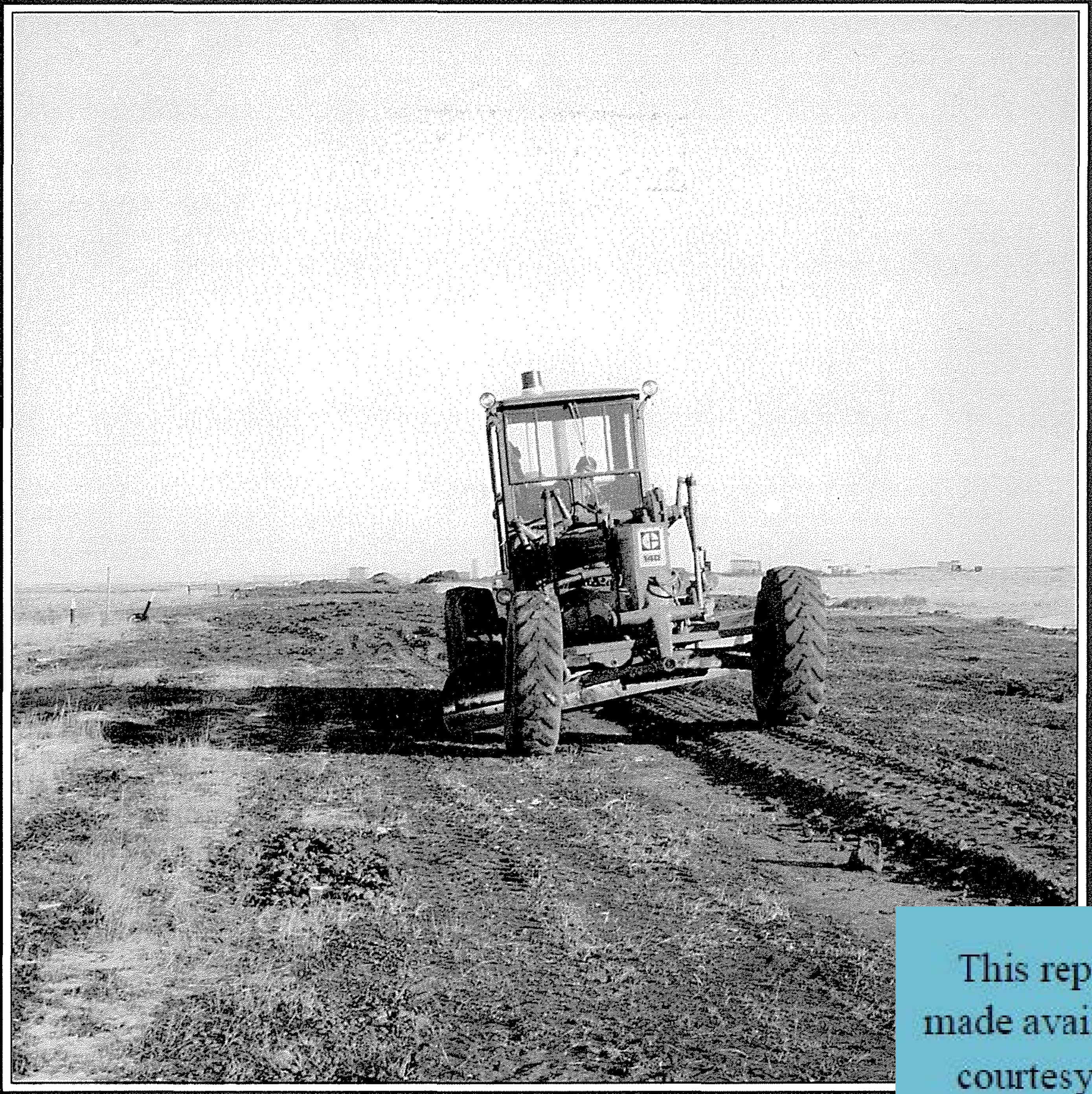
Impacts of

Overstripping Topsoil on Native Rangelands in Southeastern Alberta: A Literature Review



NOVA Gas Transmission

IMPACTS OF OVERSTRIPPING TOPSOIL ON NATIVE RANGELANDS IN SOUTHEASTERN ALBERTA: A LITERATURE REVIEW

by

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FOREWORD

NOVA Corporation (NOVA) is a major Canadian energy company involved in pipelining and the manufacturing and marketing of produced petrochemicals. NOVA Gas Transmission Ltd. (NGTL) of NOVA is concerned with natural gas system design, pipeline construction, research and facility operations throughout the province of Alberta. Since its incorporation in 1954, NGTL has installed more than 18,000 km of natural gas pipeline and continues to operate, maintain and expand this system.

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This study was commissioned to evaluate the available literature on the effects of overstripping topsoil during pipeline construction on native rangelands in southeastern Alberta. This report was prepared by Sandra Landsburg, a department staff member and Karen R. Cannon, a private consultant.

NGTL welcomes public and scientific interest in its environmental activities. Please address any questions, comments or requests for reports to:

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ABSTRACT

This literate review evaluates the information available on the effects of overstripping topsoil during pipeline construction on native rangelands in southeastern Alberta. The effects on soil quality and handling of Chernozemic and Solonetzic soils are presented in detail as these are the dominant soils in southeastern Alberta.

The available information indicates that overstripping and subsequent replacement of topsoil can produce horizon characteristics similar to plow depth characteristics resulting from cultivation.

In Chernozemic soils, overstripping may not greatly change quality of the soil replaced over the trench after pipeline construction because these soils have low salinity and sodicity levels, and only minor textural differences between A and B horizons. Overstripping may, however, decrease surface organic carbon content in Chernozemic soils. These minimal changes in soil quality suggest that Chernozemic soils could be overstripped without significant impact.

In most Solonetzic soils, overstripping topsoil can increase the clay content, soil strength in the Ap horizon, salinity, sodicity and pH in the soil replaced over the trench. It can also decrease water infiltration and organic carbon content, thereby increasing water erosion. Seedling emergence from the seedbed may be reduced by these changes. Some Solods may be overstripped without significantly changing topsoil quality, but this depends on the physical and chemical characteristics of the soil. The negative potential impacts of overstripping topsoil on many Solonetzic soils indicate that Solodized Solonetz and Solonetzic soils should not be overstripped.

ACKNOWLEDGMENTS

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1.0 INTRODUCTION

In the province of Alberta, topsoil is conserved during pipeline construction in both winter and summer. Topsoil (A horizon material) is conserved because of its relatively high organic matter and its superiority over B horizon material to support plant growth.

Topsoil conservation in southeastern Alberta during pipeline construction is difficult because topsoil depths are minimal. The small amount of topsoil is difficult to handle, often resulting in loss and mixing of the topsoil and subsoil. In this area, where semiarid conditions prevail, soil development is slow and organic matter contents are low (approximately 2%). Low precipitation and high potential for wind erosion make soils difficult to revegetate and reclaim after pipeline construction.

There is limited information on the effects of pipeline construction on these thin soils, and on methods of handling the soils to reduce construction impacts. One method of reducing impacts may be to overstrip topsoil to add good-quality B horizon material to the topsoil, thereby providing an adequate rooting depth for plant growth.

2.0 OBJECTIVE

The objective of this literature review is to evaluate the potential impacts on native rangeland soils in southeastern Alberta of overstripping topsoil during pipeline construction. To make this evaluation, the following information is first reviewed: characteristics of soils in the area, pipeline construction procedures and impacts of pipeline construction procedures. Following this information, the effects of topsoil overstripping are assessed.

The information in this literature review will be helpful in establishing appropriate soil-handling procedures for native rangeland soils in southeastern Alberta.

3.0 REVIEW OF RELATED LITERATURE

3.1 SOILS IN SOUTHEASTERN ALBERTA

The soils in southeastern Alberta are in the Brown Soil Zone and consist largely of Chernozemic and Solonetzic soils. Fields under cultivation are normally dominated by Chernozemic soils whereas native rangelands are often Solonetzic soils (Alberta Environment 1985). Other soil orders are also present but do not occur to the same extent.

This literature review discusses the effects of overstripping only on these two soil orders because of their prevalence.

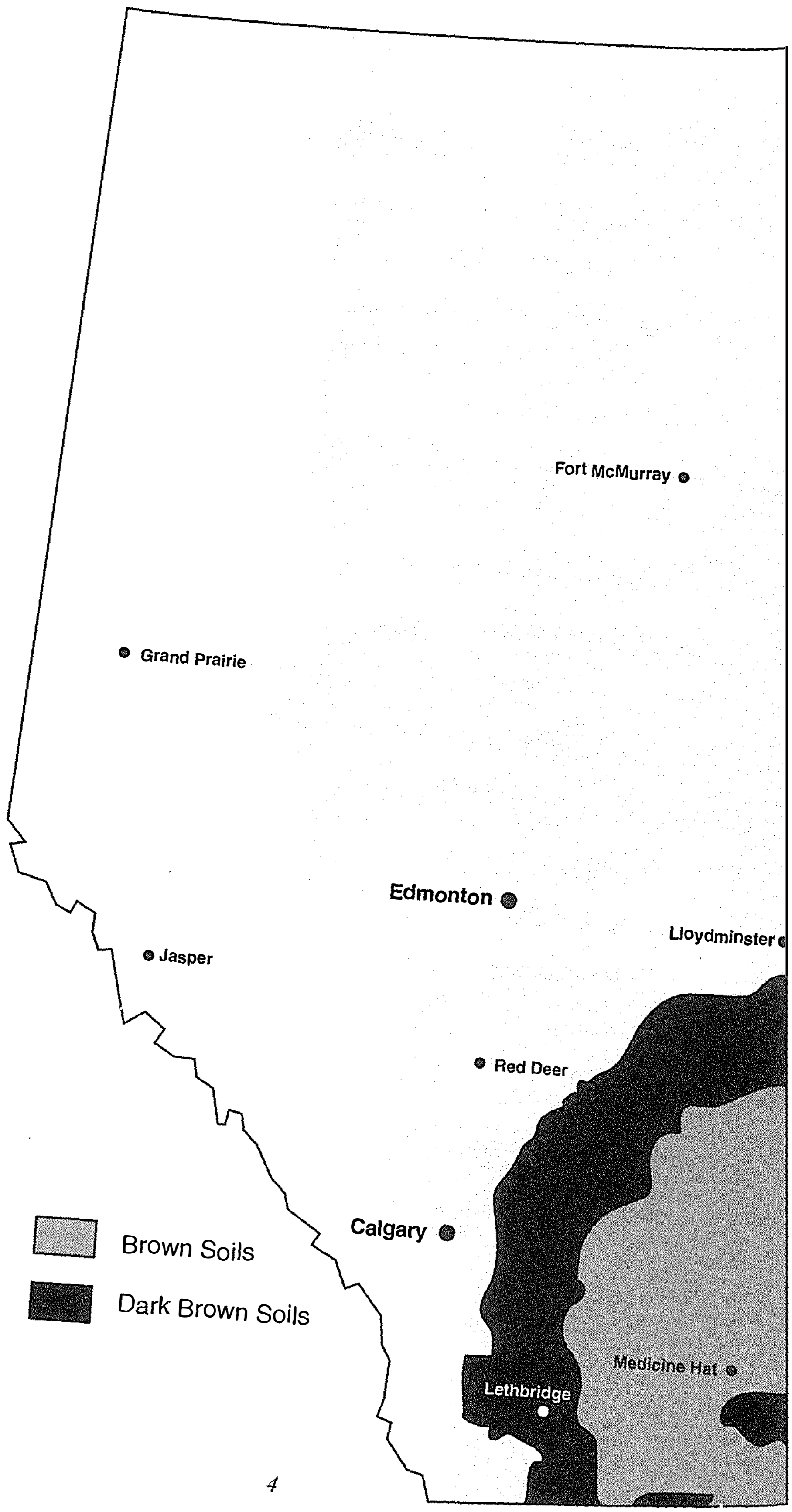
3.1.1 Ecoregion Description

The southeastern corner of Alberta is represented by the Short Grass Ecoregion (Figure 1) as delineated by the Brown Soil Zone (Wyatt et al. 1939, Wyatt et al. 1943, Peters and Bowser 1960, Bowser et al. 1963, Kjearsgaard 1976, Kjearsgaard et al. 1983, Kjearsgaard et al. 1984).

The area falls within Agro-climatic Subregion 3A as defined by Bowser (1967). This subregion indicates an area characterized by a continental prairie climate with cold winters and warm summers. In this subregion, precipitation is low enough to severely limit crop growth, but frost does not jeopardize cereal crop production.

This ecoregion has the warmest summer conditions in the province with a mean temperature from May to September of 15°C (Strong and Leggat 1981). During the winter, the mean temperature (from December to February) is -10.5°C.

Figure 1. Location of the Brown Soil Zone in Alberta.



Mean summer precipitation (210 mm) and mean winter precipitation (120 mm) are the lowest in the province. The high summer temperatures, low precipitation and strong winds of this semiarid region produce a moisture deficit of approximately 300 mm, the highest of any ecoregion in Alberta. Winter conditions for vegetation are unfavorable because of shallow snow depths and relatively few days of continuous snow cover.

This ecoregion is inhabited by plants suited to the moisture deficit, predominantly the *Bouteloua-Stipa-Agropyron* (blue grama-speargrass-wheatgrass) grassland community (Strong and Leggat 1981; Alberta Environment 1985). Much of this ecoregion is used for livestock on either improved or native rangeland.

Agricultural productivity on soils in southeastern Alberta is limited mainly by dry climatic conditions. Moisture is a moderately severe limiting factor to crop growth even though more than 60% of the total precipitation falls from May to September. The frost-free period is greater than 100 days and is not a hazard to cereal crop production. High summer temperatures, low precipitation and strong winds result in a moisture deficit of approximately 300 mm.

3.1.2 Physical and Chemical Soil Characteristics

The Brown Soil Zone is characterized by soils with 5 to 15 cm of brown, surface A horizon material containing approximately 2% organic matter (Alberta Environment 1985). There is often little or no color difference between the A and B horizons, which makes topsoil stripping difficult. Topsoil depth is generally less on native rangeland than in cultivated areas.

Brown Chernozemic soils occur in the most arid segment of the climatic range of Chernozemic soils. They are well drained to imperfectly drained and have surface horizons enriched by accumulations of organic matter from the decomposition of grasses and forbs of a *Bouteloua-Stipa-Agropyron* grassland community (Canadian

Soil Survey Committee 1978). The colour values of Brown Chernozemics range between 4.5 and 5.5 (dry) and the chromas are greater than 1.5 (dry). Often, the A and B horizons differ little in colour.

The chemistry and particle size analysis of a typical Orthic brown Chernozem are described in Table 1. This Orthic Brown Chernozem has a brown A horizon 16 cm thick, sandy loam in texture and containing approximately 1.6% organic carbon. Texture changes to clay loam in the C horizon (Kjearsgaard et al 1983). pH values range from slightly alkaline (pH 7.5) at the surface to moderately alkaline (pH 7.9) at full depth. Depth to the underlying clay loam till is 55 cm. Calcium carbonates are present in the till. A profile description for this soil is shown in Table 2.

Brown Solonetzic soils develop in a semiarid climate and are associated with grass and forb vegetation. The Solonetzic order is made up of three great groups: Solonetz, Solodized Solonetz and Solod. These groups are separated on the basis of the presence of an Ae horizon or the breakdown of the Solonetzic B horizon. A solonetz does not have a continuous Ae horizon 2 cm thick or more, whereas a Solodized Solonetz has an Ae horizon and an intact Solonetzic B horizon. The Solod has an Ahe or Ae horizon 5 cm thick or more and a distinct AB horizon (which is a disintegrating Bnt horizon).

The B horizon contains concentrations of fine sodium clay particles, making the resultant Bnt horizon of the Solonetz soil hard and impermeable when dry, and plastic when wet. These clay particles have been produced through deflocculation of sodium clay particles carried by the rise and fall of groundwater and percolation of rainwater in parent materials high in sodium salts. The high salt content of the Bnt horizon can limit root penetration because it creates a high osmotic pressure in the soil solution and a very compact horizon with poor water penetration (Toogood and Cairns 1973).

Table 1. Chemistry and Particle Size Distribution of a Typical Orthic Brown Chernozem[1].

Horizon	Depth (cm)	pH (H_2O)	OC (%)	N (%)	$CaC0_3$ (%)	Sand (%)	Silt (%)	Clay (%)
Ah1	0-3	7.5	2.1	0.2	0.3	54	32	14
Ah2	3-16	7.4	1.0	0.1	0.2	59	28	13
Bm1	16-36	7.7	0.4	-	0.2	77	13	10
Bm2	36-55	7.7	0.2	-	0.2	73	16	11
IICk	55+	7.9	-	-	10.6	21	51	28

[1]Kjearsgaard et al. 1983. Antonio Orthic Brown Chernozem. Procedures used for soil analyses include pH in water, total nitrogen by Kjeldahl, total organic carbon by Leco induction furnace, $CaC0_3$ equivalent by gravimetric loss and particle size distribution by pipette. All methods are described by McKeague (1978).

Table 2. Profile Description of a Typical Orthic Brown Chernozem[1].

Classification:	Othic Brown Chernozem
Parent Material:	Coarse loamy fluvial veneer over till
Topography:	Undulating (2 to 15% slopes)
Drainage:	Rapidly to well drained
Stoniness Class:	Stone-free (SO)

Horizon	Depth (cm)	Description
Ah1	0-3	Dark grayish brown (10YR 4/2 m); sandy loam; coarse prismatic breaking to granular; very friable
Ah2	3-16	Brown to dark brown (10YR 4/3 m); sandy loam; weak to moderate, medium to coarse, subangular blocky; loose
Bm1	16-36	Brown to dark brown (10YR 4/3 m); sandy loam; medium to coarse, subangular blocky; loose
Bm2	36-55	Dark yellowish brown (10YR 4/4m); sandy loam; very weak, medium subangular blocky; very friable
IICk	55+	Dark yellowish brown (10YR 4.5/4m); clay loam; moderate, medium to coarse, subangular blocky; friable

[1]Kjearsgaard et al. 1983. Antonio Orthic Brown Chernozem.

Further leaching of rainwater depletes the alkali cations in the A horizon, resulting in formation of an Ae horizon, which characterizes a Solodized Solonetz soil.

With continual leaching of rainwater at the surface and with groundwater fluctuations at greater depths, calcium replaces sodium within the soil, producing a more friable B horizon that is characteristic of a Solod soil. It is more penetrable by water and plant roots, and more manageable and productive than that of Solonetz soils (Toogood and Cairns 1973).

The chemistry and particle size analysis of a typical Brown Solodized Solonetz are shown in Table 3. This Brown Solodized Solonetz has a brown Ah horizon about 5 cm thick, containing 2.4% organic carbon, and an Ae horizon about 5 cm thick, containing 1.5% organic carbon. Textures change from silty loam at the surface to silty clay loam in the Bnt and upper C horizons (Kjearsgaard et al. 1983). pH values range from neutral to acidic at the surface (pH 6.5) to alkaline at depth (pH 7.4 to 8.2). The Ca/Na ratio in the Bnt horizon is 8. A lime horizon (Ck) occurs at 30 to 41 cm. Below this depth, lime is accompanied by salt-enriched (Csk) horizons (See Table 4 for a soil profile description).

3.1.3 Cultivation

Cultivation of native prairie grassland reduces soil organic matter levels, fertility and soil aggregation (Cameron 1981). Soil organic matter is decreased by increased microbial decomposition caused by improved soil aeration (Biederbeck et al. 1981). In tilled fields without vegetative cover, microbial activity is also increased from increased soil moisture resulting from cultivation. Cultivation can also disrupt peds, exposing previously inaccessible organic matter to microbial attack.

Table 3. Chemistry and Particle Size distribution of a Typical Brown Solodized Solonetz[1].

Horizon	Depth (cm)	pH H_2O	OC (%)	N (%)	Na	K	Ca	Mg	$CaCO_3$ (%)	Sand (%)	Silt (%)	Clay (%)	SAR
					Exchangeable Cations (meq/100 g)								
Ah	0-5	6.5	2.4	0.2	0.2	1.4	5.6	2.1	-	18	63	19	-
Ae	5-10	6.6	1.5	0.1	0.3	0.9	4.5	2.0	-	18	65	17	-
Bnt	10-30	6.9	1.1	0.1	1.3	0.9	10.5	6.8	-	11	52	37	-

Horizon	Depth (cm)	pH (H_2O)	OC (%)	N (%)	Na	K	Ca	Mg	$CaCO_3$ (%)	Sand (%)	Silt (%)	Clay (%)	SAR
					Soluble Cations (meq/L)								
Ck	30-41	8.2	-	-	4.9	0.1	2.0	0.3	2.5	4	56	40	-
Cskl	41-107	8.0	-	-	17.4	0.3	23.1	6.4	3.5	2	60	38	-
Csk2	107-163	7.5	-	-	22.6	0.2	20.6	11.6	0.9	1	61	38	-
Csk3	163-274	7.4	-	-	39.1	0.4	22.1	12.5	1.0	10	57	33	-

[1]Kjearsgaard et all. 1983. Wardlow Brown Solodized Solonetz. Procedures used for soil analyses include pH in water, total nitrogen by Kjeldahl, total organic carbon by Leco induction furnace, cation exchange capacity by NH_4OAc, $CaCO_3$ equivalent by gravimetric loss and particle size distribution by pipette. All methods are described by McKeague (1978).

Table 4. Profile Description of a Typical Brown Solodized Solonetz[1].

Classification: Brown Solodized Solonetz

Parent Material: Fine loamy fluvial or lacustrine

Topography: Undulating (2 to 9% slopes)

Drainage: Moderately well

Stoniness Class: Stone-free (SO)

Horizon	Depth (cm)	Description
Ah	0-5	Brown to dark brown (10YR 4/3 m); silty loam; weak, fine granular; very friable
Ae	5-10	Brown to dark brown (10YR 4/3 m); silty loam; weak, fine platy; friable
Bnt	10-30	Brown to dark brown (10YR 4/3 m); silty clay loam; moderate, medium columnar and moderate, medium subangular blocky; very firm
Ck	30-41	Brown (10YR 5/3 m); silty clay loam; moderate, medium to coarse, subangular; firm
Csk1	41-107	Light brownish gray (10YR 6/2 m); silty clay loam; massive; firm
Csk2	107-163	Pale brown (10YR 6/3); silty clay loam; massive; firm
Csk3	163-274	Pale brown (10YR 6/3); silty clay loam; massive; firm

[1]Kjearsgaard et al. 1983. Wardlow Brown Solodized Solonetz.

Aggregation of surface soils is dependent on the kind of tillage implement and its speed of operation, as well as soil texture and moisture content. Tillage operations destroy the native vegetation and its associated root mass, leaving little protection for the soil from wind or water erosion. With cultivation, native prairie soils tend to compact, increasing soil bulk densities and decreasing soil porosities. As well, cultivation decreases the amount of large pore space, which can decrease infiltration rates. These effects can reduce soil aeration, increase mechanical impedance and restrict root growth. Tillage can alter land stability by breaking down soil aggregates and burying plant residues, thereby increasing susceptibility to erosion.

In southeastern Alberta, cultivation of Chernozemic soils is not harmful to the immediate productivity of the land. These soils are already low in organic matter and have relatively thin Ah horizons. Mixing of the thin Ah horizon and some of the B horizon during tillage would not greatly affect soil quality (Alberta Environment 1985). The Chernozemic A horizons generally have desirable granular structure and the Chernozemic B horizons are generally permeable and nearly neutral in pH (McGill 1982). These soils also have low salinity and sodicity with minor textural differences between the A and B horizons.

Cultivation of Solonetzic soils to depths greater than 10 to 15 cm and less than 41 cm can create problems in seedbed preparation (Toogood and Cairns 1973). Bringing the hard Bnt horizon to the surface during tillage increases soil baking and crusting by increasing the surface clay content. As well, increased salinity and sodicity values at the surface can make vegetative establishment difficult. Generally, Solonetzic soils are easier to work when moderately dry. Cultivation of these soils when wet can result in cement-like clods.

3.2 PIPELINE CONSTRUCTION AND CONSERVATION PROCEDURES

3.2.1 Common Summer Methods

NOVA Gas Transmission Ltd. (NGTL) topsoil conservation procedures for native rangelands are related to pipe diameter and location in the province (personal communication, October 5, 1992, Mike Houser, Environmental Construction Specialist, NGTL; October 5, 1992, Kevin Evans, Environmental Planner, NGTL). In general, as pipeline diameter increases, topsoil stripping widths become wider.

Topsoil conservation procedures for rangelands in southeastern Alberta include:

- ditchline topsoil stripping, used when the pipe diameter is less than 16 inches and when the spoil can be removed from a well-developed sod layer with little mixing and can be backfilled within trench confines (Figure 2)
- blade-width topsoil stripping, used with pipe diameters of 16 to 30 inches and when spoil can be removed from a well-developed sod layer with little mixing but cannot be backfilled within trench confines (Figure 3). Extra topsoil stripping may be required in order to feather out the spoil so there is no pipeline roach; additional stripping is done at time of clean-up.
- ditch and spoil side topsoil stripping, generally used when pipe diameters are greater than 24 inches where the spoil is undesirable and the sod layer is disturbed (Figure 4)
- ditch and work side topsoil stripping, generally used when pipe diameters are greater than 24 inches and when there is a probability the work side will be disturbed through wind erosion, topsoil mixing or soil pulverization (Figure 5)

Figure 2. Topsoil Conservation over the Ditchline during Summer Construction (NGTL 1990).

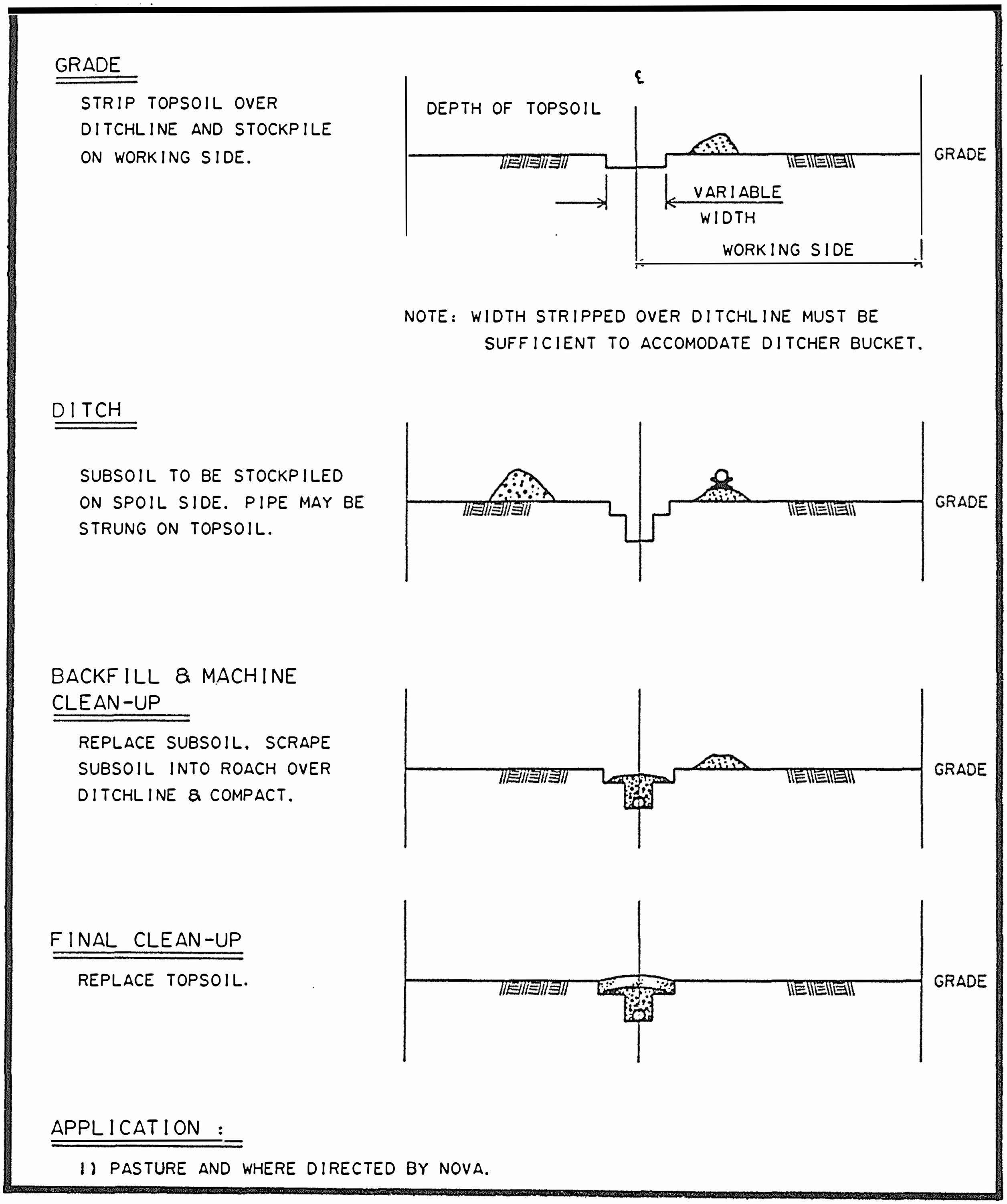
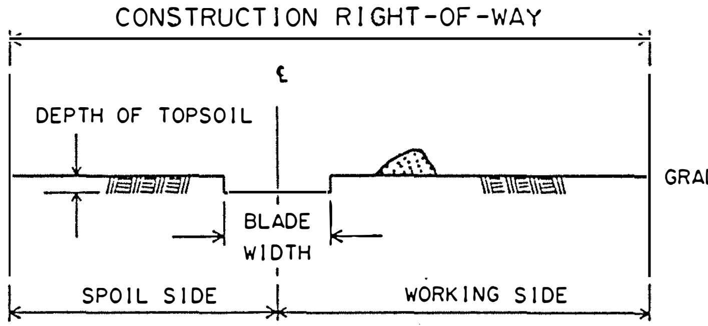


Figure 3. Topsoil Conservation using Blade Width Stripping during Summer Construction (NGTL 1990).

GRADE

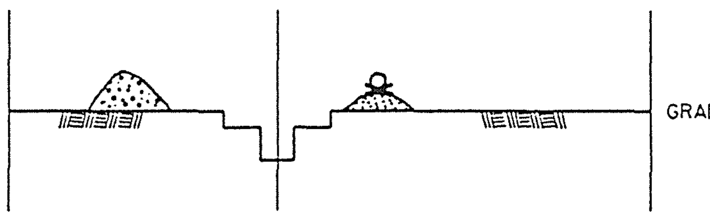
STRIP TOPSOIL FOR BLADE WIDTH OVER DITCH LINE & STOCKPILE ON WORKING SIDE.



SPECIAL ATTENTION IS NECESSARY TO ENSURE SEPARATION OF TOPSOIL AND SUBSOIL AT SIDE BENDS AND FOREIGN PIPELINE CROSSINGS.

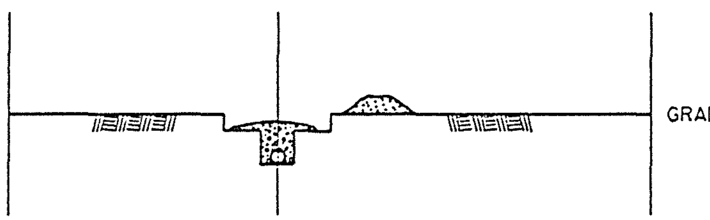
DITCH

SUBSOIL TO BE STOCKPILED ON SPOIL SIDE. PIPE MAY BE STRUNG ON TOPSOIL.



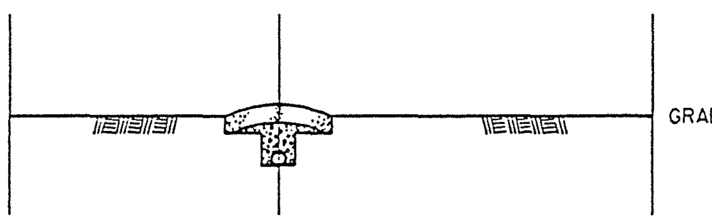
BACKFILL & MACHINE CLEAN-UP

REPLACE SUBSOIL. SCRAPE SUBSOIL INTO ROACH OVER DITCHLINE & COMPACT.



FINAL CLEAN-UP

REPLACE TOPSOIL. AND CULTIVATE WHERE DIRECTED BY NOVA.



APPLICATION :

1) PASTURE AND WHERE DIRECTED BY NOVA.

Figure 4. Topsoil Conservation over the Ditchline and Spoil Side during Summer Construction (NGTL 1990).

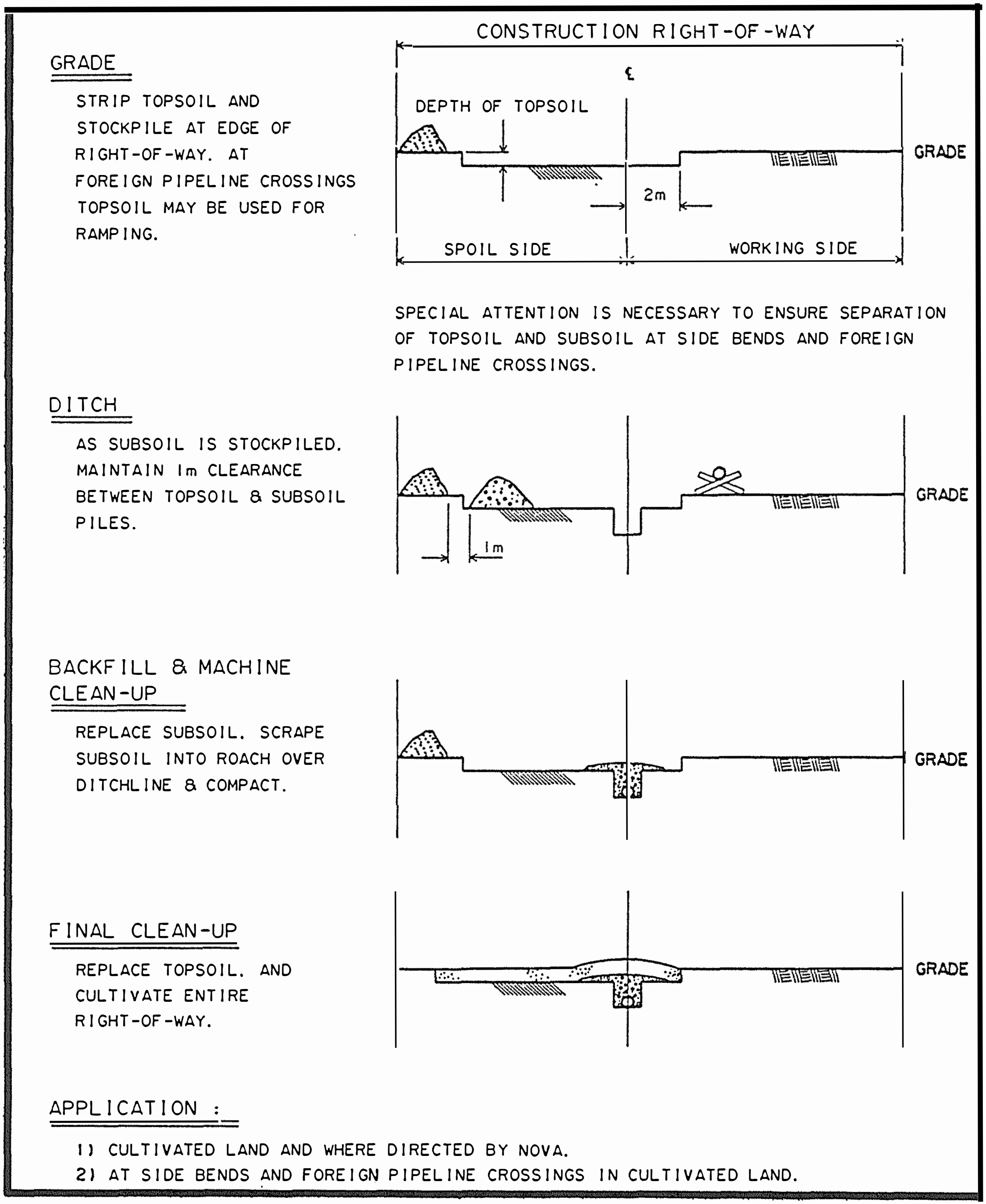
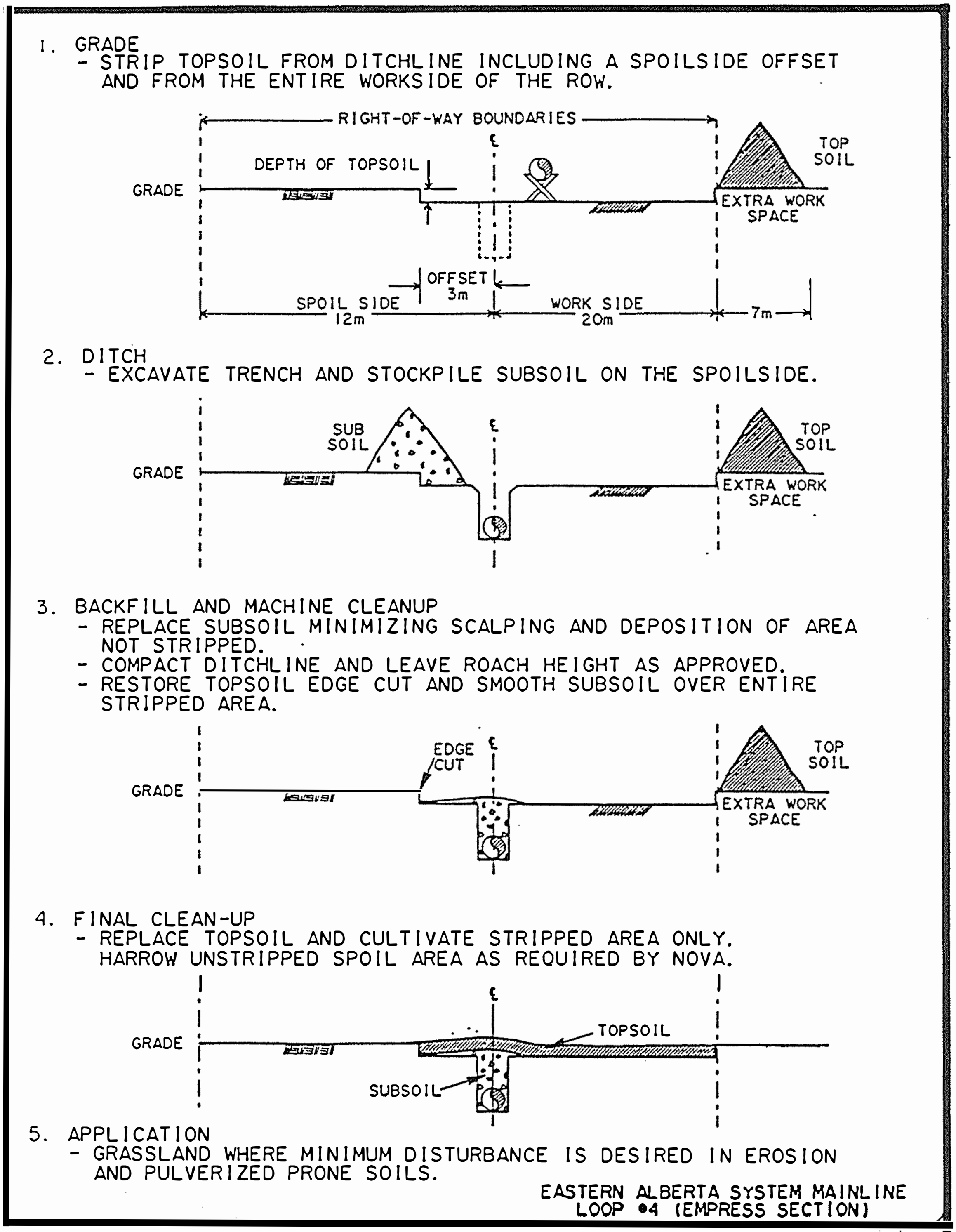


Figure 5. Topsoil Conservation over the Ditchline and Work Side during Summer Construction (NGTL 1992).



- full right-of-way (RoW) topsoil stripping, used when the sod layer is not well established, there is undesirable spoil and the work side will be disturbed (Figure 6).

Drive-on tackifiers have been used on topsoil stored in piles and on the unstripped work side to reduce topsoil loss due to pulverization, loss of soil structure and potential wind erosion.

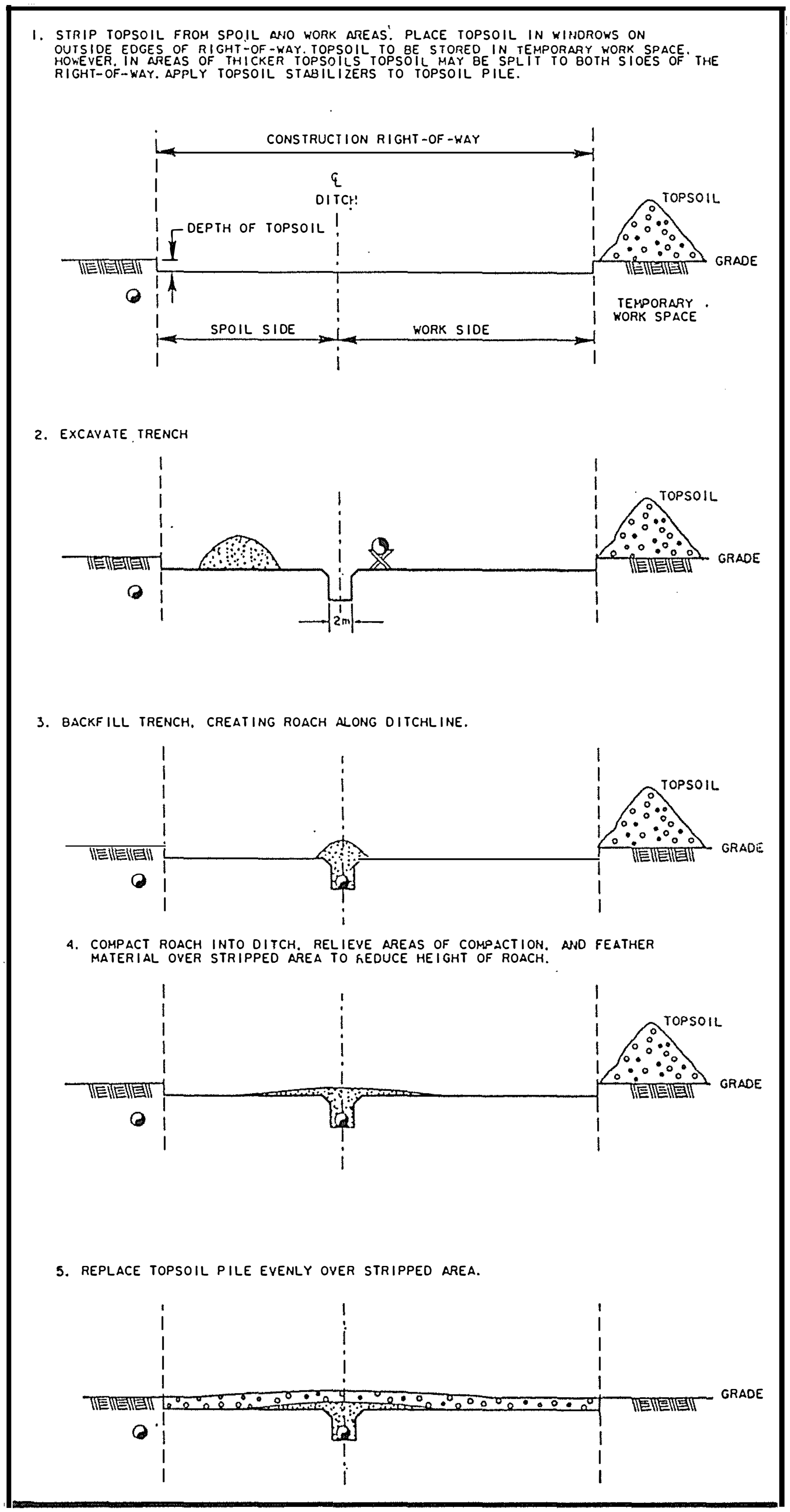
3.2.2 Alberta Environment Procedures

Currently, Alberta Environment advocates preservation of the A horizon during pipeline installation on native rangeland (personal communication, September 28, 1992, Travis Ferguson, Soil Reclamation Specialist, Land Reclamation Division, Alberta Environment). The focus is on soil preservation as compared to range preservation. This is considered important because topsoil is:

- a seed source for native prairie grasses
- an important source of nutrients
- the soil component where major biological activity occurs
- usually more friable than other horizons

On small pipelines (less than 12 inches in diameter), Alberta Environment recommends one- to two-blade width stripping of the A horizon in native rangelands in the summer and narrower widths in winter. Stripping of the narrowest width possible to accommodate the trench spoil is advocated. The spoil is feathered within the stripped area, so there is no pipeline roach. On larger pipelines, the work side may also have to be stripped to prevent topsoil loss caused by pulverization and wind erosion and to prevent soil mixing. Whether the work side has to be stripped is determined on a pipeline-specific basis, depending on how dry the soil conditions are, how well established the sod layer is and how much traffic will occur.

Figure 6 Topsoil Conservation using Full Right-of-Way Stripping (NGTL 1992).



Alberta Environment recommends overstripping topsoil in some circumstances, including stripping into:

- an upper B horizon when it is relatively non-sodic or non-saline compared to an underlying B horizon
- a good, non-gravelly B horizon that overlies gravel material
- an AB horizon when the organic matter, texture and structure in the horizon are not appreciably different from those of the Ah horizon. This is especially significant for Solods where the heavy texture of the AB horizon, combined with the Ae horizon, could provide a better growth medium. (However, when the Ae horizon is thick (20 to 25 cm) and a thick LFH horizon is present, the area should be understripped to prevent excessive dilution of organic material.)
- a good quality B horizon when there is a thin A horizon. This produces a larger volume of workable material that is easier to replace than a small volume.

Use of overstripping should be minimized.

3.2.3 Public Lands Procedures

Alberta Forestry Lands and Wildlife, Public Lands Division (Industrial Land Management) prefer to see minimal surface disturbance during pipeline construction on native rangelands (pers. comm., September 18, 1992, David Lloyd, Manager of Industrial Land Management; Alberta Forestry Lands and Wildlife). For example, Public Lands recommend no topsoil stripping or trenchline topsoil stripping to minimize soil disturbance in the following instances:

- hilltop areas
- areas where A horizons are very shallow on Brunisolic or Regosolic soils
- when the probability of soil erosion by wind is high

Under these conditions, specifying no topsoil stripping or limiting topsoil removal to the trenchline and maintaining an intact sod layer on the work and spoil sides of the right-of-way:

- minimizes damage to the native soil and its vegetative cover
- reduces the number of passes down the RoW by heavy equipment
- reduces the extent of topsoil and subsoil mixing
- reduces susceptibility of soil to wind erosion

No topsoil stripping or limiting topsoil removal to the trenchline ensures maintenance of the organic fraction of the native soil most efficiently across the RoW.

3.3 IMPACTS OF PIPELINE CONSTRUCTION

Pipeline construction may affect soil capability. Changes identified include:

- soil horizon mixing
- soil compaction
- topsoil loss
- lowered organic content
- soil erosion
- changes in soil chemistry
- altered internal drainage
- increased stoniness in surface horizons

(Button and de Jong 1970; de Jong and Button 1973; Shields 1979; Culley et al. 1981; Hardy Associates (1978) Ltd. 1983; Naeth 1985).

Most phases of construction activities have the potential to affect soil quality. These activities include grading, topsoil stripping, trenching, trench backfilling and RoW traffic. On Solonetzic rangeland in southern Alberta, trenching was found to be responsible for the most profound changes in soil physical and chemical properties (Naeth 1985). The impacts of pipeline construction, as well pipeline reclamation, are influenced by climate, topography, topsoil an subsoil composition, hydrology and biological systems.

3.3.1 Topsoil Mixing

Topsoil can be mixed with subsoil in various ways and at various stages of pipeline construction. Alberta Environment (1985) reports topsoil can be mixed with subsoil when:

- it is not stripped from the pipeline installation area
- subsoil is stripped along with topsoil (overstripping of topsoil)
- subsoil is stored on topsoil
- replaced subsoil overflows the trench and spreads over undisturbed topsoil
- heavy equipment ruts the soil under wet conditions and mixes the A and B horizons

Soil mixing is of greatest concern when topsoil is mixed with mineral subsoil. Topsoil organic matter and nutrients can be diluted or lost, and the newly formed soil can have different chemical and physical properties than the adjacent undisturbed soil.

These changes usually reflect the inherent properties of the soil horizons that were mixed (Zellmer et al. 1985).

Hardy Associates (1978) Ltd. (1983) evaluated reclamation practices on 24 Brown Solonetzic and 24 Brown Chernozemic sites on pipeline rights-of-way (RsoW) in the Brown Soil Zone that had been reclaimed two to 24 years previously. In these cases, all pipelines had been constructed in the summer.

Topsoil was found to be absent from the trench surfaces or thoroughly mixed with the soil parent material in 79% of the Brown Chernozemic soil sites. In the remainder of the sites, topsoil was mixed only minimally or not at all with lower horizons. Similar results were reported for the spoil and work areas of annually cultivated sites. Under forage crops, topsoil was mixed at fewer of the work areas.

In the 24 Brown Chernozemic sites, topsoil had been salvaged from the trench only on the six sites that were irrigated; in the remaining sites no attempt had been made to salvage topsoil. Of the irrigated sites, only two had unmixed topsoil over the trench.

At the 24 Brown Solonetzic soil sites, Hardy Associates (1978) Ltd. found topsoil to be mixed with C horizon material over the trench and spoil side in 92% of the sites. Topsoil was unmixed at the remainder of the sites. On the work sides of the RsoW, topsoil was mixed with C horizon material in 67% of the monitored sites. Topsoil had been salvaged from the trench of all nine annually cultivated Brown Solodized Solonetz sites, whereas topsoil was not salvaged at any of the 15 pasture sites.

3.3.2 Soil Compaction and Soil Strength

Soil compaction is a potential adverse effect of pipeline construction. The literature on the impacts of pipeline installation on soil compaction is conflicting, containing reports of either increases, decreases, or little or no changes in soil bulk densities resulting from pipeline installation. However, most studies have demonstrated that pipeline construction does cause soil compaction.

Soil compaction can cause poor root penetration, difficult cultivation, loss of soil structure, reduced permeability, lower water storage, decreased soil porosity, increased soil strength and increased erosion (Lull 1959, Swan et al. 1987).

The degree of soil compaction is dependent on soil texture, moisture content, organic matter content, original soil structure and compactive effort. Soil compaction can be caused during pipeline operations by repeated passage of equipment on the RoW or handling the soil when it is too wet. Increased bulk density can also result when denser subsoil is mixed with topsoil. Soil compaction can be reduced when a compacted horizon is broken up during the trenching operation.

Research was conducted in eastern Oklahoma on a fine sandy loam that developed in a semiarid area to determine the effect of pipeline installation on soil physical characteristics (Zellmer et al. 1985). Topsoil was not salvaged during trenching and backfilling procedures. In 16 of 20 sets of observations, bulk densities of the surface soil (0 to 15 cm) were lower in the trench than those of adjacent undisturbed control areas. In the remaining four sites, bulk densities of surface soils did not increase. Also, the bulk densities of surface soils on the work side of the trench were not significantly increased.

In another study of medium-textured Dark Brown and Black Chernozemic soils in southeastern Saskatchewan, pipeline installation procedures neither harmed nor improved the physical properties (de Jong and Button 1973). Surface bulk density increased by 51% to 82% on the RoW compared to undisturbed Brown Solonetzic rangeland near Princess, Alberta (Naeth 1985). Topsoil was not salvaged. The surface bulk density over the trench declined to the predisturbed condition within 10 years of pipeline installation.

For a cultivated Orthic Dark Brown Chernozem on the Scollard-Rumsey Pipeline 60 km north of Drumheller, Alberta (Landsburg 1988), no significant differences in Ap bulk densities of the spoil, work, trench and control areas were detected. Topsoil had been stripped from the trench and spoil side of the RoW on cultivated soils. Optimum weather conditions during pipeline construction resulted in minimal soil rutting.

For pastured Orthic Dark Brown Chernozems on the same pipeline, surface bulk density of the spoil area (1.16 Mg/M^3) was significantly higher than on the control soil (0.82 Mg/M^3). Topsoil had been stripped from the trench width only. Increased bulk density was believed to be caused by compaction from construction equipment during backfilling.

A cultivated Dark Brown Solonetz soil along the pipeline had significantly increased bulk density in the Ap horizon on the spoil side (1.22 Mg/M^3) of the RoW compared to the adjacent undisturbed control site (1.09 Mg/M^3). This increase in bulk density was attributed to the presence of spoil material on the B horizon before topsoil replacement.

3.3.3 Hydraulic Conductivity and Porosity

Hydraulic conductivity of a soil may be altered by pipeline installation. Lowered infiltration capacity may leave the soil more prone to erosion by wind and water.

Medium-to fine-textured soils on Ontario pipeline RsoW had lower hydraulic conductivities and porosities and increased soil strengths compared to adjacent undisturbed soils (Culley et al. 1982). Hydraulic conductivity was reduced by an average of 38% in trench and work side areas as compared to adjacent control sites. This study also reported that soil surface layers had lower available water capacities than surface layers of adjacent undisturbed land. Soil strength, as measured by penetrometer resistance, was 67% and 50% greater over the trench and work side areas, respectively, compared to adjacent control soils. These physical changes were attributed to increased clay content and reduced organic matter content in the surface layers.

Coarse-textured soil on this same pipeline did not have changes in hydraulic conductivity and bulk density during pipeline construction. This suggests that compaction was not a problem for this soil.

Trenching of Dark Brown Solonetzic soils in southeast Saskatchewan increased soil aeration and oxygen diffusion rates (de Jong and Button 1973). It increased the permeability of Solonetzic Bnt horizons from undesirable levels of less than 0.03×10^{-3} cm/s to satisfactory levels of 1.9×10^{-3} cm/s. These changes can improve water infiltration rates, reduce water logging and increase depths of water storage (Eck and Taylor 1969).

The moisture content of the Solonetzic and Solonetzic-like soils was decreased from -33 kPa to -1500 kPa by trenching (de Jong and Button 1973). Consequently, the amount of available water was also lowered. Trenching had little effect on the Dark Brown and Black Chernozemic soils in this study area.

3.3.4 Soil Chemistry

Changes in soil chemical properties from pipeline installation depend largely on the degree of horizon mixing and subsequent soil tillage.

In one study, the pH of Chernozemic soils within the top 30 cm of a pipeline trench changed by less than 0.5 units because of trenching, whereas the pH of Solonetzic soils increased by as much as 2.0 units (de Jong and Button 1973). Similar results were also shown by Culley et al. (1982), Naeth (1985), Landsburg (1988) and Knapik et al. (1989). Increased pH was commonly attributed to the addition and mixing of carbonates from lower horizons during trenching. The largest pH increases were reported for the top 15 to 30 cm of the trenches for both Solonetzic and Chernozemic soils.

Research in Oklahoma on semiarid agricultural land (fine sandy loam and loamy find sands) where topsoil had not been salvaged, found soil calcium (Ca), magnesium (Mg) and sodium (Na) increased within the surface layer of the trench (Zellmer et al. 1985). These increased cation concentrations reflected levels found in the subsoil samples from the control transects. Electrical conductivity (EC) measurements of the saturated soil extracts were well below 2.0 dS/m, indicating a 'good' soil quality rating based on salinity (Alberta Soils Advisory Committee 1987).

Soluble salts were increased within the top 30 cm of the trench in both a cultivated and pastured Orthic Dark Brown Chernozem, although these increases were generally not statistically significant (Landsburg 1988). These increases were not sufficient to change soil quality ratings.

Soluble salt concentrations (and therefore EC values) were increased in surface layers of Solonetzic soils in southern Saskatchewan and Alberta as a result of pipeline construction. The salts had moved into the surface soils from salt-enriched subsoil material (de Jong and Button 1973; Naeth et al. 1987; Knapik et al. 1989). Increases in EC levels were also reported throughout deep-plowed Solonetzic profiles (Harker et al. 1977; Ballantyne 1983; Buckland and Pawluk 1985; Riddell 1986).

Increased EC levels in the top 10 cm of Solonetzic soil, where topsoil was salvaged, did not decrease the soil quality rating of 'good' (Knapik et al. 1989). Below 10 cm, higher EC levels within the trench generally reduced soil quality ratings from 'good' to either 'fair' or 'poor'. After two to three years of higher EC levels, soluble salt concentrations decreased, first in surface horizons then throughout the soil profile. At the end of the five-year study, EC levels and salt concentrations approached predisturbed levels. Salt concentrations were believed to have been reduced through leaching, which was promoted by improved drainage from breaking up the dense and impermeable Bnt horizon.

Organic carbon (OC) was generally found to be lower for surface soils on pipeline RsoW than soils off pipeline RsoW (Culley et al. 1982; Zellmer et al. 1985; Naeth et al. 1987; Knapik et al. 1989). Organic matter (OM) losses usually decrease amounts of available nutrients, make a seedbed that is more difficult to cultivate and decrease soil quality ratings. OM is desirable for improving soil tilth and aeration and for minimizing soil erosion (McGill 1982). Although OM can be lost through pipeline installation, RoW revegetation can add OM through decomposition of plant roots and exudates.

Mixing of topsoil and subsoil horizons in medium-textured Chernozemic and Solonetzic soils in Southeastern Saskatchewan during pipeline construction decreased surface layer (0 to 15 cm) contents of nitrate nitrogen (NO_3), extractable phosphorous (P), and extractable potassium (K), and increased the concentrations of these nutrients below 15 cm (de Jong and Button 1973). Culley et al. (1982) ascertained in Ontario that cation exchange capacity (CEC) as well as total nitrogen (N), extractable P and exchangeable K, were lower in surface soils on RsoW than in undisturbed soils.

A study to determine agricultural soil quality following two-lift and three-lift pipeline construction at Standard, Alberta, on Dark Brown Solonetzic soils, generally found few significant differences in NO_3 and phosphate (PO_4) between soils on the RoW and soils off the RoW (Knapik et al. 1989). Available K levels were generally lower than the control in the two-lift trench, although these differences were not significant in all cases. This trend was not observed for the three-lift trench. Sulfate (SO_4) levels were found to be significantly increased in both the two and three-lift trenches (Knapik et al. 1989). SO_4 levels decreased with time to levels similar to those of the undisturbed field soils.

3.3.5 Erosion

Alberta soils most susceptible to wind erosion are those in the southern part of Alberta in the Brown and Dark Brown Soil Zones (Goettel et al. 1981). These soils are dry, coarse textured and have poor aggregation, all factors that increase the potential for wind erosion. Water erosion is more serious in Gray and Dark Gray Soil Zones where soils are fine textured and have poor infiltration rates (Goettel et al. 1981). As water erosion is not a prevalent problem for the soils discussed in this literature review, only wind erosion will be discussed.

Wind velocities in southern Alberta have been shown to be nearly double those of the central part of Alberta (Erdman 1941). Erdman reports that fine sandy soils are most seriously damaged by wind erosion, silt loams are less affected, and loam and clay soils are affected only to a very limited extent.

Relative wind erosion risk was estimated by Coote et al. (1981). This researcher based his estimations on:

- surface soil texture
- ten-year wind return frequencies
- one-hour wind velocities
- mean annual soil deficit

Wind erosion risk was assumed to be greatest where wind speeds are highest (100 km/h), soils are sandy, and annual soil moisture deficits are high (230 mm). Wind erosion risk was assumed to be greatest for clayey surface soils where both wind speed and soil moisture deficits are low. This study considered a large part of southeastern Alberta to be a high wind erosion risk area.

Wind erosion can be reduced with crop residue or trash cover farming technique, combined with strip cropping (Goettel et al. 1981). However, adequate crop residue is difficult to maintain, especially during a series of below-normal rainfall years. Practices to minimize disturbance to the vegetative cover during pipeline construction should also reduce the risk of wind erosion. However, these practices should be weighed against the risk of soil mixing.

3.3.6 Stoniness and Weediness

Evaluation of pipeline reclamation practices of RsoW indicated an increase in stoniness at only two of the 24 Brown Chernozemic soil sites, and at six of the 24

Brown Solonetzic sites (Hardy Associates (1978) Ltd. 1983). Twelve of the 24 Brown Chernozemic sites had more weeds on the RoW, and 15 of the 24 Brown Solonetzic soil sites had more weeds.

3.3.7 Crop Yield

Conflicting information exists in the literature on the impacts of pipeline installation on crop productivity. In some studies, pipeline disturbance has reduced yields, whereas in other studies, it has increased yields. In other studies yield did not significantly differ from control soils. Most yield responses reflect soil characteristics resulting from different pipeline construction procedures such as topsoil removal, trenching and backfilling.

A study in eastern Oklahoma on semiarid agricultural land, where topsoil was not salvaged, indicated that wheat yields over trenches were significantly higher than yields on either the work side of the RoW or adjacent control soils (Zellmer et al. 1985). Yield increases appeared to be caused by increased moisture retention capacity and reduced bulk density over the trench.

On Dark Brown and Black Chernozemic soils, where topsoil was not salvaged, wheat yields on trenches were not significantly different from those of undisturbed fields (de Jong and Button 1973). However, on Dark Brown Solonetzic soils, wheat yields on trenches of older pipeline RsoW were generally higher than those on the control sites. These improved yields were attributed to decreases in salt concentration over time as well as improved soil structure. Yields in Solonetzic soils on trenches of recently installed pipelines were not significantly reduced, most likely because of increased salt concentrations within the trenches. An investigation of pipeline installations in Brown Solonetz rangeland in Alberta, where topsoil was insufficient to salvage, found that ground cover of older natural gas RsoW was similar to that of adjacent undisturbed land, suggesting a return to predisturbed conditions (Naeth 1985).

In a greenhouse experiment, barley yields were monitored to determine the effect of mixing individual horizons of Solonetzic soils (Harker et al. 1977). Under both adequate moisture and moisture-stress, mixing A and B horizons significantly reduced barley yields relative to normal horizon arrangement. These results were the same whether or not the soil was fertilized. The poor plant growth was caused by dispersion of the surface soil when A and B horizons were mixed and extremely slow water intake.

Crop productivity after pipeline construction on Brown Chernozemic and Solonetzic soils was evaluated by Hardy Associates (1978) Ltd. (1983). At three of the seven Brown Chernozemic sites that were annually cropped to fall rye, plant cover was reduced less than 10% over the trench. These three sites were flood irrigated. At the four remaining sites, crop cover was reduced 38 to 48% over the trench. Similar trends occurred over the spoil and work areas of the RsoW. Decreased plant cover appeared to be the result of topsoil mixing, possible unavailability of nutrients from reactions with lime, and subsoil compaction.

Of the 17 improved dryland and native pasture sites studied, forage cover was reduced at eight sites and increased at six sites. In the three sites that were flood irrigated, vegetative cover changed less than 10%. Similar results occurred on the work side of the trench. On the spoil side, plant cover increased at fewer sites and was reduced less than 10% at more sites. Decreases in plant cover for pasture sites were attributed to lack of topsoil salvage, calcareous material at the surface, mixing of topsoil and parent material over the spoil and work sides of the RsoW, and lack of weed control.

In the Brown Solonetzic soils studied by Hardy & Associates (1978) Ltd. (1983), crop cover over the entire RoW was reduced less than 10% for the five annually cultivated sites. At four of these sites, swathing commenced before data collection. At the 15 native forage sites, vegetation cover decreased over the trench and work areas of the RoW at 13 of the sites and over the spoil area at 14 of the sites.

Decreases in plant cover on Solonetzic soils under native pasture were believed to be caused by lack of topsoil replacement, topsoil mixing with Csk, subsoil being left over spoil and work areas, a resulting finer soil texture over the RoW, increases in the number of gopher holes and competition from weeds.

4.0 EVALUATION OF POTENTIAL IMPACTS OF OVERSTRIPPING TOPSOIL IN SOUTHEASTERN ALBERTA

The potential impacts of overstripping on both Chernozemic and Solonetzic soils must be determined to allow application of appropriate measures to future pipeline construction projects in southeastern Alberta.

A review of the literature indicates pipeline installation procedures affect both chemical and physical properties of soils in the trench as well as on the work and spoil sides of the RoW. Currently, government guidelines for soil conservation during pipeline construction advocate stripping and replacement of the A horizon, which in southeastern Alberta, can often be much less than 15 cm. This is difficult to do because of A horizon thinness. It also can alter the stability of the land, as soil aggregates are broken down, increasing the susceptibility of the soil to erosion.

If topsoil were not stripped before pipeline construction, it would be excavated along with the subsoil in a single lift and mixed together in the process. The incorporation of organic matter from the Ah horizon into the subsoil during this process would not dramatically change subsoil characteristics. The organic matter would decompose quickly when incorporated with the mineral horizons. However, in Solonetzic soils, the incorporation of subsoil with topsoil would increase the bulk density, pH, salt concentrations and clay contents of the topsoil. Increased clay content could cause structural problems for surface horizons, whereas increased salt concentration may affect crop growth.

Overstripping of the topsoil during construction would result in mixing of only the B horizon with topsoil. Removal and subsequent replacement of overstripped topsoil would produce horizon characteristics similar to those observed within the plow depths of cultivated soils. Physical and chemical characteristics of overstripped topsoil lie somewhere between those of stripped topsoil and the mixed soil produced when topsoil is not stripped before soil lifting.

In Orthic Brown Chernozemic soils, incorporation of the Bm horizon with topsoil would not greatly change soil capability. These soils have low salinity and sodicity, and only minor textural differences between the A and Bm horizons. Other types of B horizons that occur in Chernozems include Bmk (Calcareous), Btj (Eluviated), Bnjtj (Solonetzic) and Bmgj (Gleyed). Incorporation of these B horizons with topsoil would not greatly change soil capability. Overstripping Calcareous Brown Chernozems could increase carbonates in surface soils, overstripping Eluviated Brown Chernozems could increase clay content, and overstripping Solonetzic Brown Chernozems could increase exchangeable Na, or Na and Mg, relative to Orthic Brown Chernozems. For all these soils, mixing of A and B horizons could dilute the surface organic carbon content, which is already low.

In Solonetz and Solodized Solonetz soils, incorporation of the hard Bnt horizon with topsoil would increase clay content. Increased clay content may cause the plow depth to crust or puddle, causing increased soil strength in the Ap horizon, lowered water infiltration, increased water erosion and possible poor seedling emergence. Incorporating the Bnt horizon into the topsoil would also increase topsoil salinity, sodicity and pH, but decrease organic carbon. Overstripping Solod soils would not cause changes similar to those for the Solodized Solonetz and Solonetz soils because of this soil's disintegrating Bnt horizon.

Ideally, overstripping topsoil should not affect crop yields in Chernozemic soils. However, in Solonetzic soils, yields would be lower compared to control soils immediately following pipeline construction. With time, yields would approach those of predisturbed conditions.

The work and spoil sides of the trench can also be affected by pipeline construction, largely because of soil mixing and compaction. The effect of soil mixing is dependent on the quality and quantity of soil involved. If the spoil side is not stripped of topsoil, soil mixing can occur following removal of subsoil stored on top of the topsoil. This mixing of subsoil with topsoil could increase surface bulk density, pH, salt concentrations and clay contents, especially for Solonetzic soils.

Review of the literature indicates little compaction of the work and spoil sides of the RoW in semiarid areas relative to areas where the soils are wetter. However, increases in bulk density and soil strength have been reported for the work and spoil sides of RsoW in southeastern Alberta.

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