SUBSOILING TO MITIGATE COMPACTION

ON THE

NORTH BAY SHORTCUT PROJECT

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Abstract

In 1982, TransCanada PipeLines Limited constructed a 426 km, 914 mm diameter natural gas pipeline in new right-of-way between North Bay and Morrisburg, Ontario. The pipe installation was complete by December 1982, but clean-up of approximately two-thirds of the route was postponed until the spring of 1983. During construction, compaction of subsoil along the working side of the right-of-way was recognized as a serious concern and subsoiling was recommended as a mitigative measure. This paper explains how the extent of the compaction problem was determined, describes the type of tillage equipment used and evaluates the degree of success achieved.

Introduction

In returning lands disturbed by construction to productive agricultural use, it is necessary to deal with the problem of soil compaction. Compacted soils exhibit impaired soil structure (decreasing aeration) slower infiltration (leading to ponding or surface erosion), and restricted rooting volumes (increasing susceptibility of plants to nutrient or moisture stress). All of these factors may contribute to reduced crop yields, particularly in abnormally wet or dry years.

Compaction resulting from pipeline construction is a recognized environmental concern (e.g. Sheilds et al 1979) especially in fine-textured soils or where construction is allowed to proceed under wet conditions. Only recently, though, have concerted efforts been made to evaluate the extent and degree of compaction on particular projects and soil types. Environmental inspection of construction, coupled with post-construction monitoring has helped to focus attention on subsoil compaction at depths greater than 40 cm and has resulted in efforts to mitigate this compaction (e.g. TransCanada 1982). Moncrieff et al (1983) have reported on research to evaluate deep subsoiling as a restoration measure some years after construction in a very severe - and fortunately atypical - situation. The present paper describes the efforts of TransCanada to integrate subsoiling into its conventional clean-up activities on the North Bay Shortcut project, and comments on the results achieved.

The Project

In 1982, TransCanada constructed a 426 km, 914 mm diameter pipeline in new right-of-way between North Bay and Morrisburg, Ontario. Though nearly half of the route was in rocky Canadian Shield terrain and though efforts were made to avoid agricultural land during route selection (Hare et al 1984), about 170 km of farmland was crossed, most of it on Spread 3, between Pembroke and Morrisburg. While pipe installation was complete by December 1982, most clean-up in agricultural land was postponed until 1983. Despite favorable weather and soil conditions for construction and clean-up, subsoil compaction on this project went from a predicted impact, to a demonstrable phenomenon, to an equipment problem, to a logistical challenge. Solving the problems and meeting the challenge resulted in an excellent clean-up job and hopefully a minimum of compaction-related crop losses in 1984.

Demonstrating Compaction

The environmental assessment report for this project (TransCanada 1980) identified compaction of the right-of-way as a serious concern and suggested that specialized heavy cultivation equipment might be necessary to loosen compacted soils.

As clean-up commenced in 1982, it became apparent that the conventional equipment being used - a chisel cultivator - could not satisfactorily loosen compacted subsoil without overworking it and further degrading the structure (TransCanada 1983a). But when the cultivator was replaced with a road grader carrying five ripper teeth on a hydraulic tool bar, it became necessary to seriously investigate the degree of mitigation being achieved. On coarser textured pasture or forest soils, the grader/ripper turned out to be quite satisfactory, but on finer-textured, cultivated soils, its average working depth (25cm) was found to be insufficient and the design and arrangement of its teeth were unable to provide the lifting action desirable for shattering compacted layers. Moreover, the weight of the grader combined with wheel-slip to re-compact the subsoil as stock-piled topsoil was re-spread. Thus, probing the soil with a core sampler on transects across the right-of-way yielded the result shown in Table 1, and bulk density measurements confirmed that the degree of compaction was a potential problem for root penetration. Residual compaction was thus demonstrably present on the right-of-way.

In the fall of 1982 and again in the spring of 1983, penetrometer, bulk density and infiltration measurements were taken at several depths in test pits on and off the right-of-way to see whether frost action would alleviate compaction. It was found to have little effect, supporting the recommendation for deep tillage.

Subsoiling Equipment

In order to select suitable tillage equipment, however, it was necessary to know the average and maximum depths of compaction and the areal extent of the problem.

It was possible to rule out subsoiling on some sections of the right-of-way for obvious reasons, where the land was forested or abandoned roughland pasture; where the water table was within subsoiling depth year round; where the land was excessively stony; or where shallow, systematic tile drainage was an unavoidable obstacle.

TABLE 1: Depth of Compaction (maximum penetration of core sampler) in Fall 1982

Location +	Average depth of penetration*	
Off right-of-way	45	a
Topsoil Stockpile	34	b
Spoil Stockpile	31	b
Workspace	25	c
Workspace	24	c
Off right-of-way	45	a

\+ samples taken in transects of 6 points across right-of-way

* average over 8 properties sampled; means followed by same letter are not significantly different at the 1% level by Duncan's New Multiple Range Test

On remaining portions of the right-of-way, probing could establish the relative ease of penetration and the depth to the compacted layer, but this would not tell how deep the compaction went or how penetration by the probe correlated with penetration by plant roots. A preliminary survey was therefore undertaken to establish the correlation of bulk density with cone penetrometer readings (soil strength) over the range of soil textures encountered. Given the reasonably good correlation (r^2=0.71), penetrometer readings were taken as an acceptable indicator of compaction and the right-of-way was systematically sampled, taking readings at four depths up to 60 cm. In addition, bulk density measurements were taken at representative locations in each of six soil series. The results (see Figures 2 and 3 for examples) suggested a fairly universal zone of compaction on the working side of the right-of-way, extending to a depth of 40 or 50 cm, and often in a fairly distinct layer at 40 to 45 cm.
The contractor was asked to provide an appropriate implement and obtained one (the Kello-Bilt Series "5000" Subsoiler) which was rugged and capable of working depths up to 65 cm. In addition, its five parabolic shanks were mounted on a V-frame and spaced at 50 cm intervals to reduce draft and to shatter pans without inverting the profile.

Flexible Specifications

Given the pseudo-experimental nature of what we were attempting, flexibility was necessarily a key component of the subsoiling specifications developed for this job. To make the field adjustments required by flexible specifications, TransCanada relied on the cooperation of its contractors and on the collective skills of equipment operators, construction inspectors and consultants. From the outset, there were three practical objections to the subsoiling recommendation, the first being stone. Because a significant proportion of the right-of-way was underlain

FIGURE 2 · Soil Density Comparison of Workspace and Control Areas *

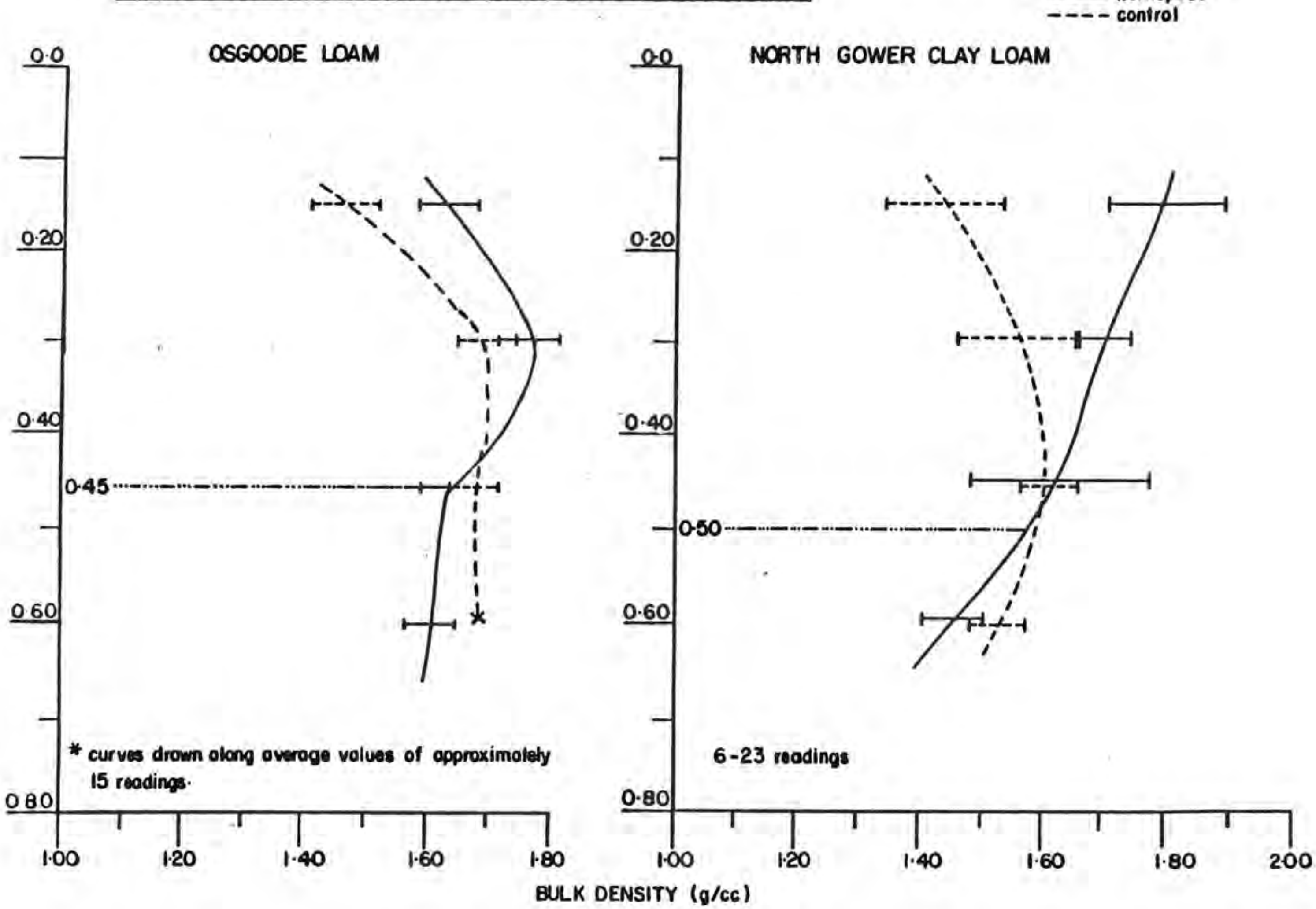
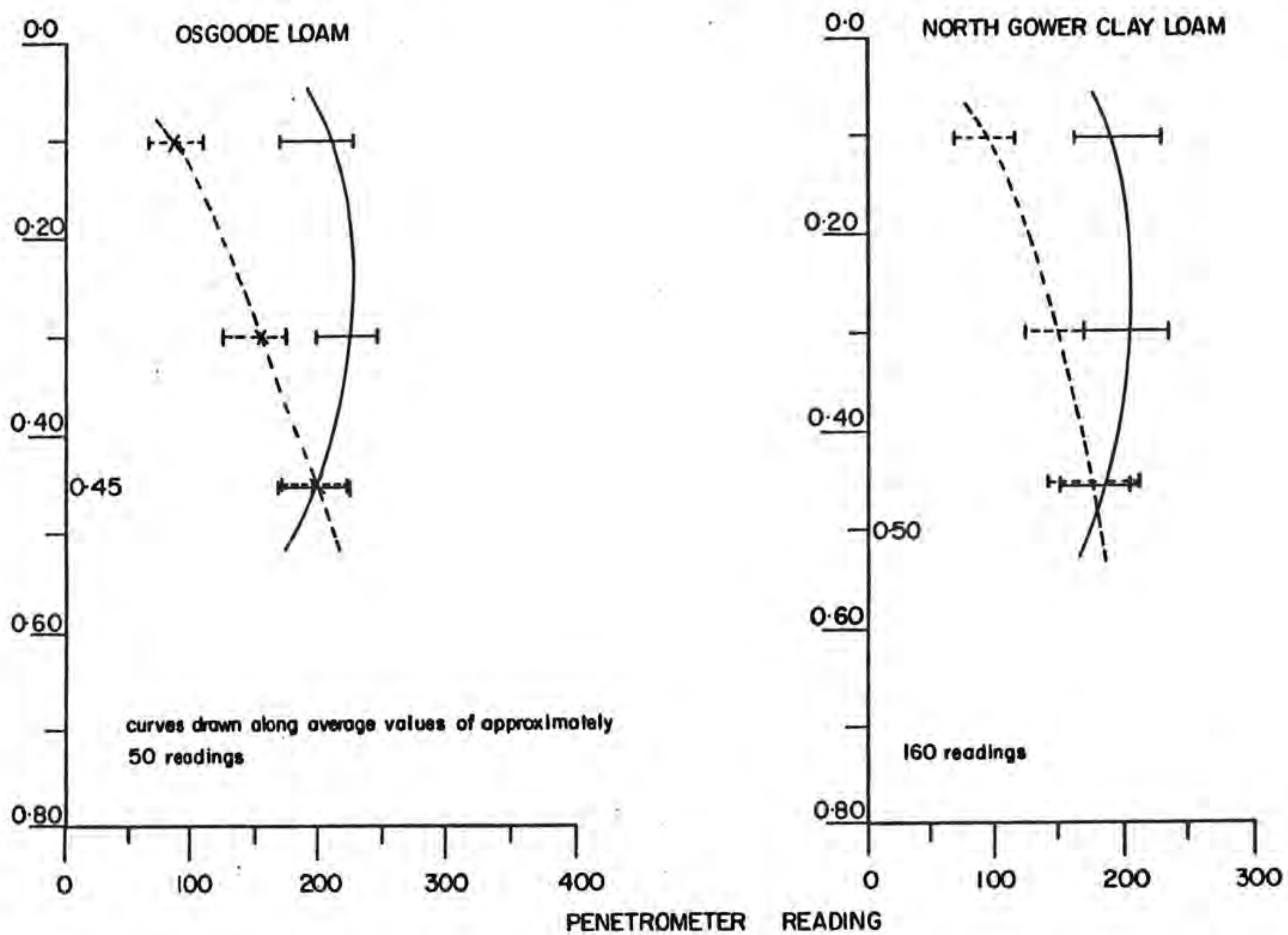


FIGURE 3: Penetrometer Reading Comparison of Workspace and Control Areas



by an undulating plain of stony, clay till, there was a legitimate concern that subsoiling would directly introduce stone into plough depth or dislodge it and allow it to migrate upward through frost action. It was feared that this would mean extra stone-picking and re-compaction of the soil, leading to a vicious clean-up cycle. Efforts were made to determine depth of the till layer by examining the trench walls and trench spoil and by selectively test-pitting prior to clean-up. Nevertheless, the specification for subsoiling depth had to remain flexible so that stony patches could be avoided; in fact, subsoiling depth was frequently reduced by field decision from 60 cm to 45 cm for this reason. Even so, considerable stone-picking was necessary in some cases.

A second concern related to subsoiling was the possible inversion of the soil profile and consequent topsoil/subsoil mixing. While the equipment used is designed to minimize this problem, dry subsoil is necessary for its proper action to be achieved. Where wet, plastic clay subsoil was encountered, a sliver of subsoil sometimes slid up the shank, to be deposited on the surface. While mixing from this source was relatively unimportant, subsoiling depth was reduced in parts of some fields to help control it.

Another source of mixing was encountered where soil was greatly compacted at the surface as well as at depth. The strength of the compacted layers caused them to slide up the shanks in a sheet before cracking into clods. In tumbling to the surface, the soil clods tended to become inverted. This problem was largely corrected by making two passes with the subsoiler, the first to a depth of 25 or 30 cm, the second to the recommended depth. Other implements, with straight shanks and lifting wings or shallower leading shanks might have had the same effect with only one pass.

The third concern about subsoiling is that it can only be done properly if the subsoil is dry enough to shatter and if the topsoil is dry enough for a tractor to maintain traction while handling the extra load. Weather and soils stayed sufficiently dry for both years of the North Bay Shortcut work, but there was a measure of luck involved; in most places in eastern Canada there are more unsuitable days for subsoiling each growing season than suitable. The extra working depth possible with the equipment selected by our contractor allowed subsoiling to be placed at the end of the clean-up sequence, even where topsoil had been removed over the working side of the right-of-way. Thus, there was flexibility to reschedule subsoiling for favorable weather conditions, if necessary, without delaying other clean-up operations. Moreover, there were essentially no compaction causing operations to be carried out after subsoiling.

Preliminary Results

In all, 85 properties were systematically probed with penetrometers and/or sampled for bulk density at two or three depths on and off the right-of-way. Of these, 77 were subsoiled, mostly to a depth of 45 cm. The total distance subsoiled was about 42 km and the production was roughly 3 km (4.8 ha) per day.

While TransCanada and its consultants are still in the process of evaluating the first-year results, a number of general observations are possible at this time. First, probing has demonstrated a reduction in resistance to penetration relative to control sites in adjacent fields (Table 4). Bulk density measurements indicate that this reduction should be beneficial to crop performance (TransCanada 1983b). Second, airborne colour infra-red data collected in June through cooperation of the Ontario Centre for Remote Sensing suggest no obvious, compaction-related infiltration or internal drainage problems on any of the subsoiled

TABLE 4: Depth of Compaction (maximum penetration of core sampler) in Summer 1983

Location +	Average depth of penetration *	
Off right-of-way	32	a
Spoil Stockpile	43	b
Trench	48	c
Workspace	41	b
Off right-of-way	33	a

\+ samples taken in transects of 5 points across right-of-way

* average over 37 properties sampled; means followed by same letter are not significantly different at the 1% level, by Duncan's New Multiple Range Test

properties. This observation is confirmed by a thorough ground-based survey which found only isolated cases of ponded water, usually calling for minor corrections of tile drainage repairs, micro-topography or previously undetectable seepage. In addition, an overview inspection of crop performance in early July showed normal crops over subsoiled properties. These preliminary observations are now being followed up with aerial colour infra-red crop data and quantified by means of soil sampling and sampling of mature crops. It should be recognized, though, that further monitoring (perhaps through a complete rotation) might be necessary to verify success. For best results, subsoiling should probably be followed by seeding down to a deep-rooted legume crop. Many farmers find this inconvenient, however, and return their fields to corn or grain production immediately following construction. Hopefully, this will not result in re-compaction and formation of a "plough-pan" on the right-of-way.

Conclusion

It should be clear from the foregoing discussion that subsoiling is potentially a very useful mitigative measure which can successfully be integrated into the pipeline construction and clean-up sequence. It should be equally obvious, however, that "DOING IT RIGHT" requires proper equipment, suitable soil conditions, skilled operators, on-going inspection and frequent field adjustments. A considerable amount of research remains to be done before subsoiling can be considered a standard or universal technique for inclusion in regulatory guidelines.

Regulators will always press industry for more detailed and precise specifications and for more objective criteria on which to base their regulations. To a degree, this is useful because it causes all concerned to study problems more carefully, to develop more information on which to base decisions and to place more information on the public record for the benefit of others. But to the extent that reliance on objective criteria reduces flexibility, and to the extent that it prevents qualified, experienced practitioners from making considered, professional judgements, it should be avoided.

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