy species during revegetation, particularly under poorer soil conditions in which topsoil had been mixed or buried. Topsoil likely was not salvaged during construction of some of these older pipelines.

At 75 percent of the pipeline sites visited on cultivated Luvisolic soils in the Peace River District, there was less than a 10 percent variation between RoWs and controls for vegetative cover (Hardy and Associates [1978] Ltd., 1983). Plant height was reduced over the trench at 40 percent of sites but was increased over the trench at another 20 percent of sites. The authors concluded that plant growth of grain crops or forage either increased or showed no change from controls four years or more after pipeline installation, under conditions in which no deleterious trench settlement or compaction had occurred. Topsoil handling, including no mixing or mixing with the B horizon only, had no effect on these results.

McCabe and Kennedy (1989) found that seeded forage had nearly 100 percent ground cover and was well-established two years after seeding a pipeline RoW constructed on northern Alberta Luvisolic soils. A non-seeded treatment developed more slowly and did not have the capability to achieve 100 percent cover with native vegetation within 5 years. However, species diversity on the non-seeded treatment was substantially higher than the seeded treatment each year of study and resembled the species composition of adjacent natural plant communities.

2.5. SUMMARY

In many instances, effects on soils following pipeline installation resemble those of normal cultivation. The mixing that occurs during trenching, particularly of the lower lift or spoil, may produce some unique effects; however, in forested Luvisolic soils, these should not alter soil quality sufficiently to produce a change in productivity compared to land broken for cultivation. Despite this, it remains essential that pipeline construction be performed under appropriate weather conditions.

3. STUDY AREA

3.1. LOCATION

A 300 m long segment of pipeline RoW in NW 30-70-12-W6 was selected as a site for the trial plots. It is part of the Mount Valley Lateral Loop, a 30 km long, 16 inch pipeline west of Elmworth in northwestern Alberta. The site was chosen for ease of access, presence of Gray Luvisolic soils and the relative uniformity of soils and topography. Its location is shown in Figure 1.

3.2. SOILS

The report of a pre-disturbance soil survey of the study area in 1989 is presented in Appendix 8.2. Soils were dominantly Gleyed Gray Luvisols, with significant Orthic Gray Luvisols and inclusions of Dark Gray Luvisols. All were in close association and could not be separated as individual map units. Parent materials were fine loamy lacustro-till or glaciolacustrine materials overlying fine loamy glacial till at depths ranging from 40 cm to more than 100 cm. Topography of the site was gently undulating.

In general, soils had a leaf litter layer (LFH) 3 to 10 cm thick overlying mineral soil. Where an Ah horizon existed, it was less than 3 cm thick. The Ahe horizon extended on average to a depth of 5 cm from the mineral soil surface, and the Ae generally extended to a depth of between 15 and 25 cm. Both Ahe and Ae horizons were very fine sandy loam to loam in texture, and were often mottled because of poor internal drainage. The Ahe and Ae horizons were weak to moderately fine platy in structure. Bt horizons with moderate fine subangular blocky structure occurred between 18 and 35 cm. They were sandy clay loam to silty clay loam in texture, frequently had clay coatings on ped surfaces and were often mottled. Representative soil profile descriptions have been included in Appendix 8.2.

These soils are best correlated to the Braeburn Series, as described in (Odynsky, et al., 1961). Soils with a lacustro-till or glaciolacustrine veneer over till are considered a close variant. There were no interpretive differences. Braeburn Series is one of the most extensive soil series mapped in that survey, covering about 268,000 acres.

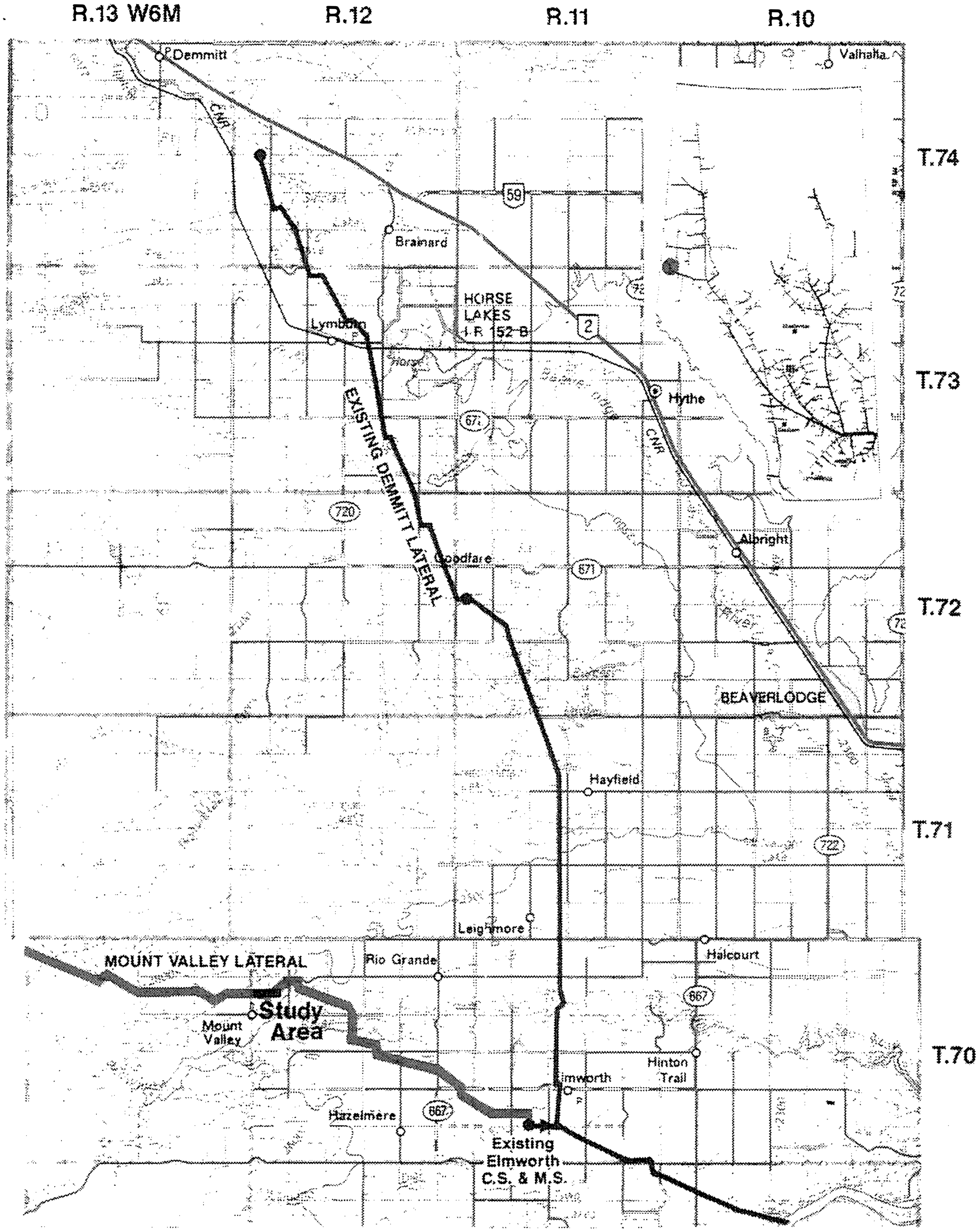

Figure 1. Study Site Location.

3.3. VEGETATION AND CLIMATE

The study area is in agro-climatic area 3H, a region where precipitation is usually adequate for crop growth, but there is a frost restriction to crop production in most years (Bowser, 1967). Grains, canola and hay are produced on surrounding cleared land. The entire study site was under a mature stand of aspen forest with an understory of willow, white spruce, rose and other shrubs prior to clearing.

4. METHODS

4.1. TREATMENT LAYOUT AND SITE SELECTION

The three topsoil stripping treatments included in the study were: 0 cm of topsoil stripped, 15 cm of topsoil stripped, and 30 cm of topsoil and subsoil stripped. The 15 cm treatment represented the existing mean topsoil depth, including 5 cm of leaf layer (LFH) and 10 cm of Ahe and Ae materials. This treatment is roughly equivalent to a root "grubbing" operation during pipeline construction. The 30 cm treatment represented the average depth of soil disturbance during normal agricultural clearing operations under mature aspen-poplar forest in this area (determined from telephone conversations in 1989 with: D. Anderson, Reclamation Officer, Land Conservation and Reclamation Council, Alberta Environment, Grande Prairie; B. Smith, District Agriculturist, Grande Prairie; and K. Hudson, Agriculture Fieldman, Grande Prairie).

The treatments were incorporated into a section of the Mount Valley Lateral RoW in NW 30-70-12-W6. Each treatment was 100 metres in length, and had an adjacent off-RoW control area 20 m wide. The plot layout is presented in Figure 2.

4.2. PLOT CONSTRUCTION

Normal pipeline construction procedures were used to construct the plots. Timing of procedures was dictated by the construction schedule of the pipeline as a whole. All phases of construction on the plots were observed and documented. Only those directly affecting the study are presented here.

Initial clearing on the RoW took place on August 29, 1989. Trees were pushed over using a D8 caterpillar tractor. Most were uprooted, but a few of the more deeply-rooted trees were broken off near ground level leaving the stumps intact. Logs were piled using a rake mounted on the D8 caterpillar tractor, sawn into pieces, and then burned (Photo 1).

During the burning, log piles were turned by caterpillar tractor several times. By September 1, 1989, the piles had burned down to ashes, which were spread out over the RoW, as was normal practice at the time.

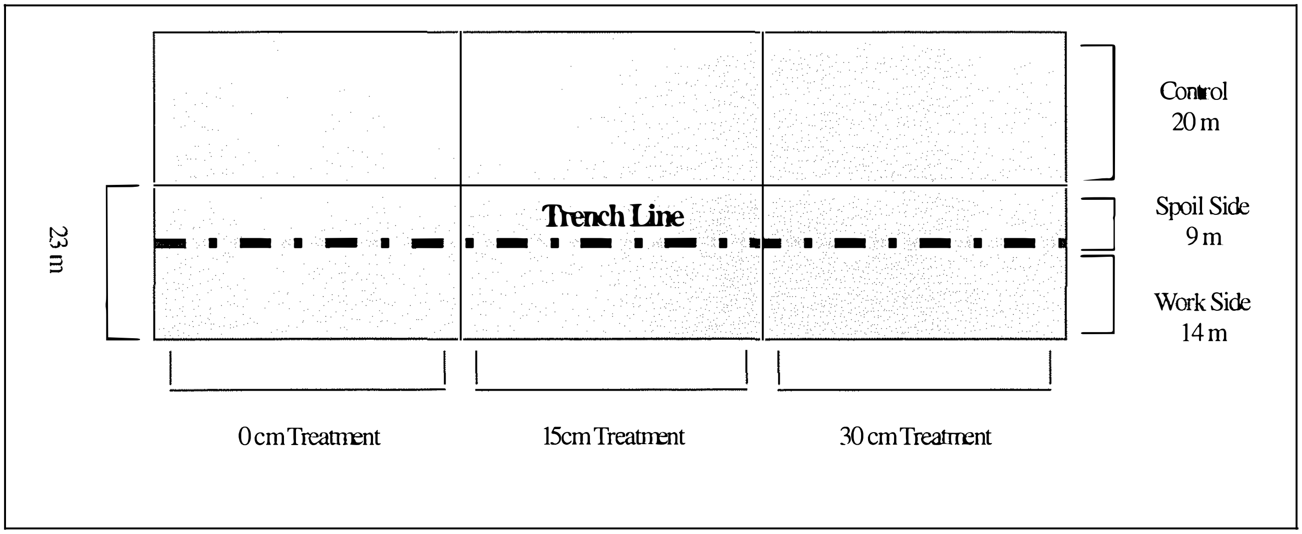

Figure 2. Plot design and layout.

Soil disturbance caused by clearing was restricted mainly to the overlying leaf litter layer. The underlying mineral horizons were left largely intact. Areas where larger tree stumps had been uprooted were often disturbed down to the Bt horizon. The surface of the soil was littered with twigs, roots and branches too small to be picked up by the rake.

In the 15 cm and 30 cm treatments, topsoil was stripped over the ditch and spoil areas of the RoW using a D8 caterpillar tractor. Each plot was stripped separately, with care being taken not to move materials from one plot to another. Materials were stored near the edge of the spoil side away from the trench area to permit good separation of spoil and topsoil after trench excavation (Photo 2). Plots were touched up using a D6 caterpillar tractor after initial stripping operations were completed. This procedure evened edges of storage piles and removed any remaining topsoil from the plots. Topsoil stripping and storage procedures are illustrated in Figure 3.

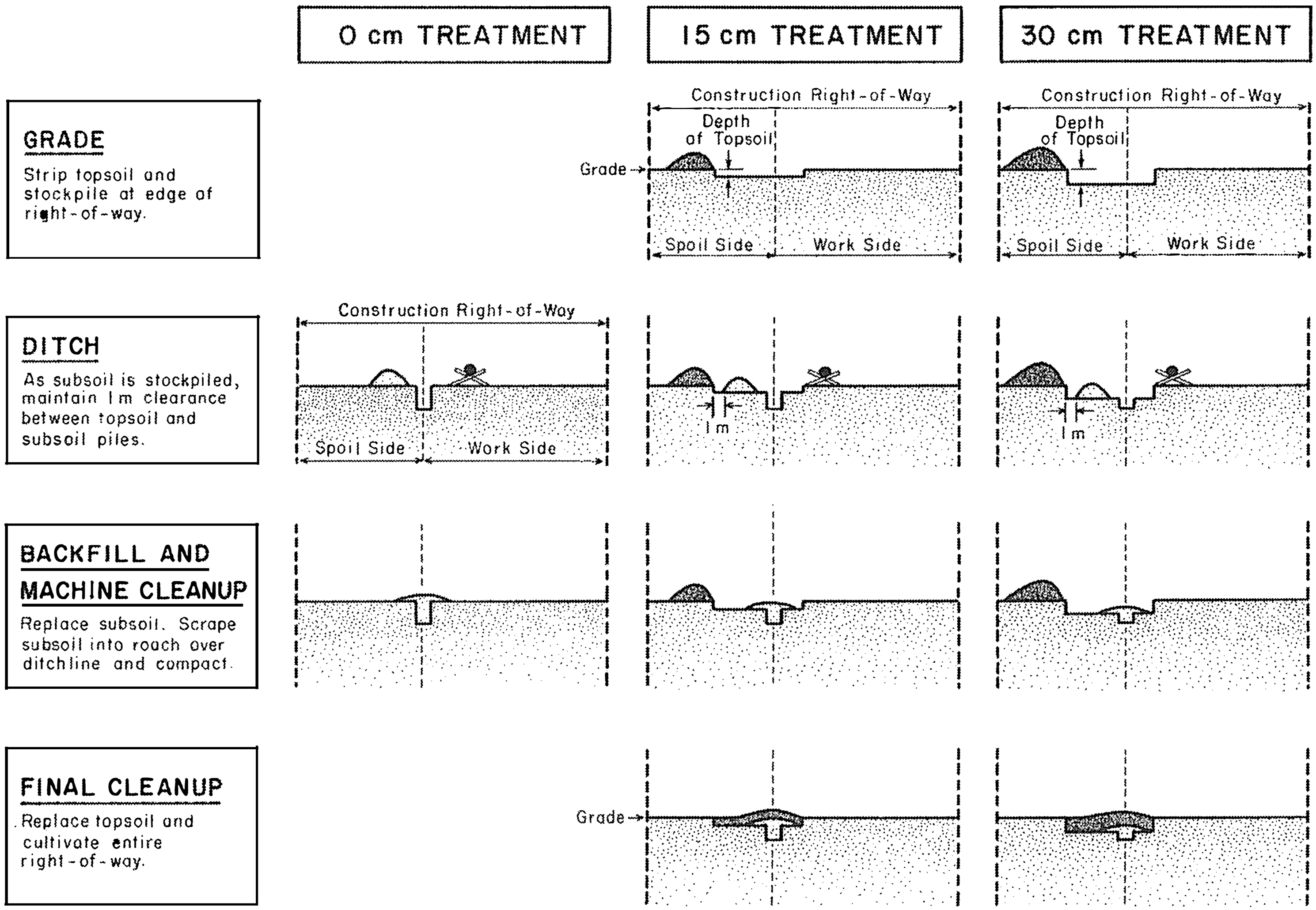

Figure 3. Topsoil and spoil stripping and storage.

The trench was excavated on September 24, 1989, using a wheel ditcher (Photo 3). The excavation was approximately 1.7 m in depth and 1 m wide. Spoil was windrowed on the spoil side. Excellent separation between topsoil and subsoil, averaging 1.4 m, was achieved throughout the plot area. Because a "grubbing" operation had not taken place, roots in the non-stripped plot caused minor ditching problems. The trencher had to be slowed or shut down on several occasions to extract roots stuck in the wheel and belt system. A rock had to be removed from the trench on the unstripped plot using a backhoe, which widened the trench and disturbed the topsoil and spoil piles in the immediate area, resulting in a decrease in separation distance. No topsoil/subsoil mixing appeared to have occurred, however. Trench excavation and storage procedures are illustrated in Figure 3.

Initial backfilling took place using a 'flyswatter' (backhoe with a flat edged D6 blade welded onto the bucket) (Photo 4). Backfilling minimized movement of materials up and down the trench and prevented disturbance of the control area. D6 caterpillar tractors were used to complete the backfill job, leveling spoil materials and compacting and creating a slight roach over the trench itself. The final operation before topsoil replacement consisted of leveling the roach with a D6 caterpillar tractor.

Both the 15 cm and 30 cm plots were stripped over the ditch and spoil areas. No problems occurred during backfilling operations; however, it proved difficult to accurately replace all spoil from the spoil side of the unstripped plot. Wherever the original soil surface was uneven due to disturbance during clearing, or where there were branches and roots on the surface, spoil was left on the surface in depressions after backfilling. The alternative, replacing some of the topsoil from higher areas into the trench with spoil materials, was considered less desirable. In an effort to keep the organic-rich layer intact, the operator tended to err on the side of leaving too much spoil on the surface, rather than risk losing topsoil.

Topsoil was replaced on the RoW using a D6 caterpillar tractor (Photo 5). Care was taken to ensure that materials were not moved between plots. After completion of final leveling, topsoil materials were examined for depth and quality. Quality of replaced topsoil was generally good, but some mixing occurred in a few locations associated with large roots or branches mixed in the topsoil. This resulted in uneven spreading and a rougher soil surface (Photo 6). During replacement, materials were moved between plots approximately 10 m to the east of each plot boundary and 5 m to the west. No soil or vegetation sampling took place within these areas during monitoring.

The entire RoW was disked, using a heavy duty breaking disk and tractor. This procedure was followed by manual root and rock picking.

Clearing of the off-RoW control area commenced September 8, 1989. Trees were pushed down with a D8 caterpillar tractor using a mounted rake. As occurred during clearing of the RoW, logs were piled using a caterpillar tractor mounted rake, then sawn into pieces and burned. Ashes were spread over the control areas. Control area soil breaking could not be carried out before freeze-up. It was subsequently carried out in June, 1990 using a 24-inch breaking plow pulled by a D6 caterpillar tractor.

The seedbed was prepared over the entire area using a root rake (Photo 7, 8), disk and harrows, and the entire study area, both broken control and RoW, was seeded to a forage mix. The mix consisted of 23% Cicer Milk Vetch, 21% Alsike Clover, 20% Tall Wheatgrass, 16% Intermediate Wheatgrass, 8% Orchard Grass, 6% Tall Fescue, 4% Creeping Red Fescue, and 2% Timothy.

After spring break-up, slight subsidence had occurred on some portions of the trench within all three treatment areas. Subsided portions of the trench were filled in with surface material during normal seedbed preparation operation using disk and harrows.

4.3. SAMPLING AND ANALYSIS

4.3.1. Soils

Soil samples for laboratory analysis were collected from 10 locations on the trench and 10 locations on the control within each treatment plot. Pre-construction (1989) sampling was carried out on the treatment plots. Early sampling was on a horizon basis as follows: Ahe, Ae and AB combined in one surface sample (0 to 20 cm); Bt1 (20 to 40 cm); Bt2 (40 to 60 cm); BC (60 to 80 cm); Ck1 (80 to 120 cm); and Ck2 (120 to 170 cm, trench depth). Samples to 80 cm were gathered using a shovel and auger. Samples below 80 cm were taken from the trench shortly after excavation. In 1990, sampling was similar to 1989, except that it did not include the Ck2 horizon, and the Ck1 horizon was sampled from 80 to 100 cm. Because plots were constructed with 0 cm, 15 cm and 30 cm depths of topsoil stripping, the 1990 sampling also included 0 to 15 cm and 15 to 30 cm sample depths so that differences due to stripping depths would be more evident. In 1991, 1992 and 1994, only the 0 to 15, 15 to 30, 30 to 40 and 40 to 60 cm depth increments were sampled because significant differences in previous years were mainly limited to those depths. Sampling in the post-construction phase was performed using a Dutch auger. No soil samples were collected in 1993.

In 1989 surface soil samples only (0 to 20 cm) were analyzed for organic carbon content (Leco method). Organic carbon percent was converted by the laboratory to percent organic matter using a factor of 1.78. Samples collected from all depths in 1989 and 1990 were analyzed for particle size analysis (hydrometer), pH, EC, and SAR. The final three parameters were measured in a saturation extract. Soil samples from 1990, 1991, 1992 and 1994 were analyzed for the following parameters: organic carbon percentage (Leco method; to a maximum depth of 30 cm) and pH (by saturation extract). Particle size was not monitored after 1990 because it was not expected to change substantially over the study period. EC and SAR were not measured after 1990 because soils were non-saline and non-sodic and thus these factors were not considered limiting for soil quality or productivity. Standard methods of analysis were used, as outlined in (McKeague, 1978).

Soil strength of each treatment, both trench and controls, was measured using a Bush Recording Soil Penetrometer (Mark I Model). An average of ten replicate measurements at five locations on each plot was taken at 3.5 cm depth increments. Soil moisture content was also determined on soil samples collected from each of the locations. The penetrometer is limited in that no data can be collected where soil strength exceeds the limit of the machine, which was about 38 bars. This meant that in many cases it was not possible to collect data to the full 52.5 cm depth.

4.3.2. Vegetation

Vegetation biomass was measured by hand clipping, drying and weighing 15 areas of 100 cm x 50 cm in size on each of the treatments, both for the control and trench. Vegetative cover percent was estimated on a 50 x 25 cm Daubemire frame nested in the corner of the main 100 x 50 cm frame. Species composition was also recorded at each location. Vegetation was monitored over four years from 1991 to 1994.

4.3.3. Statistical Analyses

Differences in soil parameters, vegetation biomass and % vegetative cover were tested with a pooled variance t-test for unpaired data (Dixon and Massey, 1969), using a level of significance of $p < 0.05$. A hierarchical cluster analysis using average linkages was carried out to link similar species compositions on trench and control for each treatment during the years 1991 to 1994 (Webster, 1979).

5. RESULTS AND DISCUSSION

5.1. VEGETATION

Both the control and treatment plots were seeded with forages in the fall of 1990, after the controls were broken for cultivation. Mean forage yields for 1991 and 1992 on the trench were higher, (but not significantly at $p < 0.05$), than on the control for all treatments (Figure 4). Over the 5 year period of this study, mean forage yields on the trench were equal to or greater than that of the adjacent controls although none of the differences were significant ($p < 0.05$). Yields doubled between 1991 and 1992 and thereafter yields stabilized near 1992 levels.

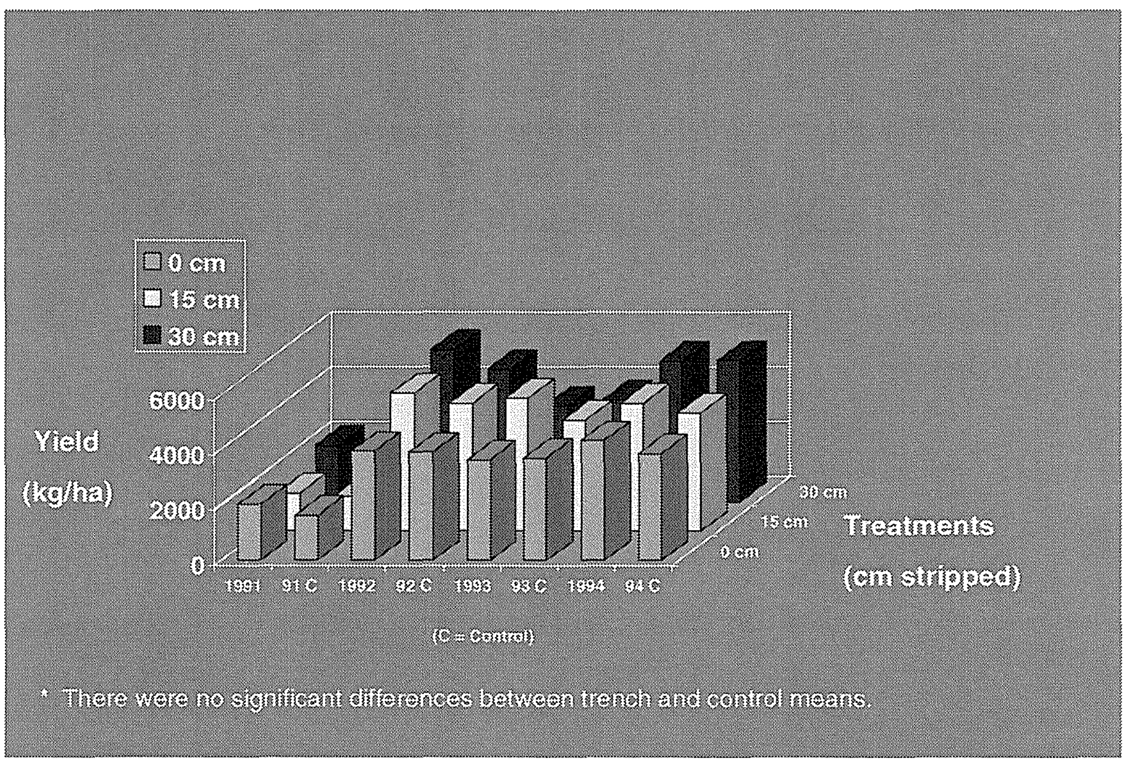

Figure 4. Forage yield, trench and control, 1991 to 1994.*

Control values tended to be more variable (i.e. higher standard deviations) than the trench values for forage yield (Table A1, Appendix 8.3). The lack of statistically significant differences in forage yields between the trench and control over the four year monitoring period is similar to the results of earlier studies of pipeline installation in Luvisolic soils in Alberta (Toogood, 1974; Hardy and Associates [1978] Ltd. 1983).

There were no consistent trends in vegetation cover on trench and control plots (Figure 5). Differences between trench and control vegetative cover for 1991 and 1992 were not statistically significant for any treatment. Although control values tended to have higher standard deviations than the trench values for forage yield, the reverse occurred for vegetation cover (Tables A1 and A2, Appendix 8.3). In 1993, vegetative cover in the 30 cm stripping treatment was higher on the trench than the control. This difference appeared to be a result of lower than average vegetation cover in the 30 cm treatment control, rather than higher than average cover on the trench.

Similarly, in 1994, vegetation cover on the trench was significantly higher than the cover on the control in the 15 cm stripping treatment (Figure 5). Again, the difference appeared

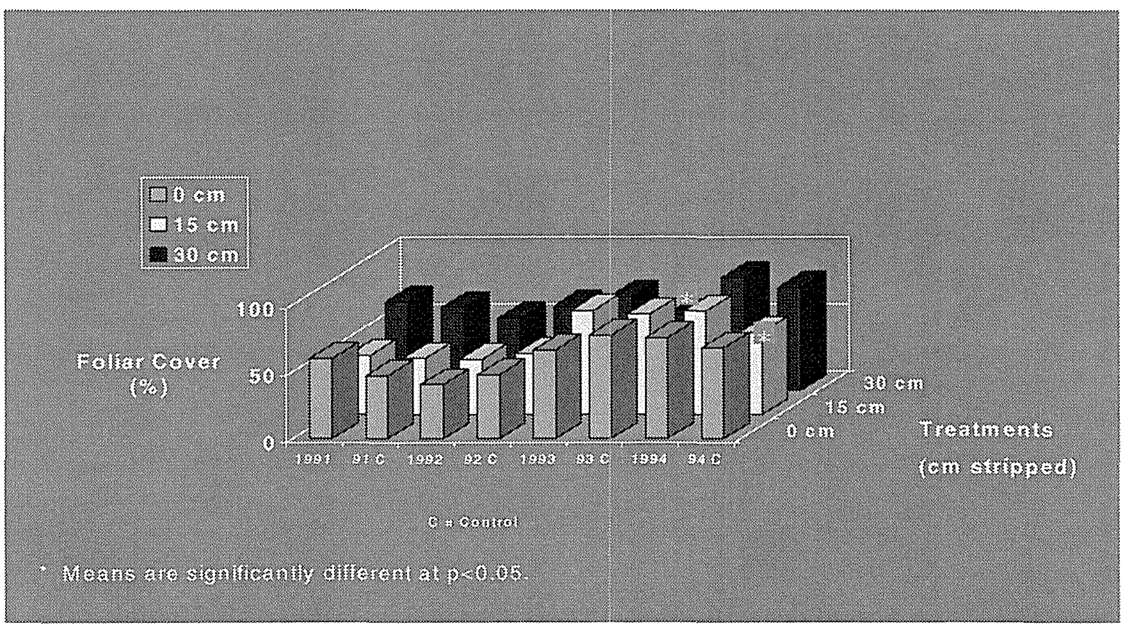

Figure 5. Percent vegetative cover, trench and control, 1991 to 1994.

to be the result of lower vegetative cover on the control, not higher vegetative cover on the trench. Reasons for lower vegetative cover in the 30 cm control were not clear, but may have been due to early spring water ponding in part of the control.

Cluster analysis grouped all treatments and controls closely together in terms of species composition. All sites tended to show similar trends in the development of species distribution. Mean ratios of seeded agronomic species to total species during the four years of vegetation monitoring varied from 0.60 to 0.97, with little difference between trench and control plots (Table 1). There was a slight trend towards an overall increase in the ratio of seeded to total species over time. This, and other changes in plant species composition, did not appear to be associated with topsoil stripping treatments. Species composition of each treatment in 1994 is presented in Appendix 8.4.

Table 1. Ratio of seeded to total species, trench and control plots, 1991 to 1994.

	1991		1992		1993		1994	
Treatment	Trench	Control	Trench	Control	Trench	Control	Trench	Control
0 cm	0.68	0.66	0.78	0.81	0.85	0.79	0.88	0.77
15 cm	0.78	0.73	0.90	0.87	0.81	0.73	0.85	0.89
30 cm	0.87	0.70	0.96	0.97	0.76	0.60	0.85	0.76

5.2. pH

5.2.1. Pre- and Post- Construction

The largest increase in pH in the surface 20 cm depth increment occurred in the 0 cm treatment where no topsoil was stripped (pre-construction pH=5.6, post-construction pH=7.6). Stripping 15 and 30 cm of topsoil did not preserve pre-construction surface pH as post-construction surface pH values for the 15 and 30 cm treatments (pH=7.3 and 7.2, respectively) were significantly higher than pre-construction pH on the same treatments (pH=5.6 and 5.8, respectively). In the 20 to 40 cm depth increment of 30 cm stripping treatment pH was significantly higher after construction (pH=7.5) compared to the pre-construction value (pH=5.9). In all treatments, pipeline construction resulted in significantly higher pH at depths to 60 or 80 cm (Figure 6 and Table A3, Appendix 8.3). For the most part, soil quality benefited from higher pH values after construction, bringing topsoil pH from moderately acidic into a slightly alkaline range. This resulted in improved soil quality in the topsoil in the 15 and 30 cm stripping treatments. Below the 20 cm depth, increased pH values resulted in a reduced soil quality in some treatments. However, effects on crop yields were not expected and were not seen. According to (Leskiw, 1993), subsoil pH values between 6.5 and 8.0 are unlikely to affect crop yield to any great extent, especially in the absence of soil salinity and sodicity.

A slight subsidence that occurred along parts of the trench was filled with existing surface soil during seedbed preparation activities (disking and harrowing) before seeding in August, 1990. Effects of subsidence filling from seedbed preparation were restricted to the top 20 cm of the soil. In all cases, pH values for the 0 to 20 cm depth increment fell very slightly (0.0 to 0.2 units) after filling. All differences were small and were not expected to effect plant growth.

5.2.2. Time Effects

Changes in pH over the five years following construction were minor compared to the initial increases in pH resulting from construction. As indicated in Figures 7, 8 and 9, trench pH values remained higher than control values for all treatments after 5 years, at all depths. Differences between the trench and control for all treatments and depths are statistically significant with the exception of the 0 to 15 cm depth increment in the 0 cm stripping treatment in 1990. However, by 1991 the pH of this depth increment in the trench was significantly higher than the control as well.

Trench pH values showed no statistically significant change between 1990 and 1991 (Table 2). Between 1991 and 1992, pH decreased slightly on all depth increments of the 0 cm stripping treatment. This may have been a result of carbonate leaching and plant uptake (Naeth, et al., 1987). This decrease reversed between 1992 and 1994 on the trench. Trench pH values in 1994 were significantly higher than 1992 trench values for all depths of the 0 and 30 cm stripping treatments, and for the 15 to 30 cm depth increment on the 15 cm stripping treatment (Table 2 and 3). Controls also show some increases over the same time period (Table 3). Only continued monitoring will confirm whether pH is actually increasing over time, or is simply a function of variability in laboratory analysis, or natural variability between years.

Some decrease in subsoil quality based on increased pH is indicated, however, there is no significant effect expected on crop yield.

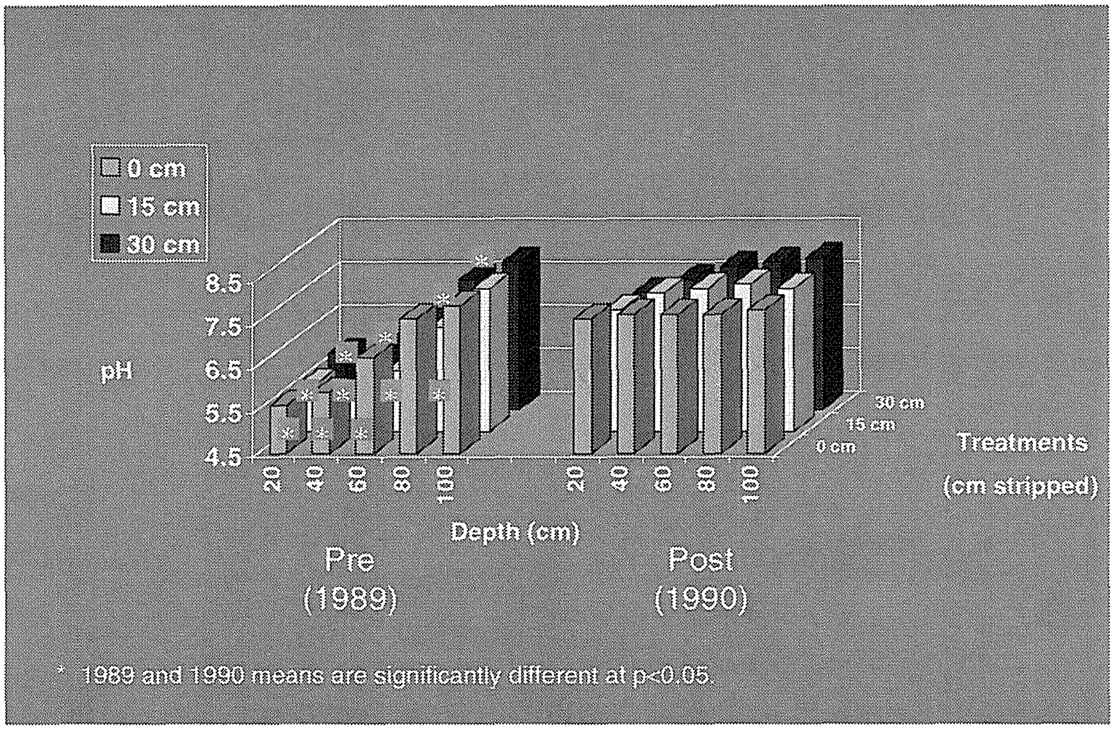

Figure 6. Differences in trench pH before construction (1989) and post-construction (1990).

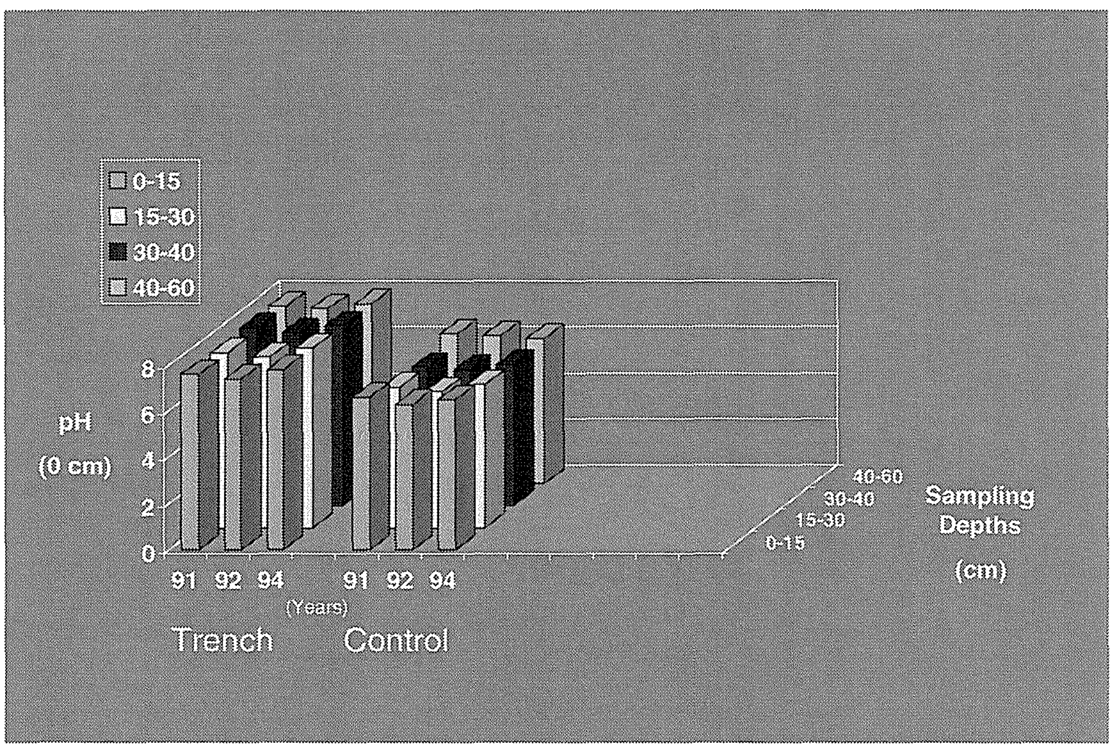

Figure 7. Changes in trench and control pH, 1991 to 1994, 0 cm treatment.

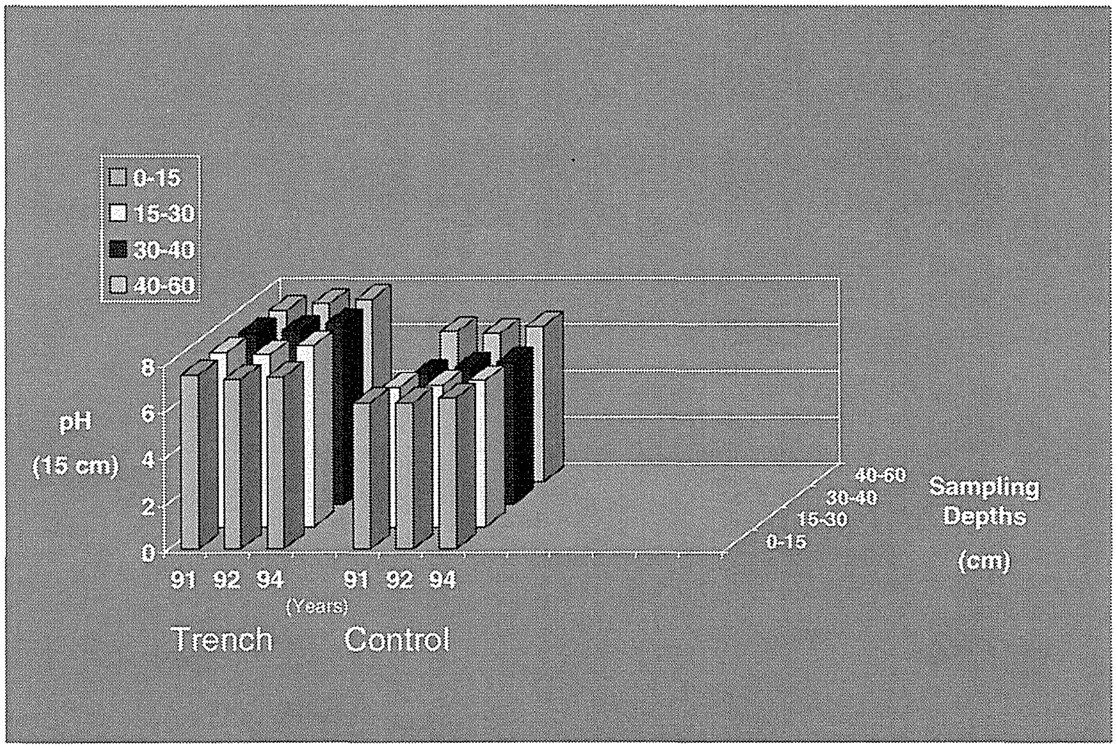

Figure 8. Changes in trench and control pH, 1991 to 1994, 15 cm treatment.

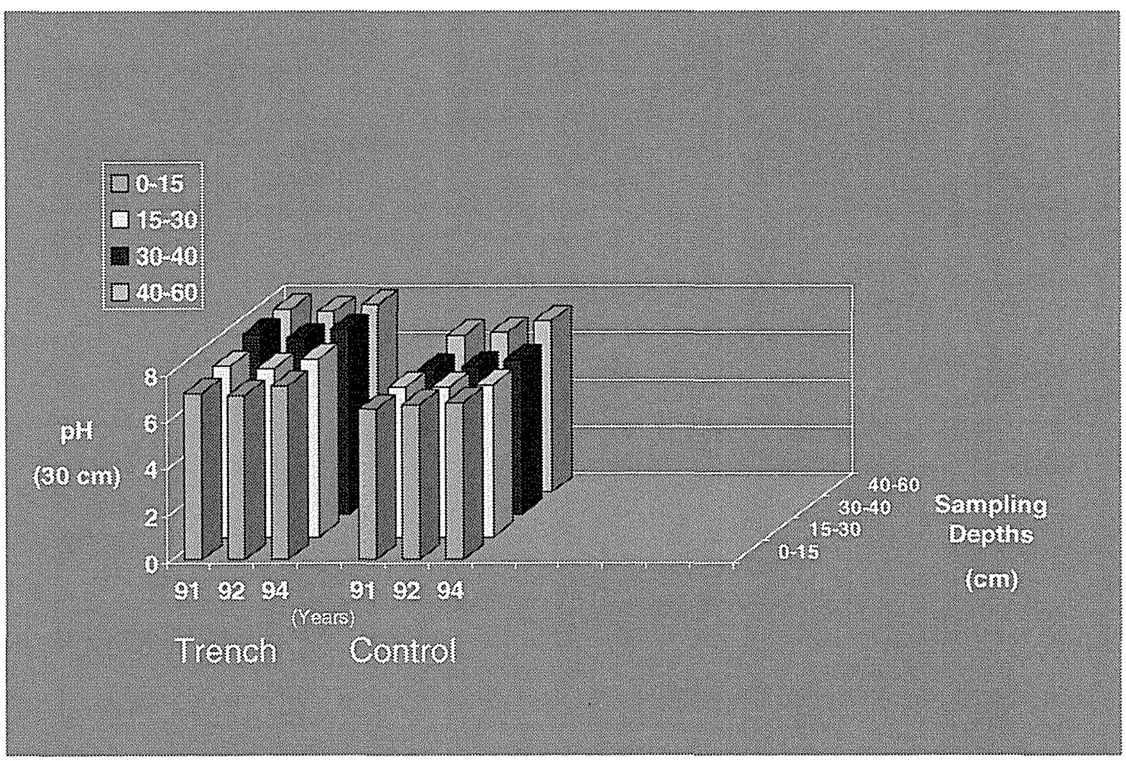

Figure 9. Changes in trench and control pH, 1991 to 1994, 30 cm treatment.

Table 2. Differences between 1990 and 1991, 1991 and 1992, and 1992 and 1994 trench samples for pH.

Years	Depth of Stripping (cm)	Depth of Sampling (cm)			
		0-15	15-30	30-40	40-60
1990 vs. 1991	0	ns*	ns	ns	ns
	15	ns	ns	ns	ns
	30	ns	ns	ns	ns
1991 vs. 1992	0	1991>1992	ns	1991>1992	1991>1992
	15	ns	ns	ns	ns
	30	ns	ns	ns	ns
1992 vs. 1994	0	1992<1994	1992<1994	1992<1994	1992<1994
	15	ns	1992<1994	ns	ns
	30	1992<1994	1992<1994	1992<1994	1992<1994

*ns = means are not significantly different at $p < 0.05$.

Table 3. Change in trench and control pH, 1992 versus 1994.

Treat-ment	Depth (cm)	1992				1994				pH Change	
		Trench Mean	Control Mean	Trench s.d.	Control s.d.	Trench Mean	Control Mean	Trench s.d.	Control s.d.	Trench (92 to 94)	Control (92 to 94)
0 cm	0-15	7.4	6.3	0.2	0.3	7.8	6.5	0.2	0.4	0.4	0.2
	15-30	7.4	5.9	0.3	0.3	7.8	6.2	0.2	0.6	0.4	0.3
	30-40	7.5	5.9	0.1	0.5	7.8	6.1	0.2	0.8	0.3	0.2
	40-60	7.6	6.4	0.2	0.9	7.8	6.3	0.2	0.9	0.2	−0.1
15 cm	0-15	7.3	6.3	0.4	0.3	7.4	6.5	0.5	0.3	0.1	0.2
	15-30	7.4	6.1	0.4	0.3	7.8	6.3	0.2	0.3	0.4	0.2
	30-40	7.5	5.9	0.6	0.4	7.8	6.1	0.1	0.2	0.3	0.2
	40-60	7.7	6.4	0.6	0.8	7.9	6.7	0.2	0.7	0.2	0.3
30 cm	0-15	7.0	6.6	0.3	0.4	7.4	6.7	0.2	0.4	0.4	0.1
	15-30	7.2	6.3	0.3	0.3	7.6	6.5	0.2	0.3	0.4	0.2
	30-40	7.5	6.3	0.2	0.3	7.9	6.6	0.1	0.2	0.4	0.3
	40-60	7.7	6.8	0.2	0.3	8.0	7.3	0.2	0.5	0.3	0.5

5.3. ORGANIC MATTER

5.3.1. Pre- and Post- Construction

The organic matter content of all treatment plots increased significantly in the Ahe/Ae horizon (0 to 20 cm) after construction (Table 4). These differences were considered to be a function of sampling. The Ahe/Ae horizons of the undisturbed pre-construction forest soils did not include the leaf litter (LFH) layer. Both pipeline construction and breaking of the controls served to mix the LFH layer with underlying mineral soil, increasing the organic matter content of the surface layers. The depth to which LFH organic matter was mixed into mineral soil depended on the stripping treatment.

Table 4. Differences in trench organic matter percent pre-construction (1989) and post-seedbed preparation (1990).

	Pre-construction 1989 (Ahe/Ae)		1990 Trench (0-15) post-seedbed preparation		
Treatment	mean	s.d.	mean	s.d.	Mean change
0 cm	1.2	0.5	5.4	1.1	+4.2
15 cm	0.8	0.4	5.8	1.7	+5.0
30 cm	1.4	0.7	7.3	1.6	+5.9

As mentioned in the discussion of pH, the slight subsidence which occurred over parts of the trench, was filled during seedbed preparation activities (normal disking and harrowing) before seeding in 1990. This resulted in some changes to the mean organic matter content of the three stripping treatments. The organic matter content of the 0 cm stripping treatment was higher after seedbed preparation (4.2 % before and 5.4 % after) while the 15 and 30 cm stripping treatments had slightly lower organic matter percent after seedbed preparation (6.4 % and 7.7 % before and 5.8 % and 7.3 % after, respectively). These changes indicate that seedbed preparation resulted in some redistribution of surface organic matter content.

5.3.2. Time Effects

Significant differences in mean organic matter percent of the 0 to 15 cm depth increment between trench and control varied somewhat from year to year, but as shown in Figure 10, the differences appeared to be more a function of the much higher variability of the controls rather than reflecting any significant change between years in organic matter percent on the trench. There was no significant change in organic matter content of the surface horizon of the trench in the five years following construction (Table A4, Appendix 8.3). This result is dissimilar to results of (Cloutier, 1988) who found an increase in organic carbon percent in the 0 to 15 cm depth increment on a pipeline constructed in Luvisolic soils. That increase was attributed in part to the formation of a sod layer under forages.

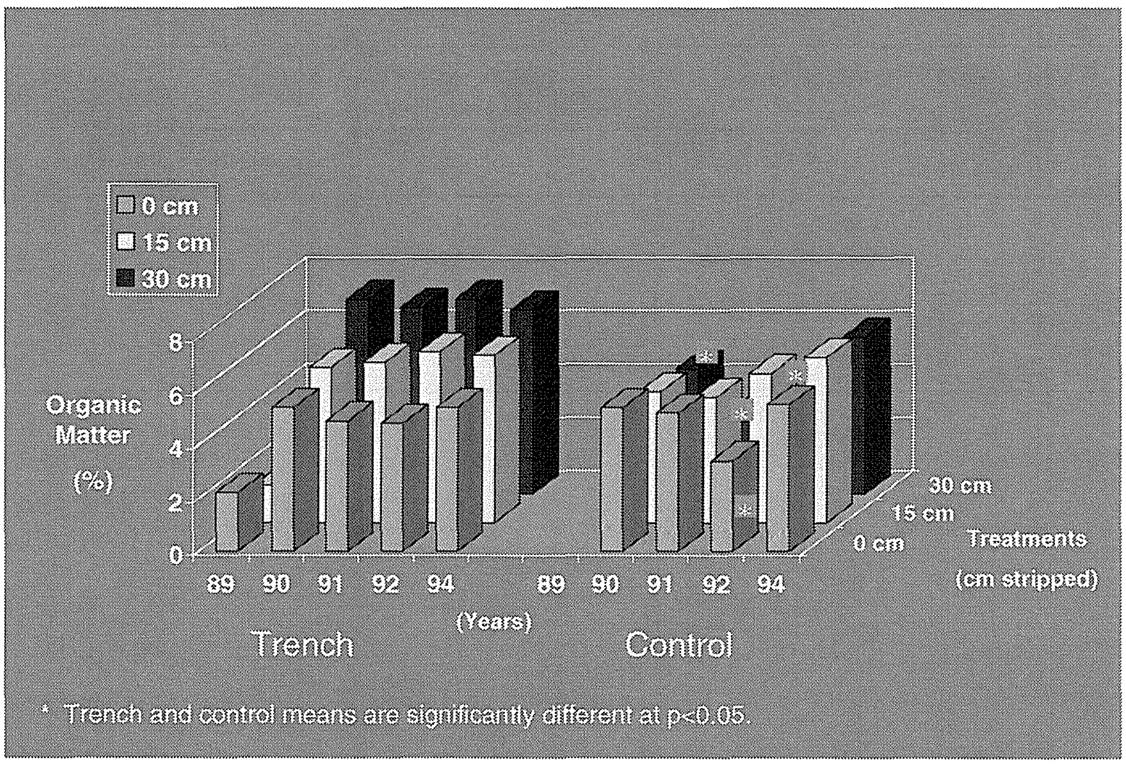

Figure 10. Percent organic matter, trench and control, 1989 to 1994, 0 to 15 cm depth.

By 1994, after pipeline reclamation, seedbed preparation, seeding, and five years of forage growth, there were no significant differences in organic matter between the pipeline trench and controls broken for agriculture, even where no topsoil was stripped.

5.4. CLAY CONTENT

5.4.1. Pre and Post - Construction

After construction the subsoil was uniformly distributed in all treatments (Figure 11; Table A5, Appendix 8.3) to trench depth below the replaced topsoil (or surface where 0 cm topsoil was stripped). After construction (1990) in all three treatments, and at all depths below depth of stripping to 100 cm, percent clay varied by about 3 percent (29 % to 32 %). Before construction (1989) percent clay at these same depths on the three treatments varied by about 14 percent and ranged from 27 percent to 41 percent.

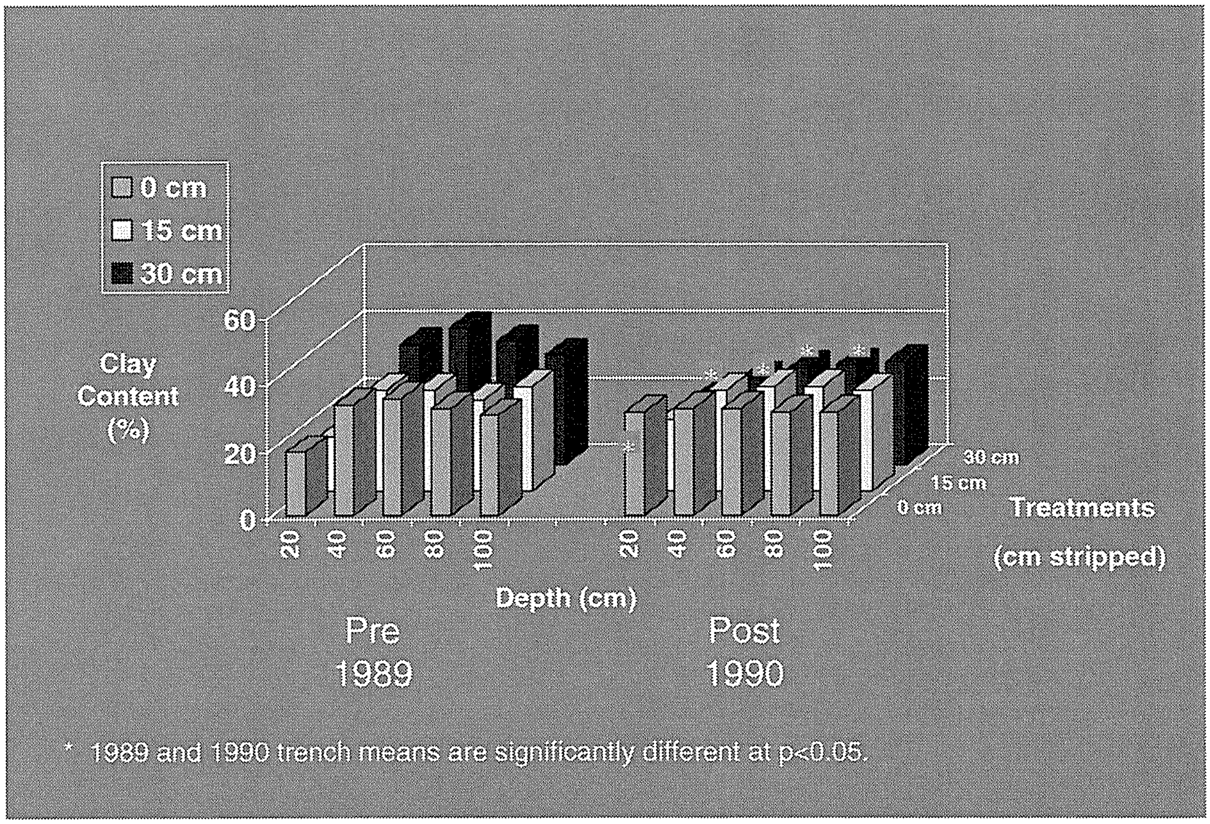

Figure 11. Trench clay content, pre-construction (1989) and post-construction (1990).

The effect of the depth of topsoil stripping on the three treatments is apparent in the post-construction (1990) clay content of the surface soil (Figure 11). Where no topsoil was stripped in the 0 cm stripping treatment, percent clay in the 0 to 20 cm depth increment was significantly higher after construction (31 percent) compared to before (19 percent). This difference corresponds to a change in soil texture from loam to clay loam. There were no significant differences between pre- and post- construction clay percent below 20 cm. Where 15 cm of topsoil was stripped, there were no significant differences in clay content before or after construction. Stripping topsoil to 15 cm retained the pre-construction clay content in the 0 to 20 cm depth increment.

Stripping 30 cm of topsoil resulted in a minor 3 percent increase in clay content after construction in the 0 to 20 cm depth increment. Although statistically significant, the difference was too small to result in a change in soil texture class. Influence of the deeper topsoil stripping in the 30 cm stripping treatment is evident in the lower depth increments. At the 20 to 40 and 40 to 80 cm depth increments, construction resulted in significantly lower clay content compared to pre-construction levels. Post-construction clay content below the depth of stripping to 100 cm was very uniform, as was also found in the 0 and 15 cm stripping treatments.

Below the depth of stripping, construction appears to have redistributed the clay content more evenly throughout the soil profile. The clay bulges apparent in the B horizons of the pre-construction profiles were not evident in the trench soils (Figure 11). This more even distribution resulted in significantly lower clay contents in the trench (particularly in the 40-60 cm range) compared to the control in some of the depth increments below the depth of stripping in all three treatments.

5.4.2. Time Effects

Clay content was not monitored after 1990. Considering the relative immobility of clays in soils, no notable changes in clay content of any of the soil horizons over the five years of this study were anticipated.

5.5. Electrical Conductivity and Sodium Adsorption Ratio

Before construction, soils in all three treatments were non-saline to 80 cm, and non- to weakly saline below 80 cm to trench depth. All pre-construction soils were non-sodic to trench depth. Salinity levels increased significantly on the trench after construction, as the slightly more saline soil materials from near trench depth were mixed into the less saline upper soil materials (Figure 12; Table A6, Appendix 8.3). The increases were most noticeable in the 0 cm stripping treatment, however, overall salinity levels on all stripping treatments after construction were non-saline to very weakly saline. All treatment and control soils were non-sodic both before and after pipeline construction (Table A7, Appendix 8.3).

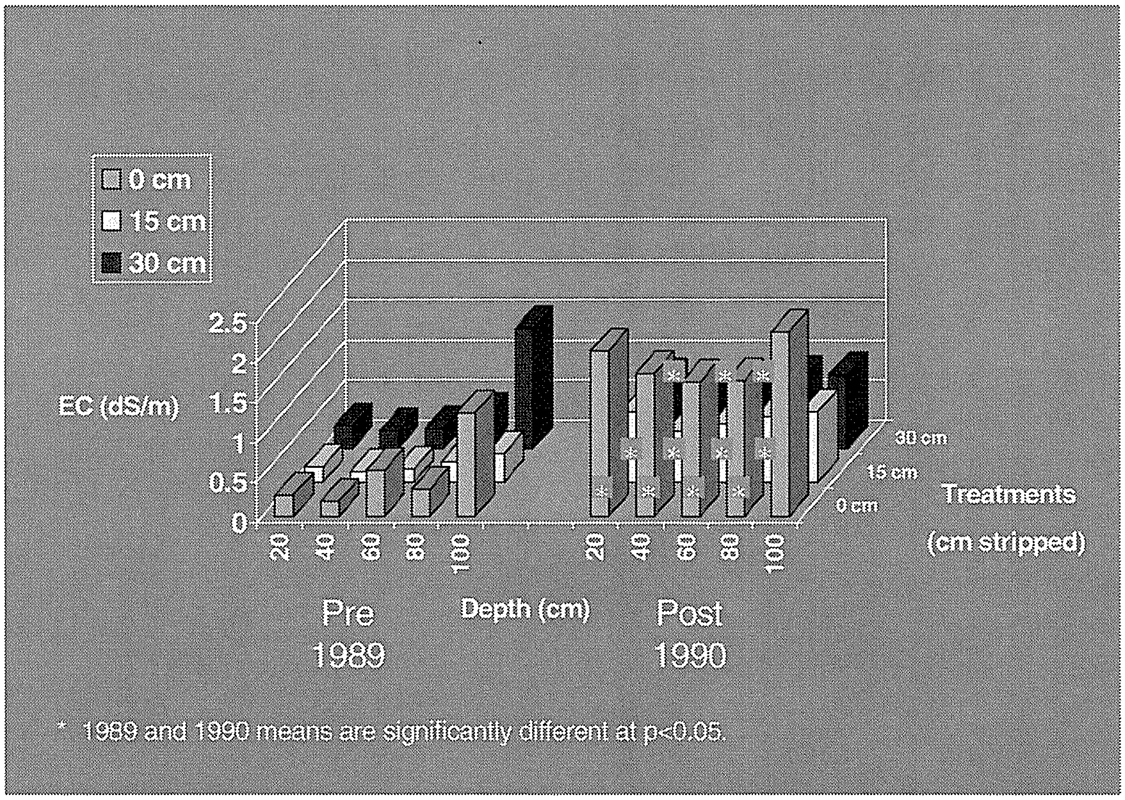

Figure 12. Differences in trench EC (dS/m), pre-construction (1989) and post-construction (1990).

EC and SAR were not monitored after 1990 because the initial low levels of salinity and sodicity in these soils both before and after construction do not affect crop growth.

5.6. Soil Strength

The only statistically significant difference in soil strength between trench and control in 1991 occurred in the first depth increment (0 to 3.5 cm) of the 30 cm treatment (Table 5). In this case, the control had a significantly higher soil strength (1.8 bars) compared to the trench (0.9 bars). Significantly higher moisture content of the 0 to 15 cm increment on the trench in the 30 cm treatment could account for this difference (Table 6). There were no other significant differences in soil moisture. Although only an indirect measure of compaction, these cone penetrometer results indicate that compaction was not a problem for plant growth on the trench in any of the treatments.

Table 5. Comparison of soil strength (bars), 1991 trench and controls.

Depth (cm)	0 cm Treatment		15 cm Treatment		30 cm Treatment	
	Trench	Control	Trench	Control	Trench	Control
3.5	1.2	1.5	1.3	1.3	0.9+	1.8+
7.0	5.8	6.1	6.9	5.8	6.4	6.3
10.5	8.6	7.6	10.4	8.8	9.6	8.7
14.0	11.6	9.8	14.6	12.7	12.3	11.8
17.5	13.1	13.9	16.5	16.8	16.8	13.2
21.0	16.3	18.4	16.7	21.2	20.0	15.0
24.5	18.1	23.1	18.2	21.1	20.0	15.9
28.0	20.0	*	18.3	*	20.6	18.4
31.5	21.2		*		19.3	22.3
35.0	21.3				21.8	*
38.5	21.1				*	
42.0	21.9					
45.5	22.1					
49.0	19.9					
52.5	18.4					

+ Means of trench and control are significantly different at $p < 0.05$.

* Maximum penetration possible.

Table 6. Comparison of soil moisture percent in 1991 trench and control plots.

Depth (cm)	0 cm Treatment		15 cm Treatment		30 cm Treatment	
	Trench	Control	Trench	Control	Trench	Control
0-15	24.4	26.1	23.0	28.1	27.9*	22.3*
15-30	22.4	24.3	16.3	21.2	24.6	39.7
30-40	19.1	16.4	13.7	15.1	16.3	20.3
40-60	18.0	15.9	15.9	15.2	15.6	16.5

* Means of trench and control are significantly different at $p < 0.05$.

5.7. AGRICULTURAL CAPABILITY RATING FOR 1994 TRENCH AND CONTROL

Soils on each treatment were rated according to the agricultural capability classification developed by (Leskiw, 1993). The soil index points calculated for the 1994 trench and controls are in Table 7.

Table 7. Soil capability index points for 1994 trench and controls.

Treatment	Trench	Control
0 cm	71	72
15 cm	74	74
30 cm	76	75

Agriculture capability ratings on trench and controls are similar to each other on all three treatments. All, including the controls, fall into Agricultural Capability Class 2, indicating slight limitations to agriculture.

6. CONCLUSIONS

The findings of this study indicate that pipeline construction on this site using any of the three topsoil handling treatments (0 cm, 15 cm, 30 cm) resulted in an agricultural land capability equivalent to that found when the land immediately adjacent to the RoW was broken for agriculture use. More specific conclusions are:

- No adverse effects on forage productivity were found on any of the treatments four years after seeding. All treatments had productivity equivalent to adjacent land broken and managed for forage cultivation, including the treatment where no topsoil salvage occurred.
- Organic matter content of surface soils on the trench was either higher than or, equivalent to, the off-RoW control surface soils in all treatments.
- In some cases pH, clay content and/or salts were higher at the surface of trench soils compared to control or pre-construction levels. These differences did not reduce plant productivity.
- Cone penetrometer results indicate that soil compaction was not a problem for plant growth on the trench of any of the treatments.
- Five years after pipeline construction, agricultural capability ratings were equivalent on all treatments and their controls.
- The pipeline trench in all three treatments (0 cm, 15 cm and 30 cm of surface soil salvaged) will not present different management requirements from those on a traditionally broken and managed field.

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8. APPENDICES

8.1. SOIL QUALITY CRITERIA

8.1.1. Criteria for Evaluating Suitability of Topsoil in the Plains Region (Alberta Soils Advisory Committee, 1987).

Property/Rating	Good	Fair	Poor	Unsuitable
Reaction (pH)	6.5-7.5	5.5-6.4 & 7.6-8.4	4.5-5.4 & 8.5-9.0	< 4.5 & > 9.0
Salinity (EC) dS/m	<2	2 to 4	4 to 8	> 8
Sodicity (SAR)	<4	4 to 8	8 to 12	12[1]
Saturation %	30 to 60	20 to 30 & 60 to 80	15 to 20 & 80 to 120	< 15 & > 120
Stoniness Class	S0, S1	S2	S3, S4	S5
Texture	FSL, VFSL, L, SL, SiL	CL, SCL, SiCL	LS, SiC, C[2], S, HC[2]	-
Moist Consistency	very friable, friable	loose	firm, very firm	extremely firm
Organic Carbon %	> 2	1 to 2	< 1	-
$CaCO_3$	< 2	2 to 20	20 to 70	> 70

1 Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.

2 C and HC may be upgraded to fair to good in some arid areas.

8.1.2. Criteria for Evaluating Suitability of Subsoil in the Plains Region (Alberta Soils Advisory Committee 1987).

Property/Rating	Good	Fair	Poor	Unsuitable
Reaction (pH)	6.5-7.5	5.5-6.4 & 7.6-8.5	4.5-5.4 & 8.6-9.0	< 4.5 & > 9.0
Salinity (EC) dS/m	< 3	3 to 5	5 to 10	> 10
Sodicity (SAR)	< 4	4 to 8	8 to 12	12[1]
Saturation %	30 to 60	20 to 30 & 60 to 80	15 to 20 & 80 to 120	< 15 & > 120
Stoniness Content (% volume)	< 3	3 to 25	25 to 50	> 50
Texture	FSL, VFSL, L, SL, SiL	CL, SCL, SiCL	S, LS, SiC, C, HC	Bedrock
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
Gypsum $CaCO_3$ Equivalent %	The suitability criteria for sodicity (SAR) may be altered by the presence of high levels of either lime ($CaCO_3$) or gypsum ($CaCO_4$) in excess of other soluble salts.			

[1] Materials characterized by an SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation percentage is less than 100%.

8.2. SOIL SURVEY

SOIL INVENTORY OF THE PROPOSED MOUNT VALLEY FORESTED LUVISOL PLOTS

for
NOVA CORPORATION OF ALBERTA

by
Nancy M. Finlayson

LAND RESOURCES NETWORK LTD.

July 1989

1. OBJECTIVE

The objective of the inventory was to map the soils of the proposed plot area in detail to determine the nature of soils present, depths of A and B horizons, and uniformity across the area.

2. METHODS

Soil inspections were made at 50 m intervals near the proposed control, work and trench areas. Additional check holes were dug to determine the extent of sandier B materials. Depths of major horizons, soil texture, colour, soil classification and materials were noted at each site. Details of each site are appended.

3. RESULTS

Soils are dominantly Gleyed Grey Luvisols, with significant Orthic Grey Luvisols, and inclusions of Dark Gley Luvisols. All are in close association, and cannot be separated out as separate map units. Parent materials are fine loamy lacustro-till or glaciolacustrine materials overlying glacial till at depth ranging from 40 cm to more than 100 cm. At a few sites, materials overlying till are slightly sandier in texture, resulting in sandy clay loam textured Bt horizons. Several profiles had thin (less than 5 cm) layers of fine sandy loam materials within the B horizon. All but 1 site had till within 50 cm.

Topography of the site was gently undulating. The general slope of the area was very gently upward to the north, so that the control sites appear to be very slightly higher than the trench area. There are some micro-topographic lows and crests in the study area. Drainage is moderately well throughout the area, despite the gleyed nature of the dominant soils. Gleyed soils are actually "pseuydogley", indicating poor internal drainage, rather than conditions of high water table. Mottling does not occur at depth. Orthic profiles tended to occur on the slightly sandier parent materials.

In general, soils have a LFH horizon 3 to 10 cm thick, although at one site it was slightly peaty and 17 cm thick. An Ah occurs at some sites, but it is thin, usually less than 3 cm, and generally discontinuous. An Ahe extends below 5 cm, the critical depth for a Dark Grey Luvisol, at 2 sites only. An Ae horizon can be found at all sites, and extends to a depth of between 15 and 25 cm. Both Ahe and Ae horizons are fine sandy loam to very fine sandy loam to loam, and are often mottled, due to poor internal drainage. They are fine platy in structure. Bt horizons occur at between 18 and 35 cm depth. They are moderate fin subangular in structure, sandy clay loam to silty clay loam in texture, and frequently have clay coatings on ped surfaces and are often mottled.

Where the till contact occurs in the profile, usually between 40 and 75 cm, colours are darker, texture is clay loam, and structure in a weak subangular blocky. It is usually calcareous at the contact, except where found high in the profile. Typical Orthic Grey Luvisol and Gleyed Grey Luvisol profiles are described in Tables 1 and 2.

4. CONCLUSIONS

An association of Gleyed, Orthic and Dark Grey Luvisols as found in the plot area are typical of soils of this type in the area, and is not considered a problem for plot development. Variability in texture does occur, but all A horizons tend to fall within the coarse loamy texture range, while all B horizons fall within the fine loamy range, with the exception of a very thin band of fine sandy loam material found in the Bt in 2 profiles. No trends within the proposed plot area could be mapped.

Table 1. Site and profile description of a typical Orthic Grey Luvisol.

CLASSIFICATION: Orthic Grey Luvisol.

PARENT MATERIAL: fine loamy lacustro-till or glacio-lacustrine materials overlying glacial till.

TOPOGRAPHY: gently sloping.

DRAINAGE: moderately well.

SURFACE STONINESS: slightly stony

PROFILE DESCRIPTION:

Horizon	Depth (cm)	Description
LFH	6-0	
Ahe	0-4	Grey silt loam; weak fine platy; very friable; many roots.
Ae	4-22	Light grey silt loam; moderate fine platy; very friable; common roots.
Bt	22-40	Brown clay loam; moderate medium subangular blocky; firm; common roots.
BC	40-60	Brown clay loam; weak medium subangular blocky to massive; firm; few roots.
Ck	60+	Brown clay loam; massive; firm; few roots.

Table 2. Site and profile description of a typical Gleyed Grey Luvisol.

CLASSIFICATION: Gleyed Grey Luvisol.

PARENT MATERIAL: fine loamy lacustro-till or glacio-lacustrine materials overlying glacial till.

TOPOGRAPHY: gently sloping.

DRAINAGE: imperfectly.

SURFACE STONINESS: slightly stony

PROFILE DESCRIPTION:

Horizon	Depth (cm)	Description
LFH	9-0	
Ahe	0-8	Grey silt loam; weak fine platy; very friable; many roots.
Ae	8-16	Light grey silt loam; moderate fine platy; very friable; common roots.
Btgj	22-35	Dark greyish brown clay loam; few diffuse dark yellowish brown mottles; moderate medium subangular blocky; firm; common roots.
BCgj	35-50	Dark greyish brown clay loam; few diffuse dark yellowish brown mottles; weak medium subangular blocky to massive; firm; few roots.
Ck	50+	Brown clay loam; massive; firm; few roots.

5. APPENDIX

5.1 DETAILS OF SITE INSPECTIONS

Plot 1 Site 1		Plot 1 Site 2		Plot 1 Site 3	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	6-0	LFH	6-0	LFH	8-0
Ahe	0-2	Ahe	0-4	Ahe	0-4
Ae	2-10	Ae	4-22	Ae	4-15
AB	10-15	Bt	22-40	AB	15-45
Bt	15-40	BC	40-60	Bt	45-60
BC	40-60	C	60-100	BC	60-70
Ck	60+			Ck	70+

Plot 1 Site 4		Plot 1 Site 5		Plot 1 Site 6	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	3-0	LFH	4-0	LFH	5-0
Ahe	0-4	Ah	0-1.5	Ahe	0-1
Ae	4-18	Ae	1.5-15	Ae	1-13
Bt	18-40	Bt	15-40	Bt	13-35
BC	40-60	BC	40-55	BC	35-60
Ck	60+	Ck	55+	Ck	60+

Plot 1 Site 7		Plot 1 Site 8		Plot 1 Site 9	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	7-0	LFH	2-0	LFH	4-0
Ahe	0-5	Ahe	0-2	Ahe	0-4
Ae	5-22	Ae	2-18	Ae	4-24
Bt	22-40	AB	18-28	Bt	24-40
BC	40-60	BC	28-40	BC	40-60
Ck	60+	Ck	40+	Ck	60+

Plot 1 Site 10		Plot 2 Site 1		Plot 2 Site 2	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	8-0	LFH	9-0	LFH	7-0
Ahe	0-4	Ahe	0-2	Ahe	0-1
Ae	4-22	Ae	2-20	Ae	1-21
Bt	22-40	Bt	20-40	Bt	21-35
BC	40-60	BC	40-65	BC	35-55
Ck	60+	Ck	65+	Ck	55+

Plot 2 Site 3		Plot 2 Site 4		Plot 2 Site 5	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	5-0	LFH	7-0	LFH	10-0
Ahe	0-1	Ae	0-14	Ae	0-20
Ae	1-24	AB	14-18	AB	20-28
AB	24-27	Bt	18-40	Bt	28-40
At	27-47	BC	40-55	BC	40-75
BC	47-65	Ck	55+	Ck	75-95
Ck	65+			Cca	95-100

Plot 2 Site 6		Plot 2 Site 7		Plot 2 Site 8	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	5-0	LFH	6-0	LFH	5-0
Ahe	0-1	Ah/Ahe	0-5	Ahe	0-5
Ae	1-24	Ae	5-18	Ae	5-15
AB	24-33	Bt	18-40	Bt	15-35
Bt	33-40	BC	40-55	BC	35-60
BC	40-70	Ck	55-70	Ck	60-70
Ck	70-100				

Plot 2 Site 9		Plot 2 Site 10		Plot 3 Site 1	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	7-0	LFH	10-0	LFH	8-0
Ahe	0-4	Ahe	0-5	Ah/Ahe	0-10
Ae	4-10	Ae	5-21	Ae	10-24
AB	10-18	AB	21-25	AB	24-28
Bt	18-35	Bt	25-40	Bt	28-40
BC	35-60	BC	40-70	BC	40-60
Ck	60+	Ck	70-100	Ck	60+

Plot 3 Site 2		Plot 3 Site 3		Plot 3 Site 4	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	5-0	LFH	5-0	LFH	8-0
Ahe	0-2	Ah/Ahe	0-3	Ah	0-4
Ae	2-17	Ae	3-16	Ahe	4-9
Bt	17-40	Bt	16-40	Ae	9-21
BC	40-65	BC	40-55	Bt	21-35
Ck	65+	Ck	55+	BC	35-55
				Ck	55+

Plot 3 Site 5		Plot 3 Site 6		Plot 3 Site 7	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	5-0	LFH	9-0	LFH	6-0
Ahe	0-7	Ahe	0-8	Ahe	0-7
Ae	7-17	Ae	8-16	Ae	7-23
Bt	17-35	Bt	16-35	Bt	23-40
BC	35-55	BC	35-50	BC	40-65
Ck	55+	Ck	50+	Ck	65+

Plot 3 Site 8		Plot 3 Site 9		Plot 3 Site 10	
Horizon	Depth (cm)	Horizon	Depth (cm)	Horizon	Depth (cm)
LFH	10-0	LFH	7-0	LFH	8-0
Ahe	0-3	Ah/Ahe	0-4	Ahe	0-7
Ae	3-17	Ae	4-22	Ae	7-19
Bt	17-35	Bt	22-40	AB	19-21
BC	35-50	BC	40-65	Bt	21-40
Ck	50+	Ck	65-80	BC	40-65
				Ck	65+

8.3. Soil Parameters

Table A 1. Forage Yields (Kg/ha), Trench and Control Plots, 1991 to 1994.

	Forage Yields (Kg/ha)															
	1991				1992				1993				1994			
treatment	trench	s.d.	control	s.d.	trench	s.d.	control	s.d.	trench	s.d.	control	s.d.	trench	s.d.	control	s.d.
0 cm	2044	1122	1632	701	3952	1318	3917	1681	3630	728	3704	858	4347	730	3868	1412
15 cm	1368	820	1245	703	4996	1990	4527	2245	4830	963	4015	1252	4625	850	4274	1030
30 cm	2023	793	1516	576	5527	1924	4800	1757	3442	874	3671	1045	5089	1243	5116	1768

Table A 2. Vegetative Cover%, Trench and Control Plots 1991 to 1994.

	Forage Yields (Kg/ha)															
	1991				1992				1993				1994			
treatment	trench	s.d.	control	s.d.	trench	s.d.	control	s.d.	trench	s.d.	control	s.d.	trench	s.d.	control	s.d.
0 cm	59.9	27.3	56.9	19	40.3	13.8	47.5	20.6	66.2	16.6	77	21.6	75.4	17.2	67.9	16.9
15 cm	44.2	22.2	42.2	13.2	41.5	20.3	45.7	22.8	77.7	15.6	75	11.4	77.6	17.4	61.5	13
30 cm	66.3	23	62.3	40	54.1	18.5	63.1	19.7	70.4	17.6	56.9	10.3	84.5	22.9	77.5	21.2

Table A 3. Differences in pH between Pre and Post Construction Trench Soils.

Treatment	Depth (cm)	Pre-Construction (1989)			Post-Construction (1990)			Statistical Significance
		mean	s.d.	rating	mean	s.d.	rating	
0 cm	0-20	5.6	0.5	fair	7.6	0.2	fair	*
	20-40	5.9	0.6	fair	7.7	0.2	fair	*
	40-60	6.7	0.8	good	7.7	0.2	fair	*
	60-80	7.6	0.7	fair	7.7	0.2	fair	
	80-100	7.9	0.4	fair	7.8	0.2	fair	
15 cm	0-20	5.6	0.3	fair	7.3	0.3	good	*
	20-40	5.5	0.3	fair	7.7	0.1	fair	*
	40-60	5.9	0.6	fair	7.8	0.1	fair	*
	60-80	6.9	0.8	good	7.9	0.1	fair	*
	80-100	7.8	0.5	fair	7.8	0.1	fair	
30 cm	0-20	5.8	0.4	fair	7.2	0.3	good	*
	20-40	5.9	0.3	fair	7.5	0.3	good	*
	40-60	6.5	0.5	good	7.8	0.2	fair	*
	60-80	7.5	0.4	good	7.9	0.2	fair	*
	80-100	7.9	0.1	fair	8.0	0.1	fair	

* Pre and post-construction means are statistically significantly different at $p < 0.05$
Alberta Soils Advisory Committee (1987).

Table A 4. Organic Matter %, Trench and Control, 1989 to 1994 (0-15 cm depth).

	Trench								
	0 cm Treatment			**15 cm Treatment**			**30 cm Treatment**		
Year	mean	s.d.	rating	mean	s.d.	rating	mean	s.d.	rating
1989	2.2	0.9	fair	1.4	0.7	poor	2.6	1.2	fair
1990	5.4	1.1	good	5.8	1.7	good	7.3	1.6	good
1991	4.9	1.2	good	6.0	2.0	good	7.0	1.8	good
1992	4.8	1.2	good	6.4	2.4	good	7.3	2.7	good
1994	5.4	1.3	good	6.3	1.2	good	6.9	1.6	good

	Controls								
	0 cm Treatment			**15 cm Treatment**			**30 cm Treatment**		
Year	mean	s.d.	rating	mean	s.d.	rating	mean	s.d.	rating
1989	not sampled			not sampled			not sampled		
1990	5.4	3.9	good	4.9	2.9	good	4.7	1.9	good
1991	5.2	3.6	good	4.7	2.8	good	3.2	2.1	fair
1992	3.4	1.2	fair	5.6	2.9	good	3.4	2.4	fair
1994	5.5	5.6	good	6.2	2.5	good	5.9	3.4	good

Alberta Soils Advisory Committee (1987).

Table A 5. Trench Clay Content, Pre-construction (1989) and Post-construction (1990).

Treatment	Depth (cm)	Pre-Construction (1989) mean	s.d.	rating	Post-Construction (1990) mean	s.d.	rating	Statistical Significance
0 cm	0-20	19	8.2	good	31	1.6	fair	*
	20-40	33	7.6	fair	32	3.7	fair	
	40-60	35	6.6	fair	32	5.2	fair	
	60-80	32	6.6	fair	31	3.9	fair	
	80-100	30	6.6	fair	31	3.4	fair	
15 cm	0-20	16	6.6	good	21	3.5	good	
	20-40	30	9.6	fair	30	3.9	fair	
	40-60	30	11.4	fair	31	2.9	fair	
	60-80	27	5.7	fair	31	2.4	fair	
	80-100	31	9.8	fair	30	2.2	fair	
30 cm	0-20	17	1.6	good	20	2.4	good	*
	20-40	36	7.2	fair	26	2.6	good	*
	40-60	41	6.6	fair to poor	29	4.1	fair	*
	60-80	37	4.4	fair	30	4.2	fair	*
	80-100	33	8.8	fair	31	4.3	fair	

* Pre and post-construction means are statistically significantly different at $p < 0.05$
Alberta Soils Advisory Committee (1987).

Table A 6. Differences in Trench EC (dS/m), Pre-construction (1989) and Post-construction (1990).

Treatment	Depth (cm)	Pre-Construction (1989)			Post-Construction (1990)			Statistical Significance
		mean	s.d.	rating	mean	s.d.	rating	
0 cm	0-20	0.27	0.07	good	2.07	1.14	fair	*
	20-40	0.19	0.08	good	1.79	1.38	good	*
	40-60	0.58	0.99	good	1.68	1.31	good	*
	60-80	0.34	0.11	good	1.7	1.33	good	*
	80-100	1.3	1.78	good	2.31	1.92	good	
15 cm	0-20	0.19	0.05	good	0.89	0.2	good	*
	20-40	0.14	0.04	good	0.65	0.23	good	*
	40-60	0.17	0.12	good	0.74	0.44	good	*
	60-80	0.26	0.13	good	0.83	0.6	good	*
	80-100	0.36	0.16	good	0.88	0.72	good	
30 cm	0-20	0.28	0.11	good	0.85	0.14	good	*
	20-40	0.22	0.15	good	0.76	0.2	good	*
	40-60	0.25	0.14	good	0.78	0.52	good	*
	60-80	0.41	0.12	good	0.88	0.82	good	
	80-100	1.5	1.25	good	0.92	0.87	good	

* Pre and post-construction means are statistically significantly different at $p < 0.05$
Alberta Soils Advisory Committee (1987).

Table A 7: Differences in Trench SAR, Pre-construction (1989) and Post-construction (1990).

Treatment	Depth (cm)	Pre-Construction (1989)			Post-Construction (1990)			Statistical Significance
		mean	s.d.	rating	mean	s.d.	rating	
0 cm	0-20	0.32	0.49	good	0.53	0.26	good	*
	20-40	0.44	0.25	good	0.66	0.52	good	
	40-60	0.47	0.32	good	0.86	0.7	good	
	60-80	0.52	0.35	good	0.98	0.78	good	
	80-100	1.18	1.65	good	1.12	0.91	good	
15 cm	0-20	0.18	0.06	good	0.19	0.2	good	
	20-40	0.31	0.06	good	0.36	0.23	good	
	40-60	0.37	0.09	good	0.48	0.27	good	
	60-80	0.32	0.09	good	0.57	0.3	good	
	80-100	0.46	0.33	good	0.62	0.29	good	
30 cm	0-20	0.17	0.07	good	0.17	0.13	good	
	20-40	0.42	0.15	good	0.32	0.23	good	
	40-60	0.51	0.32	good	0.52	0.34	good	
	60-80	0.48	0.43	good	0.59	0.27	good	
	80-100	0.90	0.48	good	0.64	0.16	good	

* Pre and post-construction means are statistically significantly different at $p < 0.05$
Alberta Soils Advisory Committee (1987).

8.4. 1994 VEGETATION SPECIES COMPOSITION AND % COVER.

rep	30 cm Treatment, Trench							
1.	Festuca arundinacea 5*	Festuca rubra 2	Dactylis glomerate 20	Phleum pratense 5	Medicago 10	Taraxacum officinale 2		
2.	Festuca arundinacea 2	Festuca rubra 5	Dactylis glomerate 30	Phleum pratense 2	Lave 5	Medicago 10		
3.	Festuca rubra 3	Dactylis glomerate 60	Trifolium hybridum 20	Lave 5	Viola rigulosa 3			
4.	Festuca rubra 2	Dactylis glomerate 60	Phleum pratense 3	Trifolium hybridum 5	Medicago 10			
5.	Festuca arundinacea 3	Festuca rubra 2	Dactylis glomerate 70	Phleum pratense 3	Trifolium hybridum 20	Trifolium repens 3		
6.	Festuca arundinacea 5	Festuca rubra 2	Dactylis glomerate 40	Phleum pratense 2	Trifolium hybridum 20	Rosa woodsii 2	Taraxacum officinale 4	Vicia americana 2
7.	Festuca arundinacea 10	Festuca ruhra 5	Dactylis glomerate 10	Phleum pratense 5	Trifolium hybridum 20	Vicia americana 10		
8.	Festuca arundinacea 10	Festuca rubra 20	Dactylis glomerate 50	Phleum pratense 20	Trifolium hybridum 10	Vicia americana 20		
9.	Festuca rubra 10	Dactylis glomerate 10	Phleum pratense 30	Trifolium hybridum 40				
10.	Festuca rubra 20	Dactylis glomerate 5	Phleum pratense 20	Trifolium hybridum 20	Taraxacum officinale 20	Epilobium angustifolium 10	Vicia americana 10	Fragaria virgiana 2
11.	Festuca arundinacea 5	Festuca rubra 10	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 5	Solidago spp. 3	Epilobium angustifolium 5	Vicia americana 5 Rosa woodsii 3
12.	Festuca rubra 20	Dactylis glomerate 50	Phleum pratense 5	Trifolium hybridum 5	Solidago spp. 5	Taraxacum officinale 5		
13.	Festuca rubra 20	Dactylis glomerate 20	Phleum pratense 20	Trifolium hybridum 30	Taraxacum officinale 2			
14.	Festuca rubra 5	Dactylis glomerate 70	Phleum pratense 20	Taraxacum officinale 2	Vicia americana 10			
15.	Festuca rubra 20	Dactylis glomerate 30	Phleum pratense 5	Taraxacum officinale 4	Vicia americana 10			

* % cover

8.4 1994 VEGETATION SPECIES COMPOSITION AND % COVER (CONTINUED).

rep	30 cm Treatment, Control							
1.	Festuca rubra 2*	Dactylis glomerate 20	Phleum pratense 10	Agropyron intermedium 30	Rosa woodsii 20	Taraxacum officinale 10		
2.	Festuca rubra 5	Dactylis glomerate 20	Phleum pratense 10	Agropyron intermedium 20	Rosa woodsii 20			
3.	Festuca arundinacea 10	Festuca rubra 5	Dactylis glomerate 10	Phleum pratense 5	Agropyron intermedium 5	Rosa woodsii 10	Vicia americana 20	
4.	Festuca rubra 10	Dactylis glomerate 40	Phleum pratense 10	Trifolium hybridum 10	Agropyron intermedium 5	Lathyrus venosus 5	Vicia americana 10	Fragaria virginiana 5 Solidago spp. 5
5.	Festuca rubra 5	Dactylis glomerate 20	Phleum pratense 5	Taraxacum officinale 2	Vicia americana 5			
6.	Festuca rubra 5	Dactylis glomerate 5	Phleum pratense 10	Trifolium hybridum 50	Agropyron intermedium 5	Taraxacum officinale 5	Epilobium angustifolium 5	
7.	Festuca arundinacea 5	Festuca rubra 2	Phleum pratense 10	Trifolium hybridum 10	Agropyron intermedium 30	Vicia americana 10	Fragaria virgiana 5	
8.	Festuca arundinacea 10	Festuca rubra 10	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 5	Agropyron intermedium 2	Vicia americana 10	Fragaria virginiana 5 Medicago 2
9.	Festuca rubra 30	Dactylis glomerate 20	Phleum pratense 20	Medicago 50				
10.	Festuca arundinacea 20	Festuca rubra 20	Dactylis glomerate 20	Phleum pratense 10	Trifolium hybridum 10	Epilobium angustifolium 5	Taraxacum officinale 3	
11.	Festuca arundinacea 5	Festuca rubra 20	Phleum pratense 10	Trifolium hybridum 10	Medicago 5			
12.	Festuca arundinacea 5	Festuca rubra 20	Phleum pratense 20	Trifolium hybridum 10	Taraxacum officinale 5			
13.	Festuca rubra 2	Phleum pratense 40	Trifolium hybridum 5	Medicago 30				
14.	Festuca rubra 2	Dactylis glomerate 70	Phleum pratense 5	Trifolium hybridum 20	Taraxacum officinale 3	Vicia americana 5		
15.	Festuca rubra 5	Dactylis glomerate 10	Phleum pratense 5	Trifolium hybridum 10	Agropyron intermedium 5	Carex spp 30		

* % cover

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8.4 1994 VEGETATION SPECIES COMPOSITION AND % COVER (CONTINUED).

rep	15 cm Treatment, Trench							
1.	Festuca rubra 5	Dactylis glomerate 30	Phleum pratense 20	Trifolium hybridum 20	Agropyron intermedium 10	Taraxacum officinale 10	Solidago spp. 4	
2.	Dactylis glomerate 90	Trifolium hybridum 10	Vicia americana 1					
3.	Festuca rubra 20	Dactylis glomerate 70	Phleum pratense 3	Trifolium hybridum 10				
4.	Dactylis glomerate 60	Phleum pratense 5	Trifolium hybridum 20	Vicia americana 10				
5.	Dactylis glomerate 10	Phleum pratense 30	Trifolium hybridum 5	Vicia americana 20	Epilobium angustifolium 5			
6.	Festuca rubra 20	Dactylis glomerate 5	Phleum pratense 20	Trifolium hybridum 10	Vicia americana 10			
7.	Festuca rubra 30	Phleum pratense 20	Juncus spp. 10	Taraxacum officinale 5				
8.	Festuca rubra 20	Phleum pratense 20	Calagmagrostis canadiense 20	Juncus spp. 10				
9.	Festuca rubra 20	Phleum pratense 30	Trifolium hybridum 5	Taraxacum officinale 10				
10.	Festuca arundinacea 10	Festuca rubra 10	Dactylis glomerate 10	Phleum pratense 10	Trifolium hybridum 5			
11.	Festuca rubra 10	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 10	Agropyron intermedium 5	Lathyrus venosus 5	Epilobium angustifolium 10	
12.	Festuca rubra 3	Dactylis glomerate 30	Phleum pratense 5	Trifolium hybridum 20				
13.	Festuca arundinacea 3	Festuca rubra 1	Dactylis glomerate 50	Phleum pratense 3	Trifolium hybridum 20	Vicia americana 5		
14.	Festuca rubra 2	Dactylis glomerate 40	Trifolium hybridum 10	Agropyron intermedium 3	Epilobium angustifolium 20			
15.	Festuca rubra 3	Dactylis glomerate 50	Phleum pratense 3	Trifolium hybridum 10	Agropyron intermedium 3	Lathyrus venosus 20		

* % cover

8.4 1994 VEGETATION SPECIES COMPOSITION AND % COVER (CONTINUED).

rep	15 cm Treatment, Control							
1.	Festuca rubra 3	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 10	Agropyron intermedium 20	Pet. palmatus 5	Taraxacum officinale 5	
2.	Festuca arundinacea 5	Dactylis glomerate 30	Phleum pratense 5	Trifolium hybridum 5	Agropyron intermedium 5	Fragaria virgiana 3	Hordeum jubatum 1	
3.	Dactylis glomerate 30	Phleum pratense 21	Agropyron intermedium 3					
4.	Festuca rubra 20	Dactylis glomerate 30	Phleum pratense 2	Trifolium hybridum 5	Agropyron intermedium 2	Epilobium angustifolium 5		
5.	Festuca rubra 2	Dactylis glomerate 20	Phleum pratense 10	Trifolium hybridum 2	Agropyron intermedium 5	Solidago spp. 10		
6.	Festuca rubra 3	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 2	Agropyron intermedium 5	Lathyrus venosus 3		
7.	Dactylis glomerate 10	Phleum pratense 5	Trifolium hybridum 20	Rosa woodsii 10	Agropyron trachycaulum 3			
8.	Festuca rubra 10	Dactylis glomerate 5	Phleum pratense 10	Trifolium hybridum 5	Epilobium angustifolium 10	Lathyrus venosus 2	Fragaria virgiana 2	Taraxacum officinale 3
9.	Festuca rubra 20	Dactylis glomerate 30	Phleum pratense 2	Trifolium hybridum 20	Fragaria virgiana 2			
10.	Festuca arundinacea 10	Festuca rubra 5	Dactylis glomerate 20	Phleum pratense 3	Trifolium hybridum 20	Solidago spp. 2		
11.	Festuca rubra 3	Dactylis glomerate 50	Phleum pratense 10	Trifolium hybridum 3	Vicia americana 5			
12.	Festuca arundinacea 5	Festuca rubra 3	Dactylis glomerate 10	Phleum pratense 20	Trifolium hybridum 20	Agropyron intermedium 10	Solidago spp. 5	Epilobium angustifolium 2
13.	Festuca rubra 2	Dactylis glomerate 20	Phleum pratense 10	Trifolium hybridum 20	Agropyron intermedium 10	Vicia americana 5		
14.	Dactylis glomerate 40	Phleum pratense 10	Trifolium hybridum 5	Taraxacum officinale 5				
15.	Dactylis glomerate 40	Phleum pratense 5	Trifolium hybridum 10	Agropyron intermedium 10	Vicia americana 5	Lathyrus venosus 5		

* % cover

8.4 1994 VEGETATION SPECIES COMPOSITION AND % COVER (CONTINUED).

rep	0 cm Treatment, Trench							
1.	Festuca rubra 1	Dactylis glomerate 20	Phleum pratense 2	Trifolium hybridum 10	Agropyron intermedium 2	Vicia americana 5		
2.	Festuca rubra 5	Dactylis glomerate 70	Trifolium hybridum 10					
3.	Festuca rubra 2	Dactylis glomerate 30	Phleum pratense 2	Trifolium hybridum 40				
4.	Festuca rubra 1	Dactylis glomerate 20	Trifolium hybridum 30	Medicago 20	Taraxacum officinale 3			
5.	Festuca rubra 3	Dactylis glomerate 5	Phleum pratense 5	Trifolium hybridum 40	Agropyron intermedium 10	Solidago spp. 10	Epilobium angustifolium 10	
6.	Festuca arundinacea 5	Dactylis glomerate 10	Trifolium hybridum 10	Agropyron intermedium 5	Epilobium angustifolium 5	Rosa woodsii 20	Lathyrus venosus 5	Medicago 10
7.	Festuca arundinacea 10	Festuca rubra 5	Dactylis glomerate 40	Phleum pratense 5	Trifolium hybridum 20	Astor 10	Vicia americana 5	
8.	Festuca arundinacea 10	Festuca rubra 5	Dactylis glomerate 30	Phleum pratense 5	Trifolium hybridum 20	Taraxacum officinale 3		
9.	Festuca arundinacea 5	Festuca rubra 40	Dactylis glomerate 5	Phleum pratense 10	Trifolium hybridum 30	Fragaria virgiana 5	Salix spp. 10	
10.	Festuca rubra 30	Phleum pratense 30	Trifolium hybridum 40	Taraxacum officinale 5				
11.	Festuca arundinacea 30	Festuca rubra 10	Phleum pratense 20	Trifolium hybridum 10				
12.	Festuca arundinacea 30	Phleum pratense 30	Trifolium hybridum 3					
13.	Festuca arundinacea 10	Phleum pratense 30	Trifolium hybridum 20					
14.	Festuca arundinacea 30	Festuca rubra 10	Phleum pratense 10	Trifolium hybridum 20				
15.	Festuca arundinacea 20	Festuca rubra 5	Phleum pratense 20	Trifolium hybridum 5	Vicia americana 5	Epilobium angustifolium 10		

* % cover

8.4 1994 VEGETATION SPECIES COMPOSITION AND % COVER (CONTINUED).

rep	0 cm Treatment, Control						
1.	Dactylis glomerate 10	Phleum pratense 10	Trifolium hybridum 10	Rosa woodsii 10	Vicia americana 5			
2.	Dactylis glomerate 10	Phleum pratense 10	Taraxacum officinale 3	Epilobium angustifolium 5				
3.	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 20					
4.	Festuca rubra 2	Dactylis glomerate 20	Phleum pratense 2	Trifolium hybridum 5	Malva rotundifolia 30	Epilobium angustifolium 10		
5.	Dactylis glomerate 40	Phleum pratense 5	Trifolium hybridum 5	Solidago spp. 10	Rosa woodsii 5			
6.	Festuca rubra 5	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 10	Vicia americana 5	Medicago 5	Rosa woodsii 10	
7.	Festuca rubra 5	Dactylis glomerate 50	Phleum pratense 5	Trifolium hybridum 5	Vicia americana 5	Epilobium angustifolium 5		
8.	Festuca rubra 5	Dactylis glomerate 30	Phleum pratense 3	Trifolium hybridum 5	Thalictrum occidentale 5	Solidago spp. 5	Epilobium angustifolium 5	Taraxacum officinale 2
9.	Festuca rubra 40	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 3				
10.	Festuca rubra 30	Phleum pratense 30	Trifolium hybridum 20	Hordeum jubatum 3				
11.	Festuca rubra 50	Phleum pratense 20	Trifolium hybridum 10	Vicia americana 10	Taraxacum officinale 5	Plantago major 2	Aster laevis 2	
12.	Dactylis glomerate 30	Phleum pratense 20	Trifolium hybridum 20	Thalictrum occidentale 3	Fragaria virgiana 2	Gentian 3		
13.	Festuca rubra 10	Dactylis glomerate 10	Phleum pratense 10	Trifolium hybridum 5	Solidago spp. 30			
14.	Festuca rubra 5	Dactylis glomerate 20	Phleum pratense 10	Trifolium hybridum 10	Aymphoricarpos spp. 1	Epilobium angustifolium 10	Vicia americana 5	
15.	Festuca rubra 5	Dactylis glomerate 30	Phleum pratense 10	Trifolium hybridum 5	Aster 10	Epilobium angustifolium 10	Vicia americana 2	

* % cover

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8.5. PHOTOGRAPHS

Photo 1. Burning slash after clearing.

Photo 2. Clearing and stripping completed on 15 cm treatment.

Photo 3. Wheel ditcher at work excavating trench.

Photo 4. Backfilling the trench with a "flyswatter".

Photo 5. Topsoil replacement on 15 cm treatment.

Photo 6. Machine clean-up complete on 15 cm treatment.


Photo 7. Root rake in action.


Photo 8. Roots are still on surface after plowing, disk plowing and harrowing on right. Left side has roots removed .