7. DEVELOPMENT AND APPLICATION OF SOIL QUALITY CRITERIA FOR ALBERTA'S RESOURCE EXTRACTION INDUSTRIES

T.M. Macyk
Alberta Research Council
Edmonton, Alberta, Canada

ABSTRACT

Soil quality criteria for Alberta's resource extraction industries were prepared by the Soil Quality Criteria Subcommittee of the Alberta Soils Advisory Committee. The document produced was intended to be a scientific and technical manual for use by professionals. The criteria developed were compiled from a review of the pertinent literature and ongoing research and tempered in some situations by making the "best" guess where data were incomplete. Criteria were established for each of the Plains, Eastern Slopes and Northern Forested Regions of Alberta. They included the topics of soil mapping and sampling procedures, analytical requirements and criteria for evaluating the suitability of soil materials for revegetation. Criteria tables were developed for evaluating the suitability of topsoil and subsoil in the Plains Region, surface material (upper lift) and subsurface material (lower lift) in the Northern Forest Region, and root zone material in the Eastern Slopes Region. The criteria are used by a wide range of practitioners to assist in evaluating reclamation success which is defined in terms of equivalent land capability in Alberta. Specifically, the criteria are used to evaluate the baseline situation relative to soils, develop materials handling plans, predict the resultant post-disturbance soil characteristics, and determine the actual post-disturbance soil characteristics. Significant advances in "environmental soil science" research and field practices currently used relative to resource extraction activities provides the opportunity and the basis for expanding and improving the existing soil quality criteria. The updating of the criteria could include further subdivision of the three defined regions, adding criteria for additional chemical and physical properties, ranking or weighting of the various soil parameters, and consideration of the timing for completing post-disturbance soil quality measurements. This revision should be completed in a manner that results in a manageable and "user friendly" system that will be readily used by various practitioners.

7.1 INTRODUCTION

Land disturbances arising from resource extraction and transport are intended to be only temporary disruptions to the normal use of land. Although no two sites are absolutely identical, disturbances cause similar types of problems and concerns but in varying degrees of intensity. Assurance that such disturbances are temporary is possible only if information concerning a specific site is well documented and an appropriate reclamation program is planned prior to disturbance. Furthermore, measurement of reclamation success requires the ability to compare the baseline and post-disturbance characteristics of a given location or parcel of land. Evaluation of the nature of the materials at hand prior to disturbance and subsequent to reclamation, however, requires criteria by which to assess the quality of those materials.

The development of criteria that were first officially published in 1981, resulted from a process that was initiated in 1978, and was precipitated by a number of related factors:

1. Increased level of resource development
   a) during the late 1960's and into the 1970's, surface mining of coal was increasing significantly both in terms of expansion of existing operations, and the addition of new developments.
   b) oil sands development in northeastern Alberta resulted in two major operations being in place by 1970, with several more predicted to come on stream.
2. New and enhanced legislation
   a) the Land Conservation and Reclamation Act enacted by the province in 1973 (Alberta Government 1973) outlined a number of new requirements relative to rehabilitating lands impacted by resource development.
   b) the Coal Development Policy for Alberta (Alberta Energy and Natural Resources 1976) stated that "the primary objective in land reclamation is to ensure that the mined or disturbed land will be returned to a state which will support plant and animal life, or be otherwise productive or useful to man, at least to the degree it was before it was disturbed. In many instances the land can be reclaimed to make it more productive, useful, or desirable than it was in its original state; every effort will be made towards this end." It went on to indicate that "land reclamation

will include the contouring of the mined or disturbed lands, the replacement of the topsoil, revegetation for soil stabilization, biological productivity and appearance, and suitable maintenance of the vegetation or where appropriate, the conversion of the land to agricultural or other desirable use".

3. Concerns raised by industry and regulatory staff. In light of increased development and regulatory requirement, the regulators were not certain of what they should be requesting or requiring, and industry was not certain of what they should commit to in terms of achievable objectives and what the associated costs might be.

It seemed logical therefore, that the most effective approach to providing consistent guidance would be to prepare a document that could be used by all individuals concerned. As a result, the Alberta Soils Advisory Committee took the initiative and formed the Soil Quality Criteria Subcommittee.

7.2 OBJECTIVE

The objective of the Soil Quality Criteria Subcommittee was to develop a guide to assist people involved in a professional capacity in land reclamation (Alberta Soils Advisory Committee 1981). The group was to develop criteria relative to:

1. soil mapping and sampling for baseline and post-disturbance activity;
2. overburden sampling;
3. analytical requirements; and
4. physical, chemical, and biological criteria for evaluating the suitability of soil materials for revegetation.

The guidelines and criteria prepared were to provide a single or uniform target for both industry staff and government regulatory personnel. The document produced was intended to be a scientific and technical manual for use by professionals and did not contain any reference to policies or regulations of any government agency, nor was it to address economic, social or political issues. Economic and political decisions must make use of quality criteria, but the criteria themselves are independent of such considerations. It was inevitable, however, that the criteria would eventually wind up in the "policy" or "regulatory" arena.

7.3 MATERIALS AND METHODS

The soil quality criteria relative to disturbance and reclamation were compiled by a group of five soil scientists representing the private sector, regulatory agencies and research community with each individual having experience in land management, conservation and reclamation. The criteria developed were compiled from a review of the pertinent literature and ongoing research, and tempered in some situations by making the "best" or most "educated" guess where data were incomplete. In many instances the research to support the basis for specific criteria was almost complete and in some cases development of the criteria identified specific research needs or topics that were not being addressed.

More definitive guidelines and criteria could have been developed pending completion of additional research, however, the subcommittee felt it was critical to develop the best possible document and circulate it to stimulate thinking and discussion. The resulting documents entitled "Proposed Criteria Relative to Disturbance and Reclamation" (Alberta Soils Advisory Committee 1981) certainly stimulated a wealth of discussion and debate. It also stimulated the development of relevant and focused research efforts that might otherwise not have been undertaken.

7.3.1 Division of Province into Regions

The first step in the process was to divide the province into three distinct regions to allow for the establishment of criteria that would apply to each region in general. There are differences within each of these regions but it was beyond the scope of the document (Alberta Soils Advisory Committee 1987a) produced to suggest criteria for subdivisions. Individual operations within each of the major zones would have conditions or characteristics unique to that specific location or operation. The three major regions (Figure 1) are the:

1. Plains Region which includes the Central Plains and Peace River Plains and has a predominantly agricultural land use;
2. Eastern Slopes Region which includes the Lower and Upper Foothills, and the Rocky Mountains to the British Columbia border; and
3. Northern Forested Region which includes the remainder of the province.

7.3.2 Soil Mapping and Sampling

The next step in the process was to provide guidelines relative to soil survey activities. A soil survey with relevant interpretations helps in understanding the soil relationships in an area prior to preparing a development plan to ensure adequate evaluation of the potential for reclamation. These were largely adopted from guidelines prepared over several decades by the National Soil Survey Committee and its successor the Expert Committee for Soil Survey. Guidelines relative to mapping and sampling reconstructed soils were developed.

The document entitled "Soil Quality Criteria Relative to Disturbance and Reclamation" (Alberta Soils Advisory Committee 1987a) provides guidelines relative to recommended inspection density, soil profile characteristics, landscape features to be recorded, and map presentation. Use of a photo mosaic base is recommended in part because it is particularly helpful in working with post disturbance landscapes. Guidelines pertinent to sampling for baseline or evaluation purposes including sampling intensity and sampling methodology are described. Similarly, guidelines pertinent to post-disturbance or reconstructed soil sampling are provided. Again, this includes guidelines regarding sampling intensity and sampling methodology. For example, the document states that "sampling of reconstructed soils should be done on the basis of layers or materials such as topsoil, subsoil and spoil and on depth intervals within each of these discrete layers". Table 1 provides an indication of the total depth and intervals that should be sampled in reconstructed soil areas.

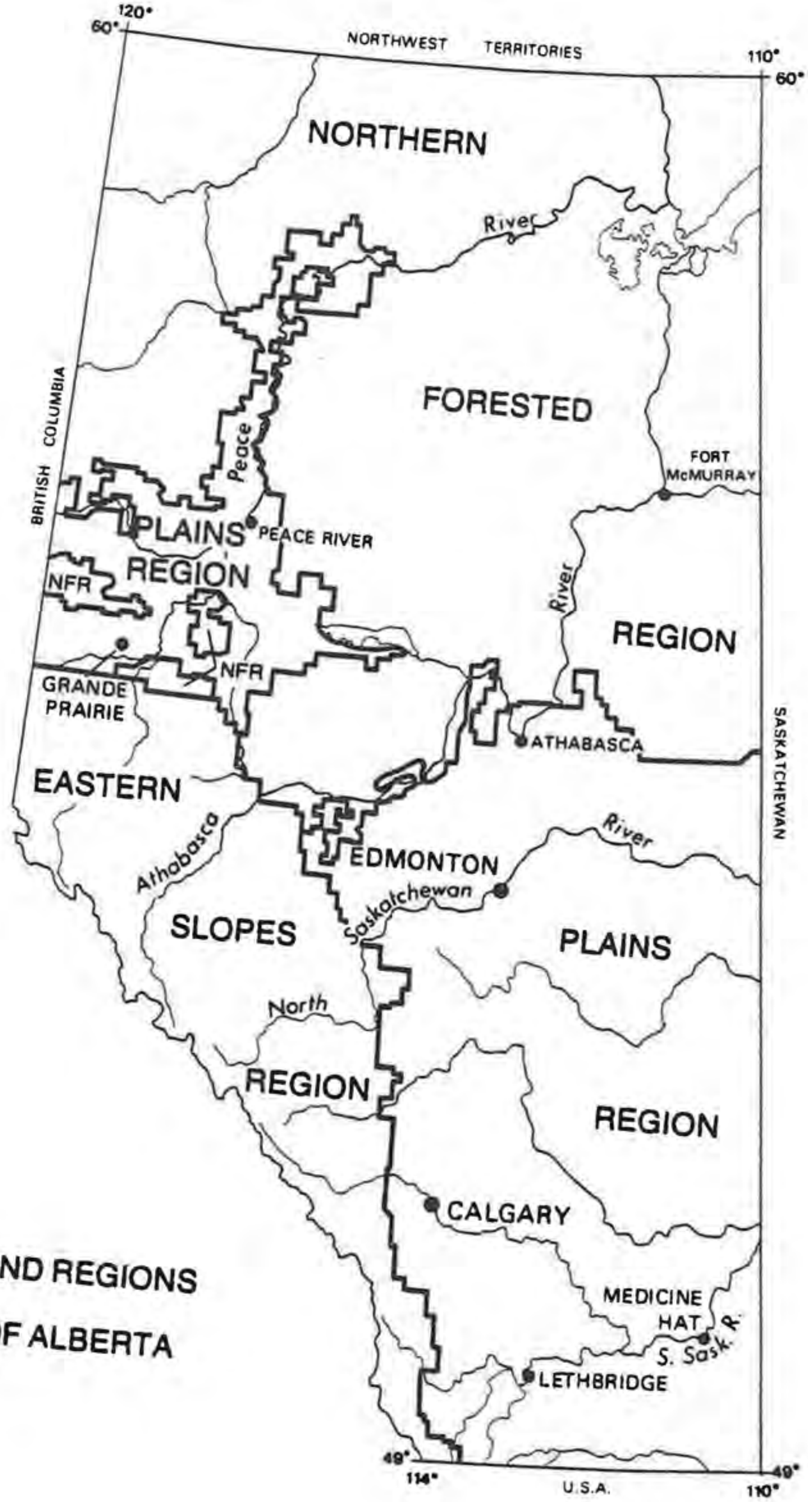

Figure 1. The major land regions of Alberta.

Table 1. Sampling depth intervals for reconstructed soils in the three regions.[1]

Region	Depth Interval (cm)		Notes
Plains			
	0 to 15 15 to 30 30 to 45 45 to 60 60 to 90 90 to 120 120 to 150	or	The topsoil layer should be taken in one sample, If topsoil depth is less than 15 cm then that depth of material should be segregated from material below. If topsoil is greater than 15 cm then first sample can exceed 15 cm in thickness. If topsoil layer is greater than 20 cm in thickness topsoil should be split into two sample intervals. Sample should be collected to and including one depth increment of spoil if depth to spoil is greater than 1.5 m.
Northern Forest			
	0 to 15 15 to 30 30 to 60 60 to 90 90 to 120		If the upper lift is less than 30 cm in thickness it could be sampled in one or two intervals. For example, if 20 cm thick then one sample interval would be appropriate, if greater than 20 cm thick it should be split into two samples. Samples should be collected to and including one depth increment of spoil if depth to spoil is greater than 1.2 m.
Eastern Slopes			
	0 to 15 15 to 30 then 30 cm increments where possible to 120 cm		If the thickness of replaced soil material is less than 30 cm then sampling could be done in one or two intervals. For example, if 20 cm thick then one sample interval would be appropriate, if greater than 20 cm thick the recommended intervals should be utilized.

[1] Sampling should be conducted on the basis of the layers replaced and depth intervals within these layers.

7.3.3 Analytical Requirements

Analytical requirements are defined for both baseline characterization and post-disturbance or reconstructed areas. The minimum analytical requirements listed aid in properly characterizing soils for classification and mapping purposes and making interpretations relative to the quality of the soils as they occur in the undisturbed and reconstructed states. They also assist in developing predictions about the degree of usefulness they may have in the post disturbance situation. Preferred methods of analysis are described in the document.

7.3.4 Criteria for Evaluating the Suitability of Undisturbed and Reconstructed Soils

In attempting to establish criteria for evaluating soils and overburden materials, a number of factors including the respective physical and chemical properties must be considered. It must be recognized however, that the establishment and maintenance of vegetation requires more than the properties of the soil namely water, light and carbon dioxide. To optimize plant production in a given environment the factors associated with the soil such as nutrients, water retention and availability must be in balance with all other factors.

Depth criteria were not spelled out - neither for undisturbed soils nor for reconstructed soils. However, occurrence and depth of master horizons (A, B, C) in the predisturbance state has a bearing or influence on how materials are salvaged, with respect to the different lifts involved, and subsequently the manner of replacement.

Replaced soil thickness should be no more limiting to plant growth than it was in the undisturbed state. It must be emphasized that thickness replaced depends not only upon soil quality but the quality of the overburden, and other factors such as mean annual precipitation, topography, slope angle, and water table position.

The materials handling procedures utilized in the three major regions identified would vary significantly since each region has unique climate features and soil types. General procedures for materials handling for each of the regions were defined in order that suitability criteria could be established.

To evaluate the suitability of soils and overburden materials in a given area one requires that a soil survey in sufficient detail is available and that the soils and overburden have been adequately sampled and characterized. The requirement for evaluating reconstructed soil areas would be similar.

Evaluations of soil suitability are made by considering the interaction of various soil properties and characteristics to give an overall rating of the degree of suitability. Three categories of suitability and one category to indicate unsuitable areas are used. The four categories are as follows:

1. Good (G) - None to slight soil limitations that affect use as a plant growth medium.
2. Fair (F) - Moderate soil limitations that affect use but which can be overcome by proper planning and good management.
3. Poor (P) - Severe soil limitations that make use questionable. This does not mean the soil cannot be used, but rather careful planning and very good management are required.
4. Unsuitable (U) - Chemical or physical properties of the soil are so severe reclamation would not be economically feasible or in some cases impossible.

7.3.4.1 Plains Region. In agricultural areas, the selective salvage of topsoil and subsoil and subsequent sequential replacement of these materials is currently required and practiced. It is also useful to characterize the material below the subsoil in the predisturbance setting because this usually becomes the "spoil" upon which the reconstructed soils are built. In some instances these parent materials can and do become part of the reconstructed subsoil. To facilitate the identification of suitable sources of soil materials for replacement relative to operations such as surface mines or quarries that result in deep disturbance, it is recommended that the upper five metres be characterized prior to disturbance. Topsoil is defined as the surface "A" (organo-mineral) horizons of the soil profile. Subsoil is defined as the "B" horizon(s) and the upper portion of the parent material.

The criteria for evaluating the suitability of the soils for their use as topsoil and subsoil are provided in Tables 2 and 3.

Table 2. Criteria for evaluating suitability of topsoil in the Plains Region (ASAC 1987a).

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.4	4.5 to 5.4 & 8.5 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stoniness Class	SO, S1	S2	S3, S4	S5
Texture	FSL, VFSL, L, SL, SiL	CL, SCL, SiCL	LS, SiC, C[2], S, HC[3]	
Moist Consistency	very friable, friable	loose	firm, very firm	extremely firm
Organic Carbon (%)	>2	1 to 2	<1	
$CaCO_3$ Equivalent (%)	<2	2 to 20	20 to 70	>70

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

[2]C May be upgraded to fair or good in some arid areas.

[3]HC (Heavy Clay) - May be upgraded to fair or good in some arid areas.

Table 3. Criteria for evaluating suitability of subsoil materials in the Plains Region (ASAC 1987a).

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)	6.5 to 7.5	5.5 to 6.4 & 7.6 to 8.5	4.5 to 5.4 & 8.6 to 9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	<3	3 to 5	5 to 10	>10
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[1]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stone Content (% Vol)	<3	3 to 25	25 to 50	>50
Texture	FSL, VFSL, L, SiL, SL	CL, SCL, SiCL	S, LS, SiC, C· HCL[2]	Bedrock
Moist Consistency	very friable, friable	loose firm	very firm	extremely firm
Gypsum $CaCO_3$ Equivalent (%)	The suitability criteria for sodicity (SAR) may be altered by the presence of high levels of either lime ($CaCO_3$) or gypsum ($CaSO_4$) in excess of other soluble salts.			

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

[2]HCL - Heavy Clay Loam.

7.3.4.2 Northern Forest Region. In the Northern Forest Region it is appropriate to salvage soil materials in two lifts. The upper lift comprising a mixture of the organic and A horizons of the soil solum and perhaps a portion of the B horizon to a depth of about 30 cm depending upon site specific conditions. The second (lower lift) comprises the material below the upper lift to a depth deemed appropriate relative to specific site conditions. The second lift need not be salvaged in areas where the overburden material is rated as suitable for use as subsoil or lower lift material. Salvage of the top lift as a separate unit is important in that:

1. Organic matter levels as well as important soil macro- and micro-organisms are less diluted.
2. It generally has better growth support capability, and
3. It may serve as an excellent seed source for some native species.

The criteria for evaluating the soil properties are listed in Tables 4 and 5.

Organic soils should be considered for salvage and used as a soil conditioner. Origin, degree of decomposition and reaction will determine the suitability of these materials.

7.3.4.3 Eastern Slopes Region

In the Eastern Slopes Region salvage and replacement of one lift of material is commonly practiced. In this region, as for the Plains and Northern Forested Regions, the material handling procedures will reflect specific site conditions.

The criteria for evaluating the soil properties are listed in Table 6.

7.3.5 Use of the Criteria to Develop Ratings

The ratings (good, fair, poor, unsuitable) are determined by assessing the site factors and analytical data in terms of the limits presented in the criteria tables. Each horizon or layer is rated relative to the individual parameters and an overall rating can be developed for each horizon or layer. The most limiting property (rating) determines the ultimate rating for each horizon or layer.

A number of the parameters assessed and used in developing ratings are interrelated. For example, sodicity, saturation percentage and texture are fairly closely related.

Table 4. Criteria for evaluating the suitability of surface material (upper lift) for revegetation in the Northern Forest Region (ASAC 1987a).

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 6.5	4.0 to 5.0 6.5 to 7.5	3.5 to 4.0 7.5 to 9.0	<3.5 and >9.0
Salinity (EC)[2] (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)[2]	<4	4 to 8	8 to 12	>12[3]
Saturation (%)[2]	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 120	<15 and >120
Stoniness/ Rockiness[4] (% Area)	<30/<20	30-50/20-40	50-80/40-70	>80/>70
Texture	FSL, VFSL, L, SiL, SL	CL, SCL, SiCL	LS, SiC, C, HC, S	
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
$CaCO_3$ Equivalent (%)	<2	2 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

[2] Limits may vary depending on plant species to be used.

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

[4] <25 cm diameter stones/rocks intercepting surface.

Table 5. Criteria for evaluating the suitability of the subsurface material (lower lift) for revegetation in the Northern Forest Region (ASAC 1987a).

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 7.0[2]	4.0 to 5.0 7.0 to 8.0[2]	3.5 to 4.5 8.0 to 9.0	3.5 and >9.0
Salinity (EC)[3] (dS/m)	<3	3 to 5	5 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12[4]
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 100	<15 and >100
Coarse Fragments (%/Vol)	<30[5] <15[6]	30 to 50[5] 15 to 30[6]	50 to 70[5] 30 to 50[6]	>70[5] >50[6]
Texture	FS, VFSL, L, SiL, SL	CL, SiC, SiCL	S, LS, S, C, HC	bedrock
Moist Consistency	very friable, friable, firm	loose, very firm	extremely firm	hard rock
$CaCO_3$ Equivalent (%)	<5	5 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

[2] Higher value takes into consideration that in the lower lift the pH values of the soils are generally higher. Normally the pH rating should not be different from those shown in Tables 9 and 11.

[3] Limit may vary depending on plant species to be used.

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

[5] Matrix texture (modal) finer than sandy loam.

[6] Matrix texture (modal) sandy loam and coarser.

Table 6. Criteria for evaluating the suitability of root zone material in the Eastern Slopes Region (ASAC 1987a).

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0 to 6.5	4.0 to 5.0 6.5 to 7.5	3.5 to 4.0 7.5 to 9.0	<3.5 and >9.0
Salinity (EC)[2] (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)[2]	<4	4 to 8	8 to 12	>12[3]
Saturation (%)[2]	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 100	<15 and >100
Coarse Fragments[4] (%/Vol/Vol)	<30[5] <15[6]	30 to 50[5] 15 to 30[6]	50 to 70[5] 30 to 50[6]	>70[5] >50[6]
Texture	L, SiCL, SCL, SL, FSL	CL, SiL, VFSL, SC, SiC	LS, S, Si, C, HC	Consolidated Bedrock
Moist Consistency	very friable, friable	loose, firm	very firm	extremely firm
$CaCO_3$	<2	2 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective
is for other end land uses, such as erosion control, and where other plant species may be more important, refer to Table 6.

[2] Limits may vary depending on plant species to be used.

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

[4] 0.2 to 25 cm diameter fragments in the soil material.

[5] Matrix texture (modal) finer than sandy loam.

[6] Matrix texture (modal) sandy loam and coarser.

It is important to note that some parameters are likely more important than others in terms of assessing quality and there are situations where management practices can overcome or compensate for some limitations. It was not the intent of the document to suggest the extent to which management practice could impact ratings that are developed. Some pertinent comments can, however, be made. For example, a soil could be rated fair, poor, or unsuitable on the basis of degree of stoniness while the remaining parameters considered are not limiting. In this instance it would be reasonable to qualify the rating with a statement to the effect that management practice (stone picking) could be utilized to improve soil quality.

7.4. THE USE OF SOIL QUALITY CRITERIA

The soil quality criteria developed are used by a wide range of practitioners for the general purpose of assessing soil material quality prior to disturbance to determine soil suitability for reclamation, and subsequent to reclamation procedures to evaluate reclamation success. The overall goal relative to use of the criteria is to minimize environmental impact occurring as a result of land disturbance.

Personnel in the government regulatory process utilize the criteria to provide guidance to industry with respect to what is expected in terms of evaluating pre-disturbance and post-disturbance conditions, and to evaluate industrial plans for soil salvage and replacement. Industry personnel utilize the criteria to evaluate the baseline situation relative to soils, develop materials handling plans, and predict the resultant expected post-disturbance or reconstructed soil characteristics. Measurements after soil reconstruction are used to evaluate reclamation success at a given time.

Despite the fact that the criteria established (ASAC 1981, 1987a) were driven to a large extent initially by surface mining activities in Alberta, they are applicable to any land disturbance in the province including oil and gas development, pipeline construction, sand and gravel operations, and a variety of others. It should be noted that use of the criteria is not limited just to the activities and impacts associated with the disturbance of the soil resulting from extraction of the resource and development of transportation infrastructure, but also those associated with treatment and disposal of the respective by-products or wastes generated.

7.4.1 Soil Quality and Measurement of Reclamation Success

The criteria are used primarily to assist in measuring reclamation success or comparing the undisturbed setting with the post-disturbance or reconstructed condition. The process of adopting and implementing a system for measuring reclamation success was and continues to be evolutionary, and is based on several strategic activities and research efforts.

Initially the productivity concept which considered measurements in tèrms of bushels per acre or bales per acre was used. In the early 1980's the capability concept was deemed more suitable because it considered the intrinsic characteristics of the soil and did not deal with specific crops and defined management practices.

A number of systems have been developed to measure land/soil capability in Alberta and Canada (Alberta Soils Advisory Committee 1987b, Brocke 1977; Canada Land Inventory 1965). Systems for measuring reconstructed soil capability have also been developed and are based largely on the original CLI Land Capability System (Macyk 1987, Leskiw and Lapointe 1992).

The current objective or goal of reclamation in Alberta is defined in terms of "equivalent land capability" under the draft Alberta Environmental Protection and Enhancement Act (Alberta Environment 1992). Equivalent land capability is defined as "the ability of the land to support various land uses after reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the ability support individual land uses will not necessarily be identical after reclamation". Land capability is defined as "the ability of the land to support a given land use on a sustained basis irrespective of future management inputs, activities or alterations". It refers to an evaluation or rating of the kind and degree of limitations on land use, in terms of physical, chemical and biological characteristics such as topography, drainage, hydrology, soils, and vegetation. It includes any existing abilities and conditions which are the result of previous alterations or management practices (Alberta Environment 1992). For the purposes of the definitions of land capability and equivalent land capability, land is defined as "terrestrial, semi-aquatic, and aquatic landscapes" (Alberta Environment 1992).

Put in economic terms, it is clearly the intent of reclamation legislation in Alberta that the cost of assuring equivalent land capability or any other measure of reclamation success in the post-disturbance landscape is to be borne as a capital investment in the land, rather than as an operating cost by the end land user.

Determining land capability and soil capability as done in the past includes the development of a rating based on climate and landscape factors as well as physical and chemical soil properties. Capability is determined on the basis of a class (1 to 7) which denotes relative level of capability and a subclass designation which denotes the limiting characteristic(s).

Comparing pre- and post-disturbance capability allows for a comparison in capability class but not necessarily a comparison of soil properties. For example, in some situations changes in topographic factors may have more impact on post-disturbance capability than change in soil parameters. Therefore comparing pre-and post-disturbance capability ratings may not explicitly or clearly indicate the relationships with respect to soil properties.

Measurement or comparison of soil quality allows for a better assessment of individual soil parameters and is a critical component in evaluating land capability. Soil quality embraces the quantification of specific soil parameters whereas soil capability is a holistic ranking of soil, landscape and climate factors.

7.4.1.1 Baseline Assessment. Prior to most land impacting activities the proponent must provide the appropriate regulatory agencies with a plan detailing what the baseline or undisturbed condition is, the nature of the activity or disturbance, and how the land will be reclaimed. Completion of a soil survey as referred to previously is one of the baseline assessments that provides an indication of the type and extent of the soils in the area to be affected. The various soil physical and chemical parameters outlined in the suitability tables can be measured directly in the field and by analyzing representative soil samples.

Based on the compilation of field and analytical data, soil suitability ratings can be prepared.

7.4.1.2 Decision Making. Once the soil suitability ratings have been prepared for a given development these ratings combined with all other considerations allow for decision-making relative to the feasibility of proceeding with a given development.

It is possible, however unlikely, that approval for a given development would be rejected solely because of soil quality issues.

7.4.1.3 Materials Handling. Soil quality and/or suitability ratings play an integral role in developing materials handling plans. Soil salvage/replacement requirements and practices are fairly well established in Alberta with the general requirement of salvaging topsoil, subsoil and parent materials where necessary. For example, in the Plains or agricultural regions of the province the general practice is to salvage and replace 15 cm of topsoil and 1 m of subsoil over spoil material. In the non-agricultural or "forested" portion of the province a "coversoil" is replaced based upon the depth and properties of the pre-disturbance soils.

Having knowledge regarding the characteristics of these different materials allows one to determine the relative suitability of the materials and their overall usefulness for reclamation purposes. Assessment of the suitability or quality of the various materials will allow for planning selective salvage and replacement of materials. In some situations suitable overburden material could be used as the surface layer for a reconstructed soil, especially if more suitable materials are not available. For example, in areas where sodic materials are present it is possible that the parent materials may be more suitable for use or provide better overall soil quality than the indigenous subsoil materials.

7.4.1.3.1 Surface Mining (Drastic Disturbance). Resource extraction operations result in different levels or degrees of disturbance. For example, surface mining of coal can result in the removal of soil and overburden to depths up to 100 m or more in some locations. Sand and gravel operations can also have impacts to significant depths.

An example of using the criteria to evaluate the impact of surface mining on soils in the subalpine region where parameters such as texture and pH are critical soil properties is provided (Table 7).

Table 7. Pre-Mining and Reconstructed Soil Characteristics (0 to 15 cm depth)

Soil	pH	Texture	Coarse Fragments (%Vol/Vol)
Pre-mining	5.8	SiL-L	2.5
Reconstructed	6.6	L	40

According to the criteria presented in Table 6 the pre-mining soil would have an overall "good" rating in terms of soil suitability. The reconstructed soil would have an overall "fair" rating due mainly to coarse fragment content. In this situation management practices such as coarse fragment removal or adopting specific revegetation practices could be undertaken to mitigate the limitation.

7.4.1.3.2 Other Disturbances. Less drastic disturbances such as road, pipeline and wellsite construction would not involve the extent or volume of material movement per unit area that is often associated with mining and quarrying operations. These disturbances may be considered less drastic in the sense that the overall depth of disturbance is generally not as great as for mining and quarrying, however considerable surface disturbance does occur. As a result soil quality and soil capability are affected.

In the realm of pipeline construction the soil quality criteria are used to assess the need for three-lift vs two-lift handling of soil to maintain soil capability. Two major types of soils require separate handling of major soil horizons to maintain soil capability (Ferguson 1990). In areas where gravel occurs in the pipeline trench it should be replaced at pre-construction depths. Similarly, soil materials that are saline and/or sodic may require three-lift soil handling when they exist below a non-saline/non-sodic subsoil layer (Ferguson 1990).

7.4.1.3.3 Waste (By-product) Disposal. Land-based disposal of industrial wastes or by-products is becoming more widely practiced in Alberta. Landspreading and landfarming are commonly used land application techniques.

Soil quality is impacted by the addition of waste materials. In some situations or for some parameters, the quality is improved whereas in others it is reduced. Time is a major consideration when assessing soil quality. For instance quality might be reduced immediately following waste application/incorporation, however it may improve with time such as in one, two or however many years thereafter.

Soil quality criteria are useful in determining how much waste can be applied to a given soil. Loading rates for various wastes have been established and used such as those associated with the application of municipal wastewater sludges to agricultural lands (Alberta Environment 1982). Similarly guidelines are in place regarding loading rates for drilling waste disposal (ERCB 1975) which are currently under revision by the joint government/industry Drilling Waste Review Committee.

An example of how the criteria can be used in assessing the impact of drilling waste landspreading is provided. The example is taken from a study of the landspreading of a salt-based mud system on a replaced "surface" soil with emphasis on EC and SAR values in (Table 8).

Table 8. Mean Values for EC and SAR in the Various Plot Treatments (0 to 15 cm depth).

Waste Rate (kg Cl/ha)	EC(dS/m)					SAR				
	Pre*	Post	Year 1	Year 2	Year 3	Pre	Post	Year 1	Year 2	Year 3
0	0.5	0.6	0.5	0.4	0.4	0.2	0.3	0.2	0.2	0.2
350	0.5	2.0	1.2	0.5	0.5	0.3	4.7	2.9	1.4	1.1
700	0.5	2.4	1.8	0.6	0.5	0.3	5.2	4.5	1.7	1.4
1400	0.6	3.0	1.8	0.7	0.6	0.3	8.5	5.3	3.4	2.4
2800	0.5	7.3	5.4	2.4	1.3	0.5	23.5	15.2	11.4	8.3

*Pre - Baseline (prior to waste application)
Post - 1 month following waste application.
Year 1 - 1 year following waste application.
Year 2 - 2 years following waste application.
Year 3 - 3 years following waste application.

The Alberta Soils Advisory Committee (1977, 1987a) presented the following limitation criteria and suitability ratings for EC and SAR levels in soil in the Northern Forested Region:

Limitation	Suitability Rating	EC Value (dS/m)	SAR Value
No limitation	good	<2	<4
Slight limitation	fair	2 to 4	4 to 8
Moderate limitation	poor	4 to 8	8 to 12
Severe limitation	unsuitable	>8	>12

The data in Table 8 indicate that based on EC and SAR levels the receiving soil was rated good or would present no limitation to plant growth. Following waste application the limitation due to EC level ranged from none to moderate depending upon waste rate applied. In subsequent years the degree of limitation decreased or level of suitability increased. By year 3 only the highest waste rate had values exceeding baseline levels. A similar trend was also exhibited by the SAR levels reported in Table 8.

This approach could be utilized for all parameters for which limitation and suitability criteria have been defined to assess soil quality.

Soil quality criteria can also be utilized to evaluate the suitability of non-soil materials for use as a plant growth medium. For example, a waste or by-product of coal mining was characterized with a view to revegetation of areas where this material had been placed (Table 9).

Table 9. Physical and Chemical Properties of a Coal Waste Material.

pH (H_2O)	Texture	$CaCO_3$ Eq. (%)	Sat'n (%)	EC dS/m	SAR
8.2	Loam	3.69	85	3.6	10

Utilizing the criteria for evaluating the suitability of root zone material in the Eastern Slopes Region provided in Table 6 one can assess the overall suitability of the material for revegetation purposes. The parameters of pH, SAR, and saturation % would be rated as poor, $CaCO_3$ equivalent and EC as fair, and texture as good. The overall suitability rating would be poor or there would be a moderate limitation to using the material for revegetation purposes. At this stage one would look at options available in terms of management practice or amendments that might be used to improve the overall suitability of the material.

7.5. EXPANDING THE SOIL QUALITY CRITERIA

The current soil quality criteria for agriculture were published in 1977 and the criteria relative to land disturbance and reclamation were initially released in 1981 followed by a revised version in 1987. The revised version was based on the existing research and the available literature to 1982. Great strides have been made in soils research and practical experience since then. Significant changes have occurred in many areas including:

1. increased public awareness regarding the environment and associated expectations;
2. improved analytical techniques;
3. improved equipment for both laboratory and field measurements;
4. improved field practices; and
5. longer record for research studies or more long-term data.

Increased public awareness has resulted in the move to more consciousness of soil conservation and better land management practices. Combining this increased awareness with enhanced regulatory requirements has resulted in the modification of practices used to extract natural resources in this province.

Improved analytical equipment and methodologies allow for more extensive and precise analytical work. For example, in the late 1970's knowledge about the trace element content of Alberta soils and wastes was minimal compared to the data currently available. Field practices associated with the preparation for resource development, the actual resource removal and reclamation/rehabilitation thereafter have improved.

As mentioned previously, the criteria currently utilized were based largely on relevant scientific data obtained prior to 1982. At that time "environmental soil science" research was really in its infancy in Alberta and in the rest of Canada and North America. A significant amount of reclamation research had been initiated by that date however very few of the projects had a record of more than two or three years. Reclamation research expanded in the early 1980's and some of it was specifically directed at evaluating the applicability, usefulness, and relevance of the criteria that had been established. Furthermore, in addition to the value of long-term research results came the transfer of research efforts to the operational scale. It is this combination of more long-term measurements at the research or plot scale and application of results to operational efforts that provides guidance to expanding the existing criteria. Results from the operational scale or the "real world" provide the most sound guidance with respect to what is feasible and practical to expect and to achieve.

As a result there is the opportunity to expand and improve the soil quality criteria currently being used. As mentioned previously criteria associated with specific practices that impact soil have been developed, others are currently in the process of being developed, and certainly others will be worked on in the future.

Suggestions regarding potential additions or modifications are described.

7.5.1 Regions of the Province

The existing criteria are defined for three discrete regions in the province. There is the potential to subdivide at least the Plains and Northern Forested Regions using alternatives such as an eco-region approach. The Plains Region currently encompasses a broad range of soil zones or Orders and climatic regimes where subdivisions could be made.

The Northern Forested Region could be subdivided primarily on the basis of climate. The Eastern Slopes Region could also be potentially subdivided with the eastern portion of the existing unit being added to the Forested Region.

Further subdivision of the various regions could be undertaken resulting in the development of more specific criteria for more well defined regions. However it must be noted that with more subdivision comes the need to understand and handle the "transition zone" that occurs in the vicinity of each subdivision or delineation.

7.5.2 Additional Parameters

Several parameters could be added to the list of physical and chemical properties for which criteria are currently defined. Both analytical (laboratory) and field measurement techniques have advanced over the past decade. As a result of these advances there is a much broader base of information available relative to Alberta soils including both the undisturbed and reconstructed.

Soil chemical properties have been emphasized in reclamation research and monitoring to date. This can be largely attributed to the fact that many of the chemical parameters utilized are measured in the laboratory where standard procedures have been utilized for many decades and that threshold values could be adopted. A limited understanding of soil physical properties and how they are measured has impacted the use of these parameters in soil quality assessment. In contrast to the chemical properties, many of the physical parameters are measured in the field and often there are a number of techniques that can be used to measure a given physical property (Naeth et al. 1991). For example, bulk density can be measured by a variety of techniques each having advantages and disadvantages for specific applications.

With the addition of selected properties comes the need to add or define the most appropriate respective analytical technique(s) or field measurement(s). These techniques must be standardized so that relevant comparisons can be made.

7.5.2.1 Chemical Properties. The existing criteria (ASAC 1987a) already include most of the more critical chemical properties pertinent to soil quality. Properties that might be added for which there are recognized standard measurement techniques include soluble ions such as Na^+ and Cl^- as well as trace element content. The latter is particularly relevant in terms of addressing soil suitability and quality issues associated with waste disposal. This is critical in evaluating the suitability of the potential receiving soil and the impact of the addition on the soil.

7.5.2.2 Physical Properties. The existing criteria include only three physical property measurements and two of these (stoniness/coarse fragments and consistency) are field measurements. Texture can be done in the field but is generally confirmed by analytical work. As mentioned previously there is a more limited understanding of soil physical properties and their role in soil - plant relationships than is the case for soil chemical properties.

Additional parameters can and should be added to address at least the general areas of soil structure and soil water characteristics. The properties should be relatively easy to measure with standard procedures that all practitioners can utilize. Bulk density and penetration resistance are two parameters that should be added along with consideration for infiltration and hydraulic conductivity.

The critical aspect of adding parameters is the availability of adequate data and experience to define the criteria or threshold values for the rating classes.

7.5.3 Ranking of Parameters

The current system used for evaluating soil quality criteria does not allow for ranking or weighting of parameters. For example, the system does not imply that pH or sodicity or any other parameter is more important or weighted more heavily relative to the remaining parameters. The lowest suitability ranking for any given parameter determines the overall suitability class which makes the system simple, straightforward and therefore relatively easy to use.

Ranking or weighting of factors is difficult because of the interrelationships between the properties, the interrelationship with plants and the landscape overall. It seems reasonable to suggest that salinity could be weighted more heavily than moist consistency or stoniness class. The implication is that stoniness class could be modified by stone removal. However this approach brings "management" practices into the process. It must be recognized that development of a weighting system or approach will likely improve the overall assessment or evaluation process, however it will be more difficult to use. A certain amount of calculation would be required to determine specific ratings. It would be appropriate to consider development of a computer program to simplify the task.

7.5.4 When to Measure Soil Quality

Another issue that needs to be addressed relative to soil quality assessment relates to when the measurement is undertaken. To establish the baseline or pre-disturbance situation the measurement is done at a reasonable time prior to development. In the post-disturbance or reconstructed setting it seems reasonable to complete the evaluation soon after the post-disturbance activities. The definition of "soon" in this context and in actual practice likely varies from a number of days to as much as one year.

Undertaking soil quality assessments one or two or more years following completion of work at a site can result in a change in ratings compared to one completed shortly after soil reconstruction. For example, bulk density values could be lower two to three years after site reconstruction compared to weeks thereafter. Similarly, oil and grease content or chloride content could be reduced due to degradation and leaching processes respectively. In summary, soil quality will change with time and these changes can be positive or negative.

These examples raise the question of the purpose of completing soil quality and ultimately land capability ratings following the site reconstruction. The investigations can be done to "certify" or demonstrate that reclamation requirements have been met and that designated end land use activities can be undertaken. They can also be undertaken to determine what specific management practices might be required.

The nature of the activity or type of resource development will have a bearing on when the post-disturbance measurements are undertaken.

7.6. SUMMARY AND CONCLUSIONS

Soil quality criteria relative to resource extraction activities have been in place in Alberta since 1981. They have been used to evaluate the suitability of pre-disturbance soils for revegetation purposes and have also been used to determine soil quality and ultimately contributed to evaluating land capability in the post-disturbance setting. The criteria and guidelines developed relative to disturbance and reclamation were originally geared to surface mining activities however, they can be applied to all land disturbing activities.

Significant advances have been made in "environmental soil science" research since the criteria were developed thereby providing the basis for upgrading or improving the existing criteria and their application in the measurement of reclamation success.

A note of caution relates to the fact that any revision or upgrading should result in a manageable and reasonably "user friendly" system that can and will be readily used by the various practitioners.

7.7 REFERENCES

Alberta Energy and Natural Resources. 1976. A coal development policy for Alberta. Department of Energy and Natural Resources, Alberta Government report and maps. 44 pp.

Albert Government. 1973. The Land Surface Conservation and Reclamation Act. Statues of Alberta, Chapter 34. The Queen's Printer, Edmonton, Alberta.

Alberta Environment. 1982. Guidelines for the application of municipal wastewater sludges to agricultural lands. Prepared by Standards and Approvals Division and Earth Sciences Division. 26 pp.

Alberta Environment. 1992. Alberta environmental protection and enhancement act (draft).

Alberta Soils Advisory Committee. 1977. Soil quality criteria for agriculture. Report printed by Agriculture Canada. 8 pp.

Alberta Soils Advisory Committee. 1981. Proposed soil quality criteria in relation to disturbance and reclamation. Prepared by Soil Quality Criteria Subcommittee (Stage II). 52 pp.

Alberta Soils Advisory Committee. 1987a. Soil quality criteria relative to disturbance and reclamation (revised). Prepared by Soil Quality Criteria Working Group, Soil Reclamation Subcommittee. 56 pp.

Alberta Soils Advisory Committee. 1987b. Land capability classification for arable agriculture in Alberta. Prepared by Agricultural Rating System Working Group and Agrometeorology Working Group. Edited by W.W. Pettapiece, 103 pp.

Brocke, L.K. 1977. Soil capability for agriculture in Alberta. 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.

ERCB. 1975. Interim Directive ID-OG 75-2: sump fluid disposal requirements.

Ferguson, T. 1990. Three-lift rationale - three lift soil handling for pipelines in Alberta. IN: Deloitte & Touche, 1990. Proceedings of the Industry/Government Three-Lift Handling Workshop. Alberta Land Conservation and Reclamation Council Report No. RRTAC 90-6. 168 pp.

Leskiw, L.A. and S.D. Lapointe. 1992. Alberta agricultural capability classification for reclaimed lands (Draft Report). Report prepared by CAN-AG Enterprises Ltd. for Land Conservation and Reclamation Council, Reclamation Research Technical Advisory Committee.

Macyk, T.M. 1987. An agricultural capability rating system for reconstructed soils. Alberta Land Conservation and Reclamation Council Report #RRTAC 87-13. 46 pp.

Naeth, M.A., D.J. White, D.S. Chanasyk, T.M. Macyk, C.B. Powter, and D.J. Thacker. 1991. Soil physical properties in reclamation. Alberta Land Conservation and Reclamation Council Report No. RRTAC 91-4. ISBN 0-7732-0880-1. 216 pp.

ENVIRONMENTAL SOIL SCIENCE

ANTHROPOGENIC CHEMICALS

AND

SOIL QUALITY CRITERIA

PROCEEDINGS OF A JOINT SYMPOSIUM

OF

THE CANADIAN LAND RECLAMATION ASSOCIATION
AND
THE CANADIAN SOCIETY OF SOIL SCIENCE

CLRA
ACRSD

Le Sol – Fondement de la Vie
CSSS / SCSS
Soil – Foundation of Life

held at
EDMONTON, ALBERTA, CANADA
1992

ENVIRONMENTAL SOIL SCIENCE

ANTHROPOGENIC CHEMICALS AND SOIL QUALITY CRITERIA

Edited by
C.B. Powter, S.A. Abboud and W.B. McGill

Compiled by
Y.A. Kalra and W.W. Pettapiece

Proceedings of a Joint Symposium
of
The Canadian Land Reclamation Association
and
The Canadian Society of Soil Science

Held at
The University of Alberta
Edmonton, Alberta, Canada
August 10-11, 1992

Suggested citation:

Powter, C.B., S.A. Abboud and W.B. McGill (editors) 1995. Environmental soil science: anthropogenic chemicals and soil quality criteria. Proceedings of a symposium held August 10-11, 1992. The Organizing Committee, Canadian Land Reclamation Association and Canadian Society of Soil Science, Edmonton, Canada. 278 p.

Copies of this publication may be obtained for $20.00 (includes postage) from:

Canadian Society of Soil Science
Box 21018, Westend Postal Outlet
Brandon, Manitoba
Canada R7B 3W8

ISBN: 0-9680185-0-5

PREFACE

The Environmental Soil Science conference was held August 8-13, 1992 at the University of Alberta, Edmonton, AB. It was sponsored jointly by the Canadian Land Reclamation Association (CLRA) and the Canadian Society of Soil Science (CSSS). The objective of the conference was to share theoretical and applied aspects of soil science. It also served to get participants from the sponsoring groups together to find areas of mutual interest. There were 330 participants from Austria, Bangladesh, Canada, England, France, Germany, India, Japan, New Zealand, Norway, Spain, the Netherlands, and USA.

Abstracts of the oral and poster papers were published in the Canadian Journal of Soil Science (Vol.72, No.3, August 1992. (p.299-353). Volunteer papers covered all aspects of land reclamation, soil science, and public participation in the environmental review process. Seventy six of the 164 volunteer papers were presented as posters.

The invited papers presented in the plenary sessions focused on soil quality and interaction of soils with anthropogenic chemicals, and are published in this proceedings. Publication of the proceedings has taken an unduly long time due to unavoidable circumstances and we apologize for the delay.

Grateful acknowledgement is expressed to our colleagues on the organizing committee (J.A. Robertson, Chair) for their contributions to the success of the conference.

Y.P. Kalra and W.W. Pettapiece, Compilers

TABLE OF CONTENTS

	Page
Title Page	i
Citation	ii
Preface	iii
Table of Contents	v
1. Soil: The Environmental Integrator (Lavkulich, L.M.)	1
2. Inadvertent Additions to Soils: Metals (Chaney, Rufus)	45
3. Environmental Fate and Transport of Organic Contaminants in Soils at Waste Disposal Sites (Rao, P.S.C. et al.)	47
4. Intentional Anthropogenic Additions to Soils: Pesticides (Bowman, B.T.)	85
5. Agricultural Soil Quality Criteria for Canada (Pettapiece, W.W. and D.F. Acton)	129
6. Sustaining Forest Productivity Through Soil Quality Standards: A Coordinated U.S. Effort (Powers, R.F. and P.E. Avers)	147
7. Development and Application of Soil Quality Criteria for Alberta's Resource Extraction Industries (Macyk, T.M.)	191
8. Development of Soil Quality Criteria for Contaminated Site Remediation (Gaudet, C. et al.)	221
9. Appendix: List of Registrants	267