AN AGRICULTURAL CAPABILITY RATING SYSTEM FOR RECONSTRUCTED SOILS

Terry M. Macyk, ALBERTA RESEARCH COUNCIL

ABSTRACT

This paper provides the rationale and a system for assessing the agricultural capability of reconstructed soils. The concept of capability rather than productivity is used in formulating comparisons between pre- and post-disturbance situations. The system developed parallels the Canada Land Inventory soil capability for agriculture rating system which is presently used to rate soil capability in Alberta. Seven classes and a number of subclasses based on climate, soil and landscape characteristics characterize the system. The degree of climatic limitation is used to establish the base level or starting point in developing and applying the reconstructed soil capability rating system. Other criteria include topography, absence or presence/thickness of topsoil, texture, stoniness, drainage, pH, electrical conductivity, sodium adsorption ratio and erosion.

INTRODUCTION

The pre- and post-mining use of land and land's productive capacity are of vital concern to the landowner, miner and regulatory authority. The concept of or at least the term "productivity" is one that has been used for a number of years when considering the impact of mining on agricultural land. Therefore, it may appear somewhat unusual to be considering the concept of soil capability rather than productivity in this context. Productivity can be described as the measure of output per unit of input as affected by technology and the mix of available resources. It can be suggested that soil productivity is not itself an inherent quality of the soil. Any precise statement about soil productivity must be in terms of a specific kind of soil, a specific kind of crop or combination of crops and a specific set of management practices.

Using productivity as a measure of performance of reclamation does not allow separation of the relative contributions of the land itself and the management inputs. For example, a given level of productivity can be achieved from either good land with minimal management input or poorer land with greater management input.

Capability for agriculture was chosen as the basis for evaluating the product of reclamation rather than productivity because capability considers intrinsic properties of the landscape.

MATERIALS AND METHODS

Developing the System

The basis for developing a capability rating system for reconstructed soils is based largely upon evaluating various soil parameters or properties of reconstructed soils and comparing the results to similar parameters or properties of unmined soils. This allows one to attempt to predict how the reconstructed soils will respond in terms of use.

Any system that is developed must have a "common thread" with a system that is utilized to rate the capability of natural or unmined soils so that meaningful concepts can be developed and relevant comparisons made.

A system that is presently used to rate soil capability in Alberta is the Canada Land Inventory (CLI) soil capability for agriculture rating system (Canada Land Inventory 1965). The system that is proposed for reconstructed soils essentially parallels the CLI system.

The CLI soil capability for agriculture rating system is an interpretive grouping that can be made from soil survey information wherein mineral soils are grouped into seven classes according to their potential and limitations for agricultural use. The first three classes are capable of sustained production of common cultivated crops, the fourth class is considered marginal, the fifth is capable for use in terms of permanent pasture and hay, the sixth is capable of use for native grazing, and the seventh class has no capability or potential for agricultural use. Therefore, if there is to be any thread of continuity between the existing CLI which is suitable for assessing suitability for a given use prior to disturbance then the system or component classes associated with reconstructed soils must reflect respectively similar capability. For example, a CLI Class 1 and a Reconstructed Class 1 should reflect similar capability.

It must be stressed that the CLI rating system is based on soil survey data which is a reflection of relatively stable soils that are generally not undergoing major change in a short time frame. In contrast to this, the data obtained in characterizing reconstructed soils represents a point source in time for any given parameter. Some of these parameters are likely to change some more rapidly than others. Therefore, when a particular rating is applied it is done so based on the properties of the reconstructed soils determined or assumed at a specific time.

It is of paramount importance that all concerned users understand and accept the concept that change is likely to, and certainly will occur, in

these reconstructed soils and the appropriate capability rating associated therewith may also change. Also, the capability system and therefore any particular rating assigned is based on existing conditions and not on what the conditions are perceived or predicted to be some time hence. Further research that involves the assessment or quantification of change in reconstructed soils will allow for improvement of the proposed rating scheme and perhaps allow it to be somewhat predictive.

The system is applicable to all mines (disturbances) in the plains region or in any region for that matter in the context of suitability for agricultural crops. This is indeed a "stand alone" system which is not based on pre-mining capability of a particular site. However, it can be suggested that if pre-mining capability is relatively low or poor then it is likely that post-mining capability will also be relatively low. Some exceptions to this will undoubtedly occur. For example, if capability prior to disturbance is low primarily because of topographic or drainage limitations then there is a strong possibility that resultant post-mining topography and drainage will result in a better or higher rating.

Adapting the CLI System

The CLI system of rating soils is based upon climate, landscape and soil factors. It follows therefore, that reconstructed soils should be rated on the basis of similar factors. The description of class and subclass as defined by CLI (Brocke 1977) follow.

The class indicates the general suitability of the soils for agricultural use.

Soil Capability Classes

Class 1 - these soils have no significant limitations to use for crops.

Class 2 - these soils have moderate limitations that restrict the range of crops or require moderate conservation practices.

Class 3 - these soils have moderately severe limitations that restrict the range of crops or require special conservation practices.

Class 4 - these soils have severe limitations that restrict the range of crops that can be grown or require special conservation practices to overcome or both.

Class 5 - these soils have very severe limitations that restrict their capability to producing perennial forage crops and improvement practices are feasible.

Class 6 - these soils are capable only of producing perennial forage crops and improvement practices are not feasible.

Class 7 - these soils or land types have no capability for arable culture or permanent pasture.

It must be emphasized that soils with a capability class are similar only with respect to the degree or intensity of limitation and not the kind of limitation. Each class includes many different kinds of soils and many of the soils within any one class may require different management practices.

Soil Capability Subclasses

The subclass is a grouping of soils with the same kind of limitation. It provides information on the kind of conservation problem or limitation. When used together, the class and subclass provide information about the degree and kind of limitation. Fourteen different kinds of limitations are recognized as a result of adverse climate, soil, or landscape characteristics. The limiting effects of the climate are considered first since they affect the initial capability class or degree of limitation on a broad sub-regional basis. Next the soil and landscape limitations are considered. The subclass limitations are as follows:

Climatic Limitations - expressed on the basis of adverse sub-regional climate where there are no other significant limitations.

Subclass A	- moisture deficiency due to insufficient precipitation.
Subclass B	- heat deficiency expressed in terms of length of the growing season and cumulative degree days over 42°F.
Soil Limitations	- caused by unfavourable inherent soil characteristics.
Subclass D	- undesirable soil structure and/or slow permeability
Subclass F	- low inherent fertility status.
Subclass M	- low available moisture holding capacity.
Subclass N	- excessive soil salinity.
Subclass S	- unfavourable soil characteristics; used in a collective sense where two or more of the above are present and/or in addition to some other limitation

Landscape Limitations

Subclass E	- erosion damage
Subclass I	- inundation
Subclass P	- excessive stoniness
Subclass R	- shallowness to consolidated bedrock
Subclass T	- adverse topography; both steepness and pattern
Subclass W	- excessive moisture
Subclass X	- cumulative effect of two or more of the above which singly are not severe enough to affect the rating.

Application of the existing CLI system requires the ability to recognize kind of limitation and evaluate the degree or intensity of limitation. It should be noted that there is a lack of specificity associated with the system, and that in many instances subjective evaluations must be made. The system outlines criteria for 14 kinds of limitations, some defined more quantitatively than others. For example, climate is based on precipitation, frost-free period, etc. which is defined to some extent, whereas fertility is generally based on parent material type.

As is done in the CLI system, the degree of climatic limitation is used to establish the base level or starting point in developing and applying the reconstructed soil capability rating system. The logic, simply stated, is that the climate which applies for the pre-disturbance also applies for the post-disturbance situation. The primary climatic factors include the amount and distribution of precipitation, the length of the growing season and frost-free period, and the quantity of heat units available for plant growth. The definition of the climatic classes and the criteria used to characterize these are as follows:

Class	Description	Precipitation	Frost-free Period	Degree days above 42° F
1	Sufficent precipitation and length of growing season to adequately mature wheat	40 to 45 cm (16 to 18")	90 days	2200
2	Moderate climatic limitations due either to a lack of precipitation or a shortened growing season or both.	adequate only 50% of the time	75-90 days	1900-2200
3	Moderately severe limitation due to a lack of precipitation or shortened growing season or both.	30cm (12") or less	60-75 days	1750-1900
5	Very severe limitations due to a very short growing season.		60 days	1750

It should be emphasized that the above is a general guide that was originally developed to characterize climate over relatively large areas. Utilizing this general guide to climatic characteristics the initial or base level capability of an area can be established. For example in Climate Area 1, the highest capability rating would be Class 1 with favourable soils and landscape conditions. Class 1 represents the starting point and any area within Climate Area 1 with adverse soil and/or landscape

characteristics is downgraded accordingly. Similarly, in Climatic Area 3, the highest capability rating that could be assigned is Class 3 even though there are not limitations relative to soil and landscape characteristics.

After establishing the base level capability of an area as determined by climate, the next step is to evaluate the properties of the reconstructed soils and the landscape which affect agricultural use. Assessment of topographic limitation includes evaluation of the hazards imparted to cultivation by the degree of slope as well as those due to irregularity of field patterns and lack of soil uniformity as a result of complex landform patterns. This is a limiting factor especially in those areas where no spoil levelling has occurred and to a lesser extent limiting in those areas where partial levelling was undertaken. In the level and gently undulating areas a limitation due to pattern may result from the occurrence of small poorly drained areas which are often the result of levelling procedure or differential settlement. These small areas affect the efficiency and effectiveness of cultivation, harvesting procedures, etc. The criteria used for evaluating topographic limitations for CLI can be utilized in this system and are as follows:

Slope Class and Percentage	Climatic Area	Degree of Limitation (Capability Class) Simple Slopes	Complex Slopes
Aa and Bb*	1	1	1
0 to 2%	2	2	2
	3	3	3
	5	5	5
Cc	1	1	2
2 to 5%	2	2	2
	3	3	3
	5	5	5
Dd	1	2	3
5 to 9%	2	2	3
	3	3	3
	5	5	5
Ee	1	3 or 4**	4
9 to 15%	2	3 or 4**	4
	3	4	4
	5	5	5
Ff	1	5	5
15 to 30%	2	5	5
	3	5	5
	5	6	6
Gg and Hh greater than 30%		6-7***	6-7***

* Uppercase letter - simple slopes; lower case letter - complex slopes
** depending on nature of material and susceptibility to erosion
*** depending on natural grazing potential for domestic animals

Additional landscape features or limitations can be broadly defined. Excessive moisture may be the result of poor soil drainage, a high water table, seepage or the collection of runoff from surrounding areas. In reconstructed soil areas poorly drained features are often the direct result of differential settlement. The degree of limitation is dependent on the duration of the period that these soils remain wet as it affects the timing of cultivation, seeding and harvest.

The CLI system does not formally define the soil factors or limitations to the extent that topography and climate are defined. The approach adopted in developing criteria relative to determining the suitability or limitation of various soil properties was to consider general guidelines already established (Agriculture Canada 1978, Schafer 1979) and to review the characteristics of undisturbed soils that have specific class and subclass designations.

The following discussion describes the subclass limitations as defined by CLI along with remarks pertinent to applicability to reconstructed soils.

Undesirable soil structure and/or low permeability is a limitation for some of the reconstructed soils. In terms of undisturbed soils, this limitation is most commonly utilized for soils prone to crusting which tends to inhibit seedling emergence and may restrict soil aeration. Similarly the illuvial horizons or subsoil of some soils (generally fine textured) also present structural limitations that are restrictive to internal drainage and root penetration. The reconstruction process alters "normal" or pedologically developed structure. The effects of this alteration vary depending upon the soils involved. In terms of orthic soils, the resultant effect is likely to be negative or a diminution of the pre-disturbance characteristics. On the other hand, Solonetzic soils and others characterized by a dense subsoil are likely improved by the reconstruction process. Reconstructed soils that have not been topsoiled are certainly prone to crusting which tends to inhibit seedling emergence. Research conducted by other investigators within the Plains Hydrology and Reclamation Project suggests that infiltration is not necessarily restricted in reconstructed soils (A. Howard, personal communication).

Low inherent fertility status is a limitation that has been applied to Alberta soils on a very limited basis. This limitation is difficult to assess without laboratory data to evaluate fertility status and generally the application of this subclass has been confined to soils developed on very sandy parent materials. In terms of reconstructed soils, those areas where topsoil was applied likely will not have any major deficiencies. In those areas where topsoil was not applied the soils are likely to show

deficiencies, however, other subclasses or factors are likely to become limiting before fertility. Furthermore, nutrient deficiencies are relatively easily corrected.

Low available moisture holding capacity is generally associated with sandy soils. This limitation would likely be applicable to areas of reconstructed soils that are characterized by sandy or coarse textured materials.

The excessive soil salinity limitation applies to soils in which the content of soluble salts is sufficient to adversely affect crop growth or to restrict the range of crops that can be grown (salt tolerance). This subclass is frequently used in combination with the landscape limitation for excessive wetness, and in areas of Solonetzic soils where the salts occur very near the surface. This subclass has also been used in combination with the undesirable soil structure and/or low permeability limitation. In terms of reconstructed soils some quantification of levels of salinity is presented in order that the limitation can be appropriately assessed or applied. This was done on the basis of reviewing the literature and assessing the salinity and sodicity levels of undisturbed soils to which the limitation has been applied.

The erosion damage limitation has been applied in evaluating soils where actual damage by erosion (wind or water) has resulted in a limitation to agricultural use. Damage is assessed on both the restriction to the range of crops that can be grown, and the mechanical difficulties presented to farming. Presently erosion does not appear to be a significant problem in the areas of reconstructed soils except for the unlevelled spoil piles. The steeply sloping areas in existence have been relatively successfully revegetated. If these areas were not revegetated there is a strong possibility of severe erosion occurring. However, these areas represent to a large extent, closed systems meaning that material moving down any of the slopes is trapped or contained within the "between pile" depressions.

The inundation limitation has been applied to areas subject to inundation by lakes or streams but not to depressional areas subject to ponding. This limitation is not likely to be a major concern in areas of reconstructed soils.

The excessive stoniness limitation has been applied to soils that are sufficiently stony so as to hinder agricultural activities. Soils with surface stoniness ratings of S3, S4 and S5 as defined in the Canadian System of Soil Classification (Canada Soil Survey Committee 1978) have limitations to agricultural use. In terms of reconstructed soils, this subclass would rarely apply as the dominant limitation since stone removal is one of the procedures employed in preparing the landscape for cropping.

The shallowness to consolidated bedrock limitation applies in areas where consolidated bedrock restricts the depth of the rooting zone. This limitation does not often apply within the agricultural areas, however the concern associated with reconstructed soils relates to the presence of an adequate root zone layer. An adequate root zone could be defined as a layer approximately 1.5 m thick which does not have restrictive zones or layers characterized by high bulk densities. One concern that surfaces relative to a similar problem is that of the "traffic pan" which occurs in reconstructed soils. The "traffic pan" is a layer which occurs approximately in the 25 to 75 cm depth range and where bulk density is greater than that of the material above or below this "layer".

Field observations indicate that ripping does not have an appreciable effect on the density in the traffic pan zone. The effects of the traffic pan are diminished rapidly (2 or 3 years) by freeze-thaw processes and cropping. The traffic pan does not hinder infiltration/percolation because there are adequate macropores present to allow for the orderly movement of water through and away from this zone.

RESULTS AND DISCUSSION

Criteria for Placing Reconstructed Soils into Capability Classes

The soil and soil/landscape limitations defined as part of the CLI system along with their implications for reconstructed soils have been defined. Suitability rating tables that provide good, fair and poor ratings relative to various physical and chemical properties already exist and are provided in a number of publications (Alberta Soils Advisory Committee 1981, Schafer 1979).

Table 1 presents criteria for placing reconstructed soils into soil capability classes for dryland agricultural uses. Included along with the soil parameters are the topography and climate considerations. To determine capability class the top one metre of the reconstructed soil is evaluated on the basis of the parameters included in the table. One metre was chosen in part because the literature indicates that the major portion of plant roots occur in the upper 25 to 60 cm of soil (Russell 1973, Wilhelm et al. 1982). Annual crops such as cereals do not grow actively in the soil long enough for them to develop a really deep root system and in temperate countries rooting does not normally exceed 1 to 1.5 m (Russell 1973). Furthermore, it is generally the top one metre of unmined soils that is considered in developing CLI ratings.

The properties of the top metre of reconstructed soil are considered as one unit. For example, to determine the E.C. value that is applied against the rating table one would calculate a mean value of the results obtained for various samples obtained within the one metre depth. The same approach is taken to consider pH, texture, and SAR in terms of developing or determining ratings. There is the concern that an unusually high or unusually low value will distort the overall mean. In these instances it is up to the rater's discretion whether or not these values are considered in developing mean values and thereby the ultimate rating of suitability or limitation of a specific parameter.

Table 1. Criteria for Placing Reconstructed Soils into Capability Classes for Dryland Agricultural Uses

CLASS	CLIMATE (CLASS)	TOPOGRAPHY (SLOPE %)	TOPSOIL[1] THICKNESS (cm)	SOIL TEXTURE (upper 1 metre)	STONINESS[2] (CLASS)	DRAINAGE[3] CLASS	REACTION (pH)	E.C. (mS/cm)	SAR	EROSION[4]
R1	1	0-2	≥15	L,VFSL	S0-S1	MW-W	6.0-7.5	<2	<4	W1
R2	2	2-5	5-15	FSL,SCL, SiL	S0-S1	MW-W	5.5-6.0 7.5-8.0	2-4	4-8	W1
R3	3	5-9	0+-5	SC,CL	S2	I	5.0-5.5 8.0-8.5	2-4	8-12	W2
R4	3	9-15	0	SiCL	S3	I,R	8.5-9.0	4-8	12-20	W2
R5	5	15-30	0	LS,SiC,C	S4	P,VR	8.5-9.0	4-8	12-20	W3
R6		30-60		S,HC	S5	VP	4.5-5.0	8-12	20-50	W4
R7		>60		any		Water	<4.5, >9.0	>12	>50	

1 Topsoil Thickness - Amount of Ah (Ap) organo-mineral material replaced on surface.

2 Stoniness Class - S0 = Nonstony, S1 = Slightly stony, S2 = Moderately stony, S3 = Very stony, S4 = Exceedingly stony, S5 = Excessively stony (Further definition of classes provided in CanSIS Manual for describing soils in the field (1982)).

3 Drainage Class - VR = Very rapid, R = Rapid, W = Well, MW = Moderately well, I = Imperfect, P = Poor, VP = Very poor

4 Erosion - W1 = Slightly eroded, W2 = Moderately eroded, W3 = Severely eroded, W4 = Gullied (Further definition of classes provided in CanSIS Manual for describing soils in the field (1982)).

Note: 1) Chemical properties in the 0-100 cm control section are considered in applying rating.

2) A combination of more than 2 limiting factors will drop soil by at least one capability class.

A better approach might have allowed for the splitting of the one metre into two units whereby the upper 40 to 50 cm are considered and weighed more heavily than the lower 50 cm in developing a capability rating. This would undoubtedly result in a relatively complex system that is perhaps not warranted at this stage.

The proposed system recognizes the presence or absence of topsoil and some considerations pertinent to depth thereof. Topsoil refers to the organo-mineral A horizon type of material. It can be argued that in some areas topsoil cannot be replaced because it does not occur in the pre-disturbance setting. An example might be areas characterized dominantly by Luvisolic soils. A reconstructed soil in this context would likely be rated a Class R3 or R4 on the basis of climate and other characteristics rather than a lack of topsoil or the presence of poor quality topsoil.

One of the properties that is not considered in the rating scheme relates to the "structure" or relative density of the reconstructed soil. Existing methods of determining bulk density are not particularly useful for characterizing reconstructed soils. The twin probe method is appropriate but it can only be practically utilized in a limited fashion because of the nature of the equipment installations required.

It is apparent that the chemical properties of reconstructed soils are addressed to a greater extent than physical properties and this is largely due to existing knowledge and measurement capabilities. Further research and the development of appropriate equipment will positively impact the situation.

Development of Reconstructed Soil Ratings

Capability ratings are formulated on the basis of relating the reconstructed soil properties to the criteria presented in Table 1.

The class indicates the general suitability of the reconstructed soils for agricultural use. Class symbol is preceded by "R" to designate reconstructed.

Reconstructed Soil Capability Classes

Class R1 - these soils have no significant limitations to use for crops.

Class R2 - these soils have moderate limitations that restrict the range of crops or require moderate conservation practices.

Class R3 - these soils have moderately severe limitations that restrict the range of crops or require special conservation practices.

Class R4 - these soils have severe limitations that restrict the range of crops that can be grown or require special conservation practices to overcome or both.

Class R5 - these soils have very severe limitations that restrict their capability to producing perennial forage crops and improvement practices are feasible.

Class R6 - these soils are capable only of producing perennial forage crops and improvement practices are not feasible.

Class R7 - these soils or land types have no capability for arable culture or permanent pasture.

Reconstructed Soil Capability Subclasses

The subclass represents a grouping of soils with the same kind of limitation. The criteria associated with each of the subclasses in relation to class are provided in Table 1. The symbology associated with the subclasses designated follows:

Topsoil (Absence)	- A
Climate	- C
Erosion	- E
Reaction (pH)	- H
Soil Texture	- K
Salinity (E.C.)	- N

Sodicity (SAR)	- Q
Stoniness	- P
Topography and Field Pattern	- T
Drainage	- W
Adverse Soil Characteristics (cumulative effect)	- S

Applying The Reconstructed Soil Capability Rating System

It was noted previously that there is an element of subjectiveness and to an extent a certain lack of specificity relative to the "definitions" associated with the CLI rating system. Furthermore, there is a certain element of subjectiveness associated with the designation of ratings for specific parcels of land.

In terms of the reconstructed soil rating system the class and subclass criteria are defined more fully but there is still an element of subjectiveness involved in developing the final rating designation for a specific parcel of land. The most likely time for confusion occurs when a combination of 2 or more limiting factors occur. A "rule of thumb" that can be applied suggests that a combination of 2 limiting factors does not drop capability by one class. A combination of 3 limiting factors will drop rating by one class or more.

Various scoring techniques were attempted to resolve the problem associated with the element of subjectiveness, however they did not prove entirely workable or represent an improvement over the proposed technique.

Final ratings for the reconstructed soil areas designated at each of the mines are presented in Table 2. Examples are provided to demonstrate how the system should be utilized.

Example 1: The field characterization data and Table 1 provide the following summary:

Climate	- Class 1
Topography	- Class 1
Topsoil Depth	- Class 1

Texture	-	Class 1
Stoniness	-	Class 1
Drainage	-	Class 1
Reaction (pH)	-	Class 1
Salinity	-	Class 2
Sodicity	-	Class 1
Erosion	-	Class 1

Rating = R2N

Because salinity is the most limiting factor and the criteria fit Class 2 the rating is Class R2 with the N (salinity) limitation.

Example 2: The field characterization data and Table 1 provide the following summary:

Climate	-	Class 1
Topography	-	Class 1
Topsoil Depth	-	Class 1
Texture	-	Class 2
Stoniness	-	Class 1
Drainage	-	Class 1
Reaction (pH)	-	Class 2
Salinity	-	Class 2
Sodicity	-	Class 3
Erosion	-	Class 1

Rating = R3Q

Because sodicity is the most limiting factor and the criteria fit Class 3 the rating is Class R3 with the Q (sodicity) limitation.

CONCLUSIONS

The capability system developed allows for an ordered ranking of relative capability of reconstructed soil areas, however the ratings do not provide for quantification or allow for the detailed assessment of production capacities and the effects of different management techniques. This can only be accomplished through the measurement of yield.

REFERENCES

Agriculture Canada. 1978. Soil quality criteria for agriculture. Prepared by sub-committee of Alberta Soils Advisory Committee.

Alberta Soils Advisory Committee. 1981. Proposed soil quality criteria in relation to disturbance and reclamation.

Brocke, L.K. 1977. Soil capability for agriculture in Alberta. Report prepared for Alberta Environment. 24 pp.

Canada Land Inventory. 1965. Soil Capability Classification for Agriculture. The Canada Land Inventory Report No. 2. Environment Canada, Ottawa. 16 pp.

Canada Soil Survey Committee, Subcommittee on Soil Classification. 1978. The Canadian system of soil classification, Can. Dept. Agric. Publ. 1646. Supply and Services Canada, Ottawa, Ont. 164 pp.

Canada Soil Information System (CanSIS). 1982. Manual for describing soils in the field. Edited by J.H. Day, Land Resource Research Institute, Ottawa, Ontario.

Macyk, T.M. 1984. Characterization and variability of reconstructed soils. Draft report prepared for Research Management Division, Alberta Environment.

Peters, T.W. and W.W. Pettapiece. 1981. Crop yields in Alberta. Preliminary relationships to soil capability for agriculture and soil type. Alberta Institute of Pedology Contribution No. M-81-1.

Russell, E.N. 1973. Soil Conditions and Plant Growth. 10th edition, Longman Group Limited, New York. 849 pp.

Schafer, W.M. 1982. Changes in land capability class resulting from mining in the northern great plains. In Symposium on Surface Coal

Mining and Reclamation in the Northern Great Plains, March, 1982.

Schafer, W.M. 1979. Guides for estimating cover-soil quality and mine soil capability for use in coal stripmine reclamation in the Western United States. Reclamation Review Vol. 2:67-74.

Wilhelm, L.N., Mielke, L.N. and C.R. Fenster. Root development of winter wheat as related to tillage practice in western Nebraska. Agron. J. 74: 85-88.

CLRA

NINTH ANNUAL MEETING CANADIAN LAND RECLAMATION ASSOCIATION

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

AUGUST 21-24, 1984
Calgary, Alberta, Canada

CANADIAN LAND RECLAMATION ASSOCIATION

NINTH ANNUAL MEETING

RECLAMATION IN MOUNTAINS, FOOTHILLS AND PLAINS

DOING IT RIGHT!

AUGUST 21 - 24, 1984

CONVENTION CENTRE

CALGARY, ALBERTA

A C K N O W L E D G E M E N T S

These proceedings are the result of dedication and commitment of many people including members of the Canadian Land Reclamation Association, technical contributors within and outside Canada, industrial organizations and government bodies. The contribution of all these groups to the Ninth Annual Meeting is gratefully acknowledged.

In particular, we would like to recognize the financial assistance provided by:

Alberta Environment
Alberta Oil Sands Industry Environmental Association
Alberta Public Affairs Bureau
R. Angus Alberta Limited
BP Canada Inc.
Burnco Rock Products Ltd.
Canadian Land Reclamation Association, Alberta Chapter
Prairie Seeds Ltd.
Westmin Resources Limited

and the support of the meeting by Management and Staff of the following groups:

Alberta Energy Resources Conservation Board
Alberta Sand & Gravel Producers Association
Coal Association of Canada
Canadian Petroleum Association
XV Winter Olympic Organizing Committee
Gregg River Resources Limited
Gulf Canada Limited
Parks Canada
Reid, Crowther and Partners Limited
Bank of Montreal

The Organizing Committee for the Ninth Annual Meeting was:

Chairman	Jennifer Hansen, J. Hansen Consulting
Functions	Lynda Watson, Techman International Limited
Technical Sessions	P.D. Lulman, TransAlta Utilities Corporation
Registration	A.J. Kennedy, Esso Resources Canada Limited
Public Relations	M.K. Ross, Crows Nest Resources Limited
Field Tours	Karen Natsukoshi, Manalta Coal Limited
	Julia Fulford, Fording Coal Limited
Commercial Displays	L.A. Panek, Montreal Engineering Company Ltd.
Audio Visual	A. Schori, Monenco Consultants
Alternate Programs	Holly Quan, TransAlta Utilities Corporation

Citation

The citation of this document in all references is:

1984 Canadian Land Reclamation Association
Ninth Annual Meeting, Calgary, Alberta, August 21st - 24th

CANADIAN LAND RECLAMATION ASSOCIATION
PROCEEDINGS OF THE NINTH ANNUAL MEETING

TABLE OF CONTENTS

Wednesday, August 22

Thursday, August 23

13. Managing Minesoil Development for Productive Reclaimed Lands
(W. SCHAFER)

14. Reclamation Monitoring: The Critical Elements of a Reclamation Monitorin Program
(R.L. JOHNSON, P.J. BURTON, V. KLASSEN, P.D. LULMAN, D.R. DORAM)

15. Plains Hydrology and Reclamation Project: Results of Five Years Study
(S.R. MORAN, M.R. TRUDELL, A. MASLOWSKI-SCHUTZE, A.E. HOWARD, T.M. MACYK, E.I. WALLICK)

16. Highvale Soil Reconstruction Reclamation Research Program
(M.M. BOEHM, V.E. KLASSEN, L.A. PANEK)

17. Battle River Soil Reconstruction Project: Results Three Years Afte Construction
(L.A. LESKIW)

18. Gas Research Institute Pipeline Right of Way Research Activities
(C.A. CAHILL, R.P. CARTER)

19. Subsoiling to Mitigate Compaction on the North Bay Shortcut Project
(W.H. WATT)

20. Effects of Time and Grazing Regime on Revegetation of Native Range Afte Pipeline Installation
(M.A. NAETH, A.W. BAILEY)

21. Revegetation Monitoring of the Alaska Highway Gas Pipeline Prebuild
(R. HERMESH)

22. Post-Mining Groundwater Chemistry and the Effects of In-Pit Coal Ash Disposal
(M.R. TRUDELL, D. CHEEL, S.R. MORAN)

23. Assessment of Horizontal and Vertical Permeability and Vertical Flow Rates fo the Rosebud - McKay Interburden, Colstrip, Montana
(P. NORBECK)

24. Accumulation of Metals and Radium - 226 by Water Sedge Growing on Uranium Mi Tailings in Northern Saskatchewan
(F.T. FRANKLING, R.E. REDMANN)

25. How Successful is the Sudbury (Ontario) Land Reclamation Program?
(P. BECKETT, K. WINTERHALDER, B. McILVEEN)

26. Methodology for Assessing Pre-Mine Agricultural Productivity
(T.A. ODDIE, D.R. DORAM, H.J. QUAN)

27. An Agricultural Capability Rating System for Reconstructed Soils
(T.M. MACYK)